Water management strategies towards sustainable agricultural development, taking Managed Aquifer Recharge (MAR) and brackish water utilization into Account:

Case Study: Auja, LJV, Palestine.

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Abstract

Increasing water irrigation demand combined with water scarcity and deterioration of the water quality in the Lower Jordan Valley (hereafter referred to as LJV) - Palestine, has led to a serious challenge in managing current and future water demands. This problem is not restricted to Palestine but to the region in general. Providing feasible solution strategies for water management has demonstrated to be a complex task. Mismanagement of water resources aggravates the problem. Therefore, integrated water resources management promises applicable and creative solutions for the future in terms of water strategies. The main goals of this study are to develop these strategies end based on regional agricultural strategies development.

The Case Study Area (Hereafter referred to as CSA), Auja area, is located in the LJV., CSA has suffered from water scarcity and water quality deterioration, This was manifested in decreasing irrigated lands from 10,000 donums in 2010 to only about 4,000 donums in 2013and change in crop patterns in the area. Moreover high chloride concentration in shallow aquifer - with 2000μs/cm² in some wells - has caused increased deterioration in water quality. Therefore, the study investigated creative alternatives based on integrated available water resources management and the exploration of non-conventional resources in the area.

The study assumed many strategies of agricultural and water resources development, which jointly constitute strategies of firstly, agriculture development and secondly, water strategies. Both strategies should act as the core of the problem as well as its solution. Accordingly, integrated water resources management (hereafter referred to as IWRM) focused on managing aquifer recharge (MAR) and using brackish water in irrigation. This idea is the base for the assumption of this research.

MAR and brackish water eventually are top priority scenarios for meeting water requirements in the future. Decision-makers are urged to take these scenarios into consideration to achieve sustainable development plans in the Palestinian territories.

Irrigated lands in the CSA cover 3,800 donums vis-à-vis 30,000 irrigable donums. Main water resources come from Auja Springs and shallow aquifer wells. Available irrigation water does not exceed 3.5 Mm^3/a. CSA is served by field survey including soil, water, land, and agriculture cover use. CSA is composed of three Agricultural land zones: zone 1, zone 2 and zone 3. These zones reflect the current cultivated area as well as lands expansion scenarios for an additional 8,500 donums of new irrigated lands with plantations of date palm trees, intensive green house agriculture and grapes. The scenario is based on soil profile analysis of root zone and soil hydrochemistry analysis.

These three land zones represent three agricultural development strategies based on water budget analysis and are jointly linked with the three assumed water strategies. The three water strategies (WSs) are:

1- WS I which is the Do-Nothing approach which reflects large water quantities deficit;

2-The WS II is based on MAR scenario, the Mathematical model of transient GMS-Modflow It is considered as a tool for water management in the CSA. It supplies 2 million cubic meters of surplus water by direct injection into the shallow aquifer wells, in addition to infiltrated flood surface run-off from Wadi Auja.

3-The WS III, is based on 100% of IWRM using all non-conventional water resources, varying from brackish water desalination and treated effluent to importing water from outside the CSA and the use of Current Untapped Water Resources (CUWR). This strategy will change the current crop pattern taking into consideration the water budget. It could offer additional 12 million cubic meters (Mm^3) for the extra irrigated expanded land scenario.

Evaluating the best management scenarios regarding performance and impact assets based on Driving-Pressure-State-Impact-Response (DPSIR) frame work, would give several decision variables (DVs) as a prelude to form decision criteria analysis and analytical hierarchy procedure (AHP) used for scaling and weighing different decision variables (DVs) This would produce the best management scenario by mixing brackish and fresh water and completely change the crop pattern in the CSA. The change would accrue through planting date palms. In this context, MAR scenario comes as intermediate priority by evaluation results, although it would need further investigation in the future.

List of Abbreviation

ADS	Agricultural Development strategy
ADSI	Agricultural Development strategy No. 1
ADSII	Agricultural Development strategy No. 2
ADSIII	Agricultural Development strategy No. 3
AHP	Analytical Hierarchy Procedure
AR	Artificial Recharge
ARIJ	Agriculture Research Institute of Jerusalem
ASR	Aquifer Storage and Recovery
BMBF	The German Federal Ministry for Education
bsl	Below sea level
BWWTP	Al-Bireh Waste water Treatment Plant
CSA	Case Study Area
CUWR	Current Untapped Water Resources
CWR	The total Crop Water Requirement
DW	Diameter Weight
DC	Decision Criteria
DPSIR	Frame Work Driving-Pressure-State-Impact
DS	Desalination
DVs	Decision Variables
EIA	Environment Impact Assessment
EQA	Environment Quality Authority
FAO	Food and Agriculture Organization
GDP	Gross Domestic Production
GIS	Geographic Information System
GPS	Geographic Plane System
IWRM	Integrated Water Resources Management
JICA	Japanese International Cooperation Agency
JWWTP	Jericho Waste Water Treatment Plant
LJV	Lower Jordan Valley
MAR	Manage Aquifer Recharge
MDGs	Millennium Development Goals
MENA	Mediterranean and North Africa Region
MoA	Ministry of Agriculture
NGO's	Non-Governmental Organizations

NPA	National Polices Agenda
NWP	National Water Plan
OPT	Occupied Palestinian Territory
PARC	Palestinian Agriculture Relief Committees
PL	Pipelines Networking
PMD	Palestinian Metrological Department
PSF	Soil Particle Size Frequency Curves
PWA	Palestinian Water Authority
SAT	Soil Aquifer Treatment
SC I	Scenario No. 1
SC II	Scenario No. 2
SC III	Scenario No. 3
SEA	Strategic Environmental Assessment
SMART (Project)	Sustainable Management of Available Water
U.G	Under Ground
UFW	Unaccounted for Water
WBA	Water Budget Assessment
WD	Water Demand
WG	Well Group
WMR	Water Management Recovery
WMS	Water Management Strategies
WP	Water Potential
WS I	Water Strategy No. 1
WS II	Water Strategy No. 2
WS III	Water Strategy No. 3
WSs	Water Strategies
WTF	Water Table Fluctuation

List of Symbols

(ρ)	the fluid (water) density
(μ)	dynamic viscosity
ECP	saturated soil water phase(soil past)
ET0	reference Evapotranspiration
Etta	the actual evapotranspiration
Kc	Crop Factor
KY	a yield response factor
ra	aerodynamic resistance
rs	soil surface resistance
Sy	specific yield (dimensionless)
TDS	Total Dissolved Solids
ΔH	the drop of head pressure in time period
μs/cm	Micro simense per centimeter
CEC	Cation Exchange Capacity
m3/a	Cubic meter per a year
m3/hr.	Cubic meter per hour
CV	coefficient of variance
D	slope vapor pressure curve [kPa °C-1].
D10	10 % of passed weight
D60	60 % of passed weight
de	effective grain diameter
Ea.	actual vapor pressure [kPa]
EC	Electrical conductivity
Eca	bulk soil phase
ECsw	soil water (infiltrate water)
Ecw	applied water for irrigation
Ecw	soil water phase
es	saturation vapor pressure [kPa].
es - ea	saturation vapor pressure deficit [kPa].
ESP	Exchangeable Sodium Percent
Ext.	the maximum evapotranspiration
E-W	East West
f(n)	porosity function
g	psychrometric constant [kPa °C-1].
G	soil heat flux density [MJ m-2 day-1].
K	hydraulic conductivity
Kc	Crop coefficient
km^2	Square Kilometer
L/ capita/ day	liter per capita per day
LAI	Active sunlit leaf index
LF	Leached Factor
LR	Leached Rate
m^3/day	Cubic meter per day
mb	mille bar

Mm3/a	Million Cubic meter per a year
mg/L	mille gram per liter
mm	mille meter
mm/year	millimeter per a year
N-E	North East
N-S	North south
PH	Power of Hydrogen
R (t)	recharge rate
R.H	Relative Humidity
RAW	Radial(Theoretical) Available Water
RE	relative error
Rn	net radiation at the crop surface [MJ m-2
SAR	Sodium Absorption Ratio
T	mean daily air temperature at 2 m height
t	The time interval of water flocculation
TAW	Total Available Soil moisture(Water)
TDS	Total Dissolved Solid
TSS	Total soluble salt
U	Particle size uniformity
u2	wind speed at 2 m height [m s-1].
Ya	actual yields
Yx	the maximum yield
ν	kinematic viscosity

Chapter 1

Introduction

1.1 Problem statement and Integrated Water Resources Management (IWRM)

Current lack of comprehensive and efficient water resources management is one of the challenging problems facing semi-arid Mediterranean region in general and the occupied Palestinian Territory (OPT) in particular. Sharma, 1998 claimed that the real problem in semi-arid Mediterranean region is not the lack of resources but is rather the lack of an integrated water management policy in case of high pressure on water resources so as to alleviate the current dire conditions.

The concepts of water sustainability and integrated water resources management (IWRM) are poorly understood by stakeholders of water resources including planners and managers. Moreover, there are insufficient understanding and knowledge about the actual baseline conditions in terms of priority water problems and geographical areas under water stress. Accordingly, subjectivity is viewed as one weakness of the current water sector decision-making.

Water resources in the Mediterranean and North Africa (MENA) region are scarce. Due to the semi-arid climate in the OPT and its location in MENA, it suffers from shortage of water (Blue Plan, 2003). Annual water consumption per capita is about 73 L/d, PWA, 2010, Water Supply Report), and is expected to reach 50 L/d in the coming decade (PWA, 2010, Reforming Plan**).**

In terms of water quality, salinity of underground water increases gradually in years, this happens for reasons of natural hydrological system and anthropogenic activities. These activities reduced soil fertility and decreased agriculture productivity; this is due to soil salinity built up from using brackish water in irrigation. Chloride concentration and electrical conductivity (EC) in shallow aquifer wells in the CSA reach up to 1,500 mg/L and 5,000µs/cm respectively.

The overall natural water resources for Palestinians in the West Bank mostly stretch out in the mountain aquifer. Based on Israeli practice, there are three shared aquifers: the Eastern, the Western and the North-Eastern aquifers. Currently, Palestinians extract less than 15% of the estimated potential of these three aquifers. In 2010, extraction from mountain Aquifer did not exceed 98 Mm^3; From which29 Mm^3 from the North- Eastern Aquifer, 25 Mm^3 from the

Western Aquifer and 44 MCM from the Eastern Aquifer. (Figure1.1, (PWA, Water Supply Report, 2010). These 98MCM are used in different sectors and most of this available water quantity is used in the agricultural sector.

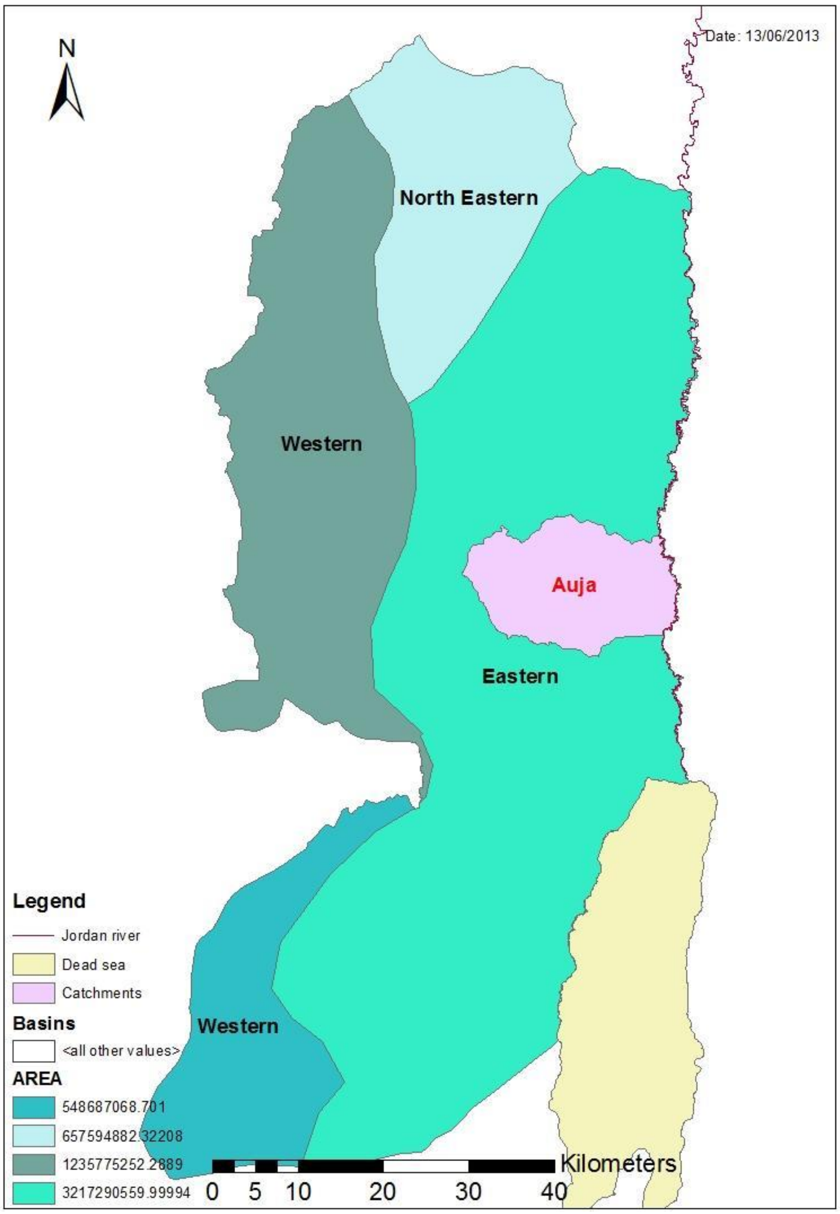


Figure.1.1: West Bank Basins and the case study area (Auja Catchment)

In CSA, irrigated lands decreased from 8,000 donums to about 4,000 donums during the last 10 years; therefore, agricultural developing scenarios (ADS) relevant to available water resources and brackish water usages should be holding in this investigation. These scenarios should be based on agricultural lands extension according to crop salinity resistivity on the one hand using saline and brackish water and on soil profile texture and irrigation with fresh water on the other.

Previous studies (Shawahna, 2010, Sobeih, 2009) showed that the agricultural sector could be improved by integrating different water sources that are not currently used. This includes wadi runoff, brackish groundwater, and potential treated waste water. These water sources plus the plantation of crops resistant to brackish water such as date palm trees. In addition, household water supplied through water distribution systems is lost due to inefficient irrigation system in the CSA, leakage from water networks and the channel system. The loss exceeded 24% in Jericho (PWA, 2010).

The available cultivable area in the Auja area is about 30,000 donums but due to limited water resources only 3,870 donums were irrigated land in 2013 and currently 4,500 donums are irrigated (Ministry of Agriculture (MoA)/Jericho District Bureau).

The fluctuation of spring discharge and the salinization of groundwater boreholes restrict selecting suitable crops. As a result, many farmers shifted from vegetables irrigation to more tolerant crops and trees due to the increase of water salinity (up to 1,500 mg/L).

There is severe water fluctuation particularly in summer months due to low precipitation (99 mm in 2011), uneven distribution and high temperature with annual evaporation reaching 2,316 mm (2011), (Jericho Station, PMD 2011). Water resources are vulnerable to global change such as climate change and are sensitive to drought which has severe impacts on soils and sub-soils that ends up dried up, thus influencing agricultural production, food security and socio-economic aspects related to water deficit.

Increasing water quality degradation caused by land use, destruction of wetlands and ecosystems, and anthropogenic causes reduce the sustainable management of water resources. Anthropogenic effects are caused by local and external sources. Pollution sources include urban sewage, solid waste, hazardous waste, industrial waste, overuse of fertilizers and pesticides. In addition, over-exploitation of underground (u.g) wells in the case study area has already led to many cases of irreversible saltwater intrusion. If pollution sources remain uncontrolled, it wills likely lead to further water scarcity in the area which already has a limited reserve of water.

A major factor in water problems is weakness in integration of environmental sustainability into the water sector policy making. High level water shortage is due to lack of adopting strategic environmental assessment (SEA) methods. Furthermore, the infrastructure of the existing Palestinian Environmental Impact Assessment (EIA) policy, MENA, 2000 for the water sector, has limitations to address the large scale and cumulative effects of several projects.

the case study area being investigated is Auja area selected to represent the (LJV) Basin. The Auja and Fari'a area (in the north of LJV) represent the main parts of the basin. This is why Auja area has been chosen for this study.

1.2 Water resources management in the Lower Jordan Valley

Auja area is one of three main sub-catchments forming Jericho-Auja catchment. Three wadis are located in three sub-catchment of Jericho-Auja study area: Wadi Auja, Wadi Nui'meh and Wadi Qilt. (Figure1.2 shows Auja sub catchment area).

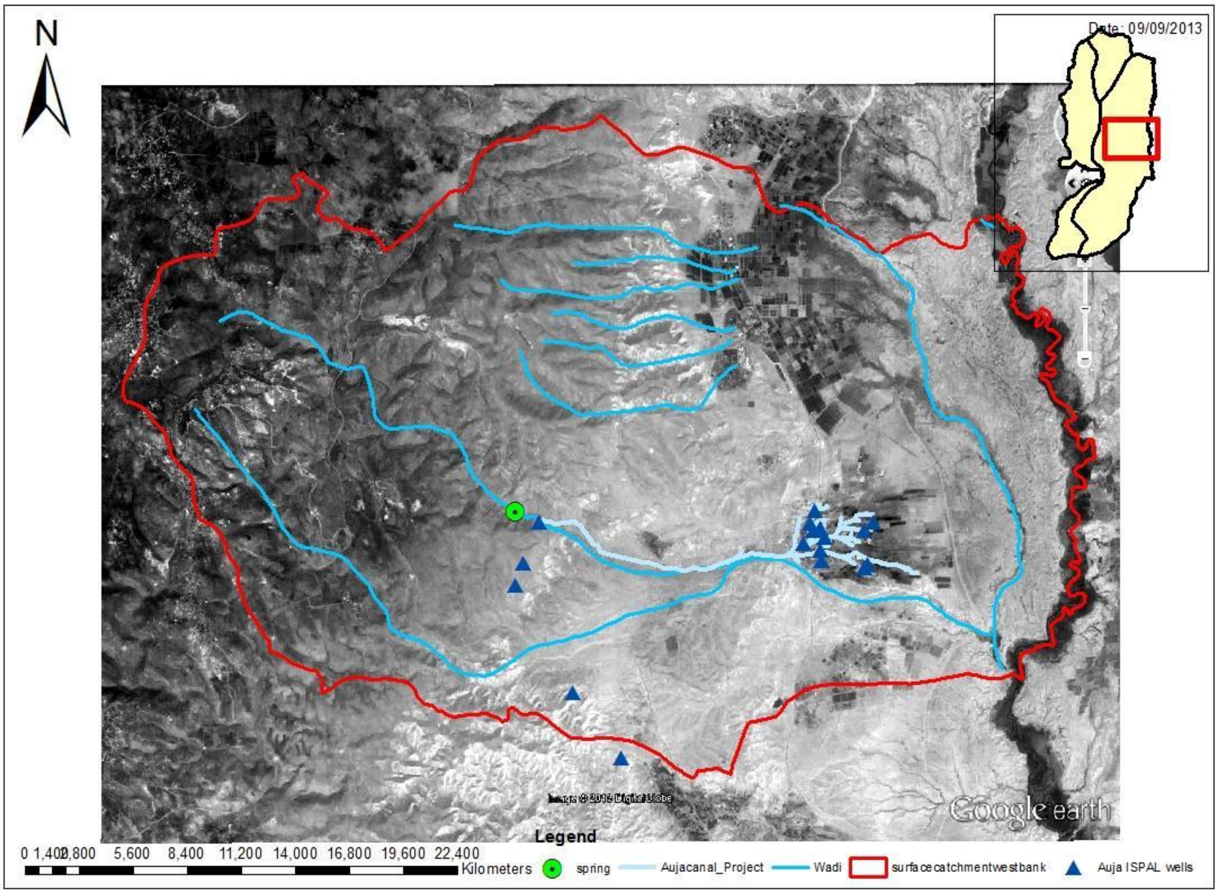


Figure 1.2: Watersheds of the Case Study area (Auja sub catchment)

The overall catchment extended from Ramallah Western Anticline to the Jordan River Eastward. Area of the three sub catchments is 616.3 km². Auja sub catchment alone is 291.4 km². CSA has classified it as arid zone. Rainfall of the upper catchment parts is distributed between 350 mm/year to 450 mm/year, with 2,350 mm/per year evapotranspiration, and the lower area of catchment does not usually exceed 130 mm/year in wet years. Surface runoff reached 3 MCM in wadi Auja. With regards to these surface runoff quantities, see Table 1.1, (PWA 2010, MoA 2010, JICA, 2008).

Table 1.1: Wadi Basins of Jericho-Auja including the Case Study Area, PWA, MoA, 2010

Sub Catch. Name	Catch. Area (Km²)	Avg. Rainfall (mm/year)	Surface Runoff (Mm^3)
Wadi Auja	291.40	350	2-3
Wadi Nui'meh	172.40	350	1-2
Wadi Quilt	152.50	450	3-11

Major exploited water resources in the study area are ground water wells and springs with 12 underground wells in shallow aquifer in Auja area all of which are used for agricultural purposes. Maximum allowable extraction from these wells is 1,109,000 m^3/annually. It is worth mentioning that only 10 of these wells are still operating with a capacity range between 50 and 100 m^3/hr. and with 0.5 Mm^3 as yearly mean extraction. (Figure 1.3)

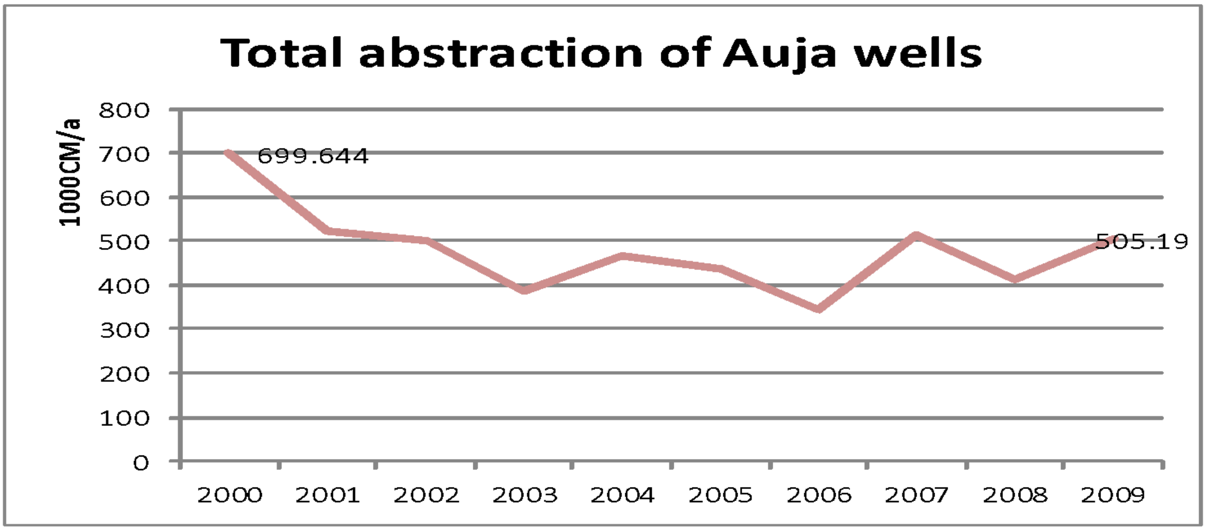


Figure 1.3: Auja wells annual Extraction during the period 2000- 2009

There are Israeli wells in the CSA located in the lower of the upper aquifer; Palestinian wells are located in shallow alluvial aquifer in the eastern part of catchment area at an elevation of 200- 300 meters below sea level (bsl). Over exploitation and over pumping and drought facing these underground wells depleted them with an approximate reduction of 1m/year the historical observed water table. On the other hand these wells have become more saline with an increase in chloride concentration and electrical conductivity of the pumped water. This high salinity of underground water reduces the productivity of the agriculture sector and increases the salinity of the soil. In the CSA, underground wells are in shallow aquifer with a mean extraction of 0.5 Mm^3/a. (Table 1.2 shows the shallow aquifer wells in the CSA).

Table 1.2 Wells and abstraction capacity in Auja area

Code	X	Y	Z	Depth (m)	Work	Max. Abstraction (m^3/a)	Abstraction capacity (m^3/hr)
19-14/001	195910	149990	-268	59	Yes	74000	80
19-15/005	194750	150440	-242	108	Yes	65000	50
19-15/007	194870	150760	-250	105	Yes	164000	100
19-15/008	194320	150600	-240	102	Yes	120000	90
19-15/010	194510	151100	-247	102	Yes	88000	50
19-15/011	194750	151000	-251	90	Yes	128000	50
19-15/012	194590	150940	-248	103	Yes	133000	100
19-15/015	196150	151140	-278	65	No	76000	X
19-15/023	196020	150090	-273	50	Yes	94000	50
19-15/019	195907	150936	-274	92	Yes	133000	100
19-15/028A	194800	150170	-246	90	No	X	X
19-15/013	194620	151450		100	Yes	110000	80

The majority of Palestinian wells were drilled between 1955 and 1966 at a total depth of 50 m to 145 m and they pump between 40 m^3/hr and 80 m^3/hr, with a 10 hours pumping average per day. Usually pumping in summer lasts for 20 hours per day. These wells are made of cast iron and plastic pipes and fittings. Throughout years of pumping, screens have clogged with high silt accumulation at the bottom of the well and penetrating corrosion of cast iron inside these wells appeared. As a result of this deplorable case, more than 20 wells in Jericho area stopped pumping causing increased salinity and, in some cases, water table depletion resulting from mechanical and hydro geological reasons.

Palestinian wells are clustered in two main areas: the southern east part of Auja village close to Wadi Auja and the northern west of Auja village to the east of main fault in the area. This fault divided the upper aquifer from the lower shallow aquifer, with wells located in the agriculture areas. Fifty four agricultural ponds received fluctuated water from Auja canal; they were used as reservoirs for irrigation in the area. Of Spring water coming through the Auja canal and sometimes for mixing the brackish water from wells with fresh water from the Spring. More explanation will be provided in the Agriculture and Land Use Chapter.

Spring water constitutes one of the important water resources in the study area. It becomes less in summer while it remarkably increases in winter. Thus, water volume largely varies depending on the rainfall amount. On the other hand, ground water availability responds to the rainfall amount which sometimes lags depending on geological conditions in each location, (JICA, 2008).

1.3 Study area (including some basics on the hydrogeology and geology of Eastern Aquifer)

Auja sub catchment is one of three sub catchments, which are forming Jericho-Auja catchment; they are Wadis of Auja, Wadis of Quilt and Nui'meh. Auja sub catchment extends from the water divide running along the Ramallah anticline axis in the west to the Jordan Valley in the east, and from the Fasael area in the north to Nui'meh in the south, closed to the Jordan River in the east. The CSA have total area of 291.4 Km², and around 4548 capita population, in addition to Bedouin distributed at the area near by water resources (Auja Spring).The elevation of the catchment is between 900m at the upper aquifer (Kafer Malik) also and -250m (bsl) along alluvial aquifer. The climate is arid to semi-arid average annual rainfall between 100mm and 700mm. Also, high evaporation quantities reaching 2300mm/a (PMD, 2011), figure 1.4.

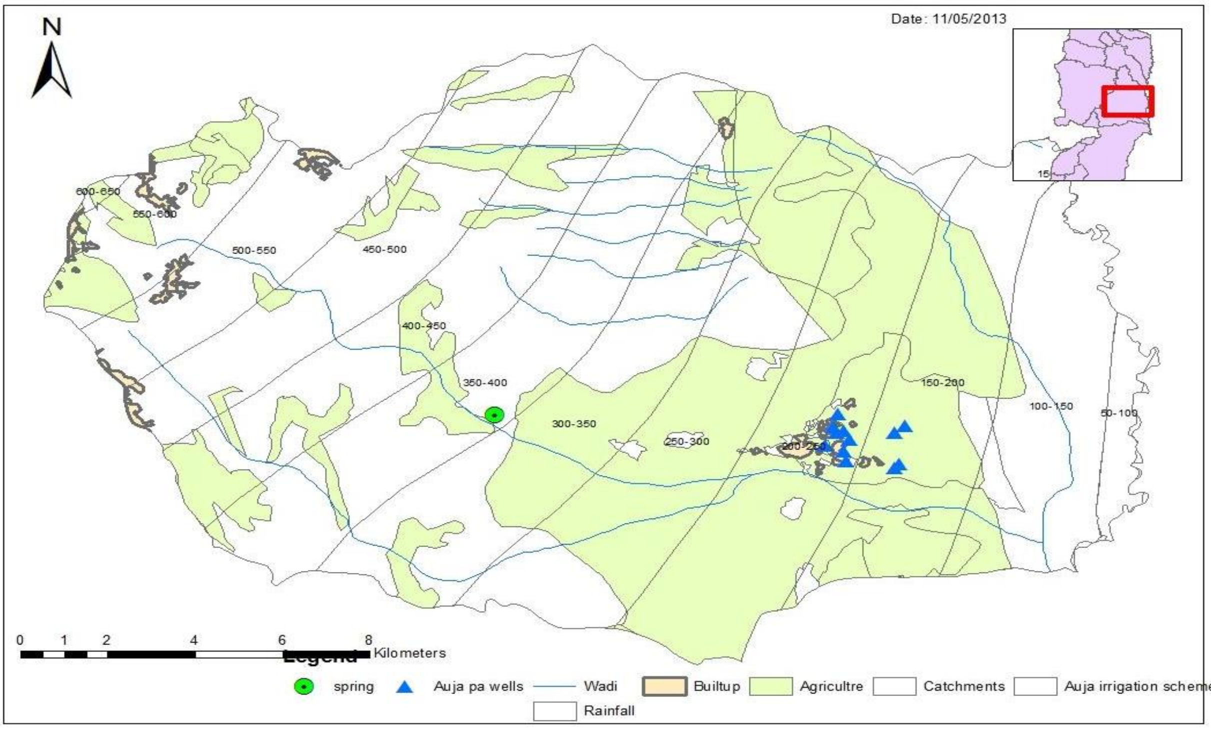


Figure 1.4: Base map of the CSA catchment

1.3.1 CSA Geological Back ground

West Bank is located in the northern shield of the Arabian Shield, (Precambrian age), and consists of crystalline plutonic and metamorphic rocks. The metamorphic rocks are mainly of sedimentary origin, Roof and Raffty, Geological Mapping, 1963. The Arabian Shield extends over an area that stretches from the eastern and southern edges of the Arabian

Peninsula to the southeastern shores of the Mediterranean and formed the great Afro-Arabian shields. The Arabian shield extended through the Aqaba Gulf to Turkey in the northward,

passing through the Dead sea, the Jordan Valley, Lebanon and Syria. In the West Bank, the basement complex is not cropped; it is shelf deposits (continental and carbonate deposits).
By the faults associated with the Jordan Rift valley, the West Bank structural geology is dominated by series of regional, parallel and SW-NE trending faults including the CSA in the Eastern Aquifer which has been classified into four main geological systems: the upper Cenomanian, the Turonian, the Senonian and the Quaternary system. (Figure 1.5)

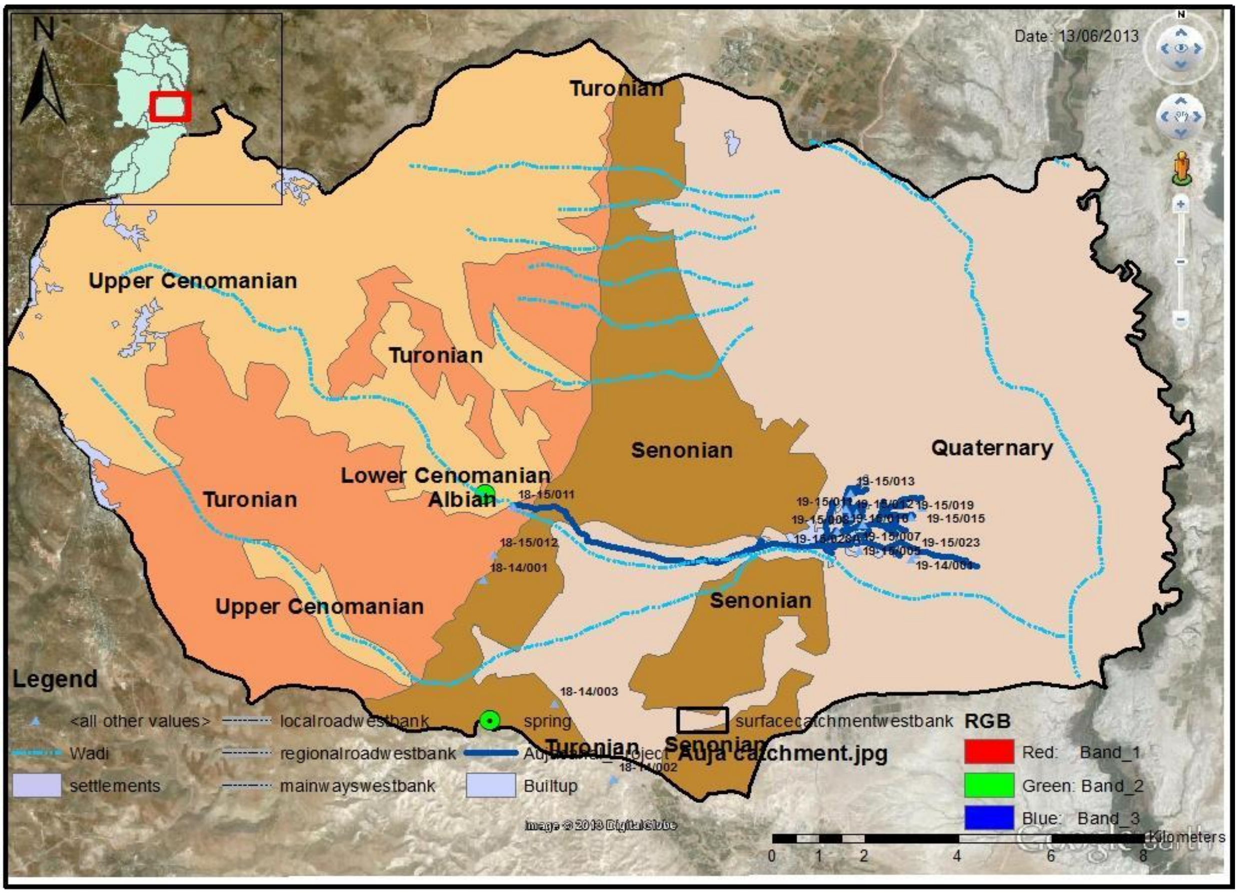


Figure 1.5: CAS Geological System

Jordan Rift valley is passes into the CSA and is divided into two main hydro geological areas- the upper deep and the lower shallow aquifer. The Upper Aquifer includes upper and lower cretaceous systems. This cretaceous aquifer system is formed of Senonian, Turonian and Senonian geological systems. Abu Deis, Jerusalem and Ramallah formation has resulted from this cretaceous system and have lithological construction of sand stone, limestone, karstic dolomite, carbonate, chalk and marl. The Quaternary system is the second part of the resulting system by the division of the Jordan Rift valley. It is the agricultural area of our CSA. The main formations of this system are Alluvium, Lisan, Samra, and Gravel. These formations consist of Marl, Gravel, alluvium, and thinly laminated Marl with gypsum bands.

Regarding the Jordan rift valley deposits, which were mainly composed of Marl & Pleistocene; the geologic formations in the Jericho district (CSA) have the following characteristics:

1-Alluvium Formation (Dead Sea group):

This formation covers the area adjacent to the Jordan Valley and is found in the adjacent sides of the Wadi Quilt streams; it starts by 1 km wide in the north and 5 km in the south. It is of the Pleistocene to Recent in age**.** Structurally, it is bordered by the Jordan Rift regional fault in the east and by another fault of 12 km long in the west.

Alluvium deposits started to sediment on both sides of the area's streams ten thousand years ago during the Holocene age. They are located in the entire area mixed with sub and top soils; this formation is 5-12 m thick **(**Begin, 1974).

2 -Lisan & Samra Formation (Dead Sea group):

This formation covers the greatest part of the Jericho district. It is of the Pleistocene to Recent age and includes three local faults of up to 3 km long. This area is bordered by the alluvium formation in the east and by a greater fault of about 13 km long to the west. It is mainly composed of marl, chalk and conglomerates (Arij, 1995).

Samra formation consists of conglomerates, sandstones and silts and is subdivided into two members. Silt member is 20 m thick on average and is mainly located in the western sides of Jericho city. It is composed of silt, sand, and clastic pebble lenses, Begin, 1974. The coarse clastic member with an average of 35 meters thick and is composed of sand and unconsolidated materials chiefly conglomerate and gravel. It is located near the ancient place called "Kherbet Al-Samra" to the north of Jericho city and also in the outlet of Wadi Al-Qilt (Begin, 1974).

Lisan formation exists in the eastern part of Jericho area as well as in the whole Jordan Rift Valley and the Wadis. It consists mainly of laminated aragonite-chalk, gypsum and clay with some sandstone and pebble beds. Consecutive thin layers of clay and gypsum make it highly distinguishable. Lisan formation interfingers with conglomerates and silt beds of the above Samra formation. Sedimentation of the Lisan formation started 60,000 years ago (Kaufman, 1971).

3- Chalk and Chart (Jerusalem) Formations (Ramallah group):

These formations occupy the western part of Jericho district. They are composed of the Senonian Chart and Chalk deposits and are covered structurally by minor faults. Limestone is colored yellow, red or gray and lies in the lower parts of this formation. At the base there are chalk and nodular limestone rich in Ostried. Poorly preserved ammonites were found in the lower parts and they mark the upper Cenomanian age (Rofe and Roffty, 1963). The middle parts of this formation consist of dark – gray dolomite. Ammonites were also found and marked the lower Turonian age. The upper parts of this formation consist of limestone, dolomite, and marl with some charts. The age of this formation is Turonian – Cenomanian. This formation is 90 m to 100 m thick (Wolfer, 1998).

4- Dolomitic Limestone (Bethlehem) Formation, (Ramallah group):

This formation is composed mainly of limestone, dolomite and marl in the lower parts and forms a rugged morphology. It belongs to the Cenomanian-Turonian age and occupies very small portions of the southwestern and northwestern parts of Jericho district. It is of the upper Cenomanian age. Bethlehem formation thickness is 120 m - 140 m, (Rofe and Roffty, 1963).

The faults system is distributed all over the district and is responsible for the main existing springs (ARIJ, 1995).

5- Metamorphic Rock (Abu Dies) formations of Senonian to Neogene Ages (Mount Scopus Group):

These formations are composed mainly of calcium silicates. They occupy small areas within the Chalk and Chart formations.

During the Senonian Age better circulation with the open sea was established as indicated by the deposition of the pelagic chalk. It is of Santonian – Campanian age and mainly consists of chalk with absents of bedding. It covers a large area of the West Bank and is composed of Abu Dies formation only (Rofe and Roffty, 1963, Wolfer, 1998).

Lower parts of Abu dies formation consist of gray hard chalk and lime chalk, fossil-ferrous and sometimes bituminous. The upper part consists of chalk and chart with some limestone and phosphates (Wolfer, 1998).

1.3.2 CSA Hydrogeological System

Figure1.6 shows two main Aquifer systems composed of the eastern aquifer, a largely phreatic upper Cenomanian-Turonian Aquifer, and a largely confined lower Cenomanian aquifer

Foothills, the Jordan valley, (SUSMAQ2005), and Upper aquifer have stronger fluctuate than those of lower aquifer. It is not continuous to be utilized everywhere. In many places, it is dry and in others it leaks downward into the lower aquifer along open fault planes where the two aquifers juxtapose extension into vertical leakage can occur and seepage into aquiclude of

Limy formation makes it less impervious. Many springs in the catchment are located in the upper Aquifer, like Samia and Bettin. Auja Spring is located in the central mountain aquifer which is closed to the lower aquifer and is adjacent to N-S fault which divided the upper

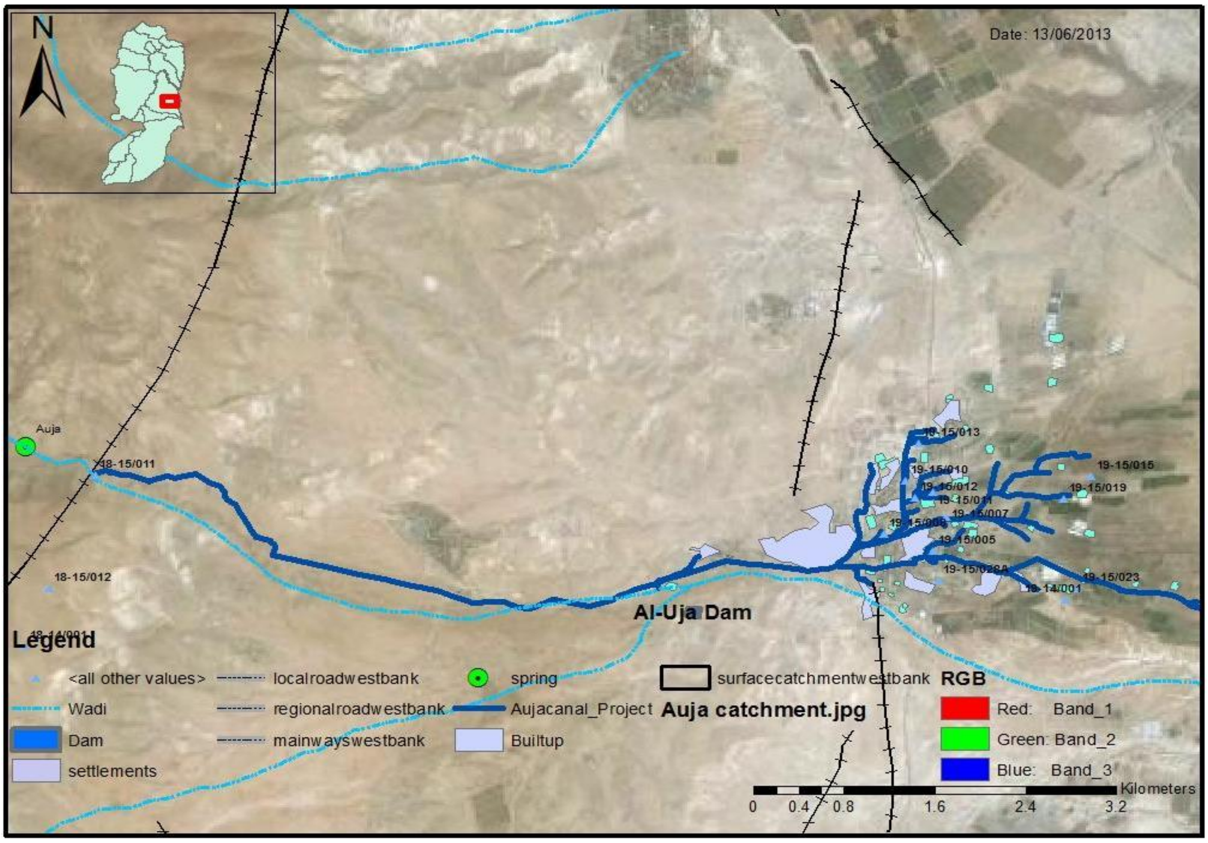


Figure 1.6: CSA Hydrogeological map of lower and upper Aquifer

Aquifer, like Samia and Bettin. Auja Spring is located in the central mountain aquifer which is closed to the lower aquifer and is adjacent to N-S fault which divided the Cenomanian and Turonian systems. On the other hand, Al Duke and El Nui'meh springs lie on the edge of the Turonian system which the agriculture wells distributed in shallow alluvial lower Quaternary aquifer.

1.4 Literature Review

Review of Relevant Works

The National Water Plan (NWP) was developed in 2000 to summarize the main concepts. Findings and recommendations of Water Sector Strategic Planning Study (WSSPS) adopted the Integrated Water Resources Management (IWRM) concepts and developed investment plan for the water sector in Palestine (CEDARE, 2005).

The best management plan for groundwater systems in the West Bank will be one that takes 80% of the potential recharge as the safe yield. The best scenario that meets the Palestinian water demand over the coming decade is the one that considers the various economic, social, political and environmental needs. In addition, it is imperative that adequate plans be prepared to accommodate urban development and to ensure that potential areas of groundwater recharge in the West Bank are protected (Rabi A., Khaled A., Carmi N., 2005). The additional water that will be available for the Palestinians will be either from a. Eastern aquifer, b. the Jordan River, or c. treated wastewater. However, all of this water is saline and another source such as the mountain aquifers seems to be difficult to be secured soon (Sheikh M.Y, 2004). Water management in the Dead Sea basin and elsewhere must be based on systemic solutions such as allocation priorities for different water qualities plus changes in water usage patterns. Solutions for sustainable development will not come simply from providing “more water for more development”. Sustainable development will have to be sensitive to social, cultural and ecological resources as well (Clive L., 2005). The level of monitoring rainfall and the hydrologic system in the Eastern Drainage area, as well the level of modeling the hydrologic system there are inadequate for planning the management of drought conditions in this area. The regression analyses carried out in the course of the study are initial steps in modeling the groundwater system in the Eastern Drainage area which needs to be continued (Khalid A.M, 2000).

Blank in 1928 described Auja area as Auja monocline, Hull, (1886; Picard, 1943). The Jericho sheet includes part of the eastern flank of the Judean Arch ,Begin Z.B,1974, the mountain system (Judea Group) manifested by Ein Samia and Ein Auja, with fresh water. Ein Auja supplies anualy13 MCM water to Auja e-Tahta' (Rad A. & Michaeli A., 1967). The structure of the northern part of the Judean Wilderness is simple (halocline) without any important tectonic interruptions while the southern half contains a number of structure converge (Rofe and Rafety, 1963).

North of Jericho in the Jordan Rift Valley the floor of the valley is covered by alluvial sediments. Cretaceous limestone may be found in the underground area where there is outcrop in the hills to the west and the intake area of rainwater. Water drainage in this aquifer is to the east into the graben. The problem is locating this aquifer below these alluvial sediments in high structural position (Ginsburg A., 1964). There are six main wadis cross the Jericho district: Wadi Al-Makalak, Wadi Al-Auja, Wadi Abu Ubeida, Wadi An-Nui'meh, Wadi Al-Qilt and Wadi Al-Ghazal. Wadi Al-Makalak runs north south, while the remaining five wadis run east west. Wadi Al-Auja and Wadi Al-Qilt have permanent water flow while the rest are intermittent (ARIJ, 1996).

Special attention should be drawn to the values of nitrate(>40mg/L) in the groundwater especially in Sultan and Dyouk springs (Abu Hilo F., Khayat S., Marie A., Geyer S, 2008).

Such geophysical survey would lead to three-dimensional understanding of the hydrological situation and would help build a good conceptual model that is necessary for a substantial management of the Pleistocene aquifer (Gropius M, 1999). The ground water in Jericho area is very limited with lower quality in the last year (2005) due to decreasing recharge water. The mixing calculation shows that there is kind of mixing between fresh and brackish water toward the east while salinity increases toward the east (Al-Jundi M.R., 2005).

Water quality of the eastern aquifer differs from one sub aquifer to another and shows varieties within the same sub aquifer. The majority of sub aquifers belongs to the Cenomanian age and drain from the lower deep aquifer (Ghanem M., Tamimi A.R, Khayat S., Geyer S., Ali W. and Hotzl H.,2008). Public-Private Partnership (PPP) fulfils the need to develop wastewater reuse practices in Palestine. This also helps in establishing large reuse schemes, which facilitate the protection of receiving water bodies, public health and ecosystem (Abed El-Hady R.M., 2008).

In conclusion there are indications of some leaching of organic contaminants into the sampled wells including 19-15/023 in Auja area. This implies that the solid waste dumps as well as agricultural activities have the potential to release contaminants into the underground water especially that the existing dumps are not lined and are poorly managed. But the level of contamination needs further monitoring before determining the extent of pollution (Sansur R.M, 2007).

Salinity of the ground water has deteriorated over time due to over pumping especially in the Jordan valley. Therefore using fresh water for irrigation is questionable. Additional water available for the Palestinians will be either from the eastern aquifer, the Jordan River, or from treated wastewater all of which is saline water. AS for other sources such as mountain aquifers, there is difficulty in securing this in the near future (Sbeih M.Y., 2006).

Furthermore, two salt bodies occurred in the study area ,Auja and Zaharat Qurrin, probably acting as the source for fresh water salination. It should be pointed out that the occurrence of salt bodies along the Rift Valley is well established. The geographical distribution and the geohydrological location of the salt bodies as well as their geometry and dimensions are essential for conducting an efficient water management (Flexor A., Guttmann J., Shulman H., Anker Y., Yellin-Dror A., Davidson L., 2005).

In the Jordan valley, water prices are US$ 0.175 per m^3 and this reduces farmers' income without any effect on the production structure; prices higher than US$ 0.325 make most agriculture production alternatives unprofitable (Hamdan M.R and Salman A., 2006). Bananas can only be grown in Al Auja and Jericho, and are relatively profitable. A kilogram of bananas yields around NIS 5 whereas the profit from growing tomatoes barely covers the cost of water (Climate Change Adaptation Strategy for the Occupied Palestinian Territory, 2009).

The available water per capita in the West Bank differs considerably among West Bank governorates; it ranges from 29 L/ capita/ day in Tubas governorate to 200 L/capita/day in Jericho (PWA 2002, 2003). The annual domestic water demand is 140MCM/a (Jayyousi 2000).

The Lower Jordan Valley is an area with high water supply, yet with very variable regional and social availability. Our data confirm the observation that indeed there is no scarcity of water but there might be a "secondary scarcity", namely the capacity to properly manage the available water supply (Trottier, 1999).

1.5 Challenges in LJV and Research Needs

The main challenges in the LJV as well as in the CSA are listed below:

- Political and administrative constraints with regards to usage of water resources;
- Complex and difficult social dimension (Rejection of using Treated Waste water (Al-Bireh WWTP: 2.0 Mm^3/a, Jericho WWTP: 3 Mm^3/a);
- Complexity of hydrological systems.
- Lack of agricultural and water sector specific legislation, regulations, means and long-term water action plans;
- Water scarcity and inequity distribution of water in irrigated agricultural lands (individual owners);
- Qualitative degradation of regional water resources;
- Leakage of sector data and net resources; and
- Poor technical level in some water sectors.

1.6 Research objectives:

For this research, the focus should be on the following aspects:

- Identify water development strategies as combined measures to ensure sustainability in agriculture;
- Study social, economic and environmental performance of these strategies.
- Identify priority interventions with regards to water production and hydro-infrastructure.
- Study different water allocations and storage schemes (MAR) for agricultural extension, taking water quality and salinization problem into consideration; and

- Compare options with regards to the extension of regular agriculture, the introduction of salt resistant crops (Date Palm trees) and new irrigations technologies.

1.7 Methodology:

1.7.1 Data collection (stakeholders' consultations and field data*)*

The following data has been collected

A- Available Data from establishments (governmental and non-governmental bodies)

Metrological data has been collected from the Palestinian Metrological Department (PMD) for the period 1994 to 2011. This Data represents upper aquifer (Ramallah) in El Bireh station and lower Aquifer in Jericho. It is also essential to have metrological data from CSA itself to have more accurate interpretation results in the area. Hydrological and hydro chemistry data relevant to water resources in the CSA in the last ten years have also been collected. There are some missed years and variations between resources from year to another, which warrants more screening and classification to obtain more accurate and reliable data from different resources.

Agricultural data relevant to soil, land use and landscape were available for Jericho Governorate. But they are mixed and should be audited and screened to be classified and accurate in case they represent real current situation in the CSA. (Resources of data are from the Palestinian Ministry of Agriculture).

GIS and database information included in the CSA Catchment, water resources and water drainage system, soil, land use, water networks, rainfall distribution, and the Geological and hydrogeological information have been collected from PWA, MOA, Al-Quds University and the Ministry of Environment Affairs (MENA). Field meetings were held with farmers and CSA village councils but little information was collected about the agriculture sector and water supplies in the CSA.

A large number of publications from governmental and non-governmental organizations (NGO's) and educational establishments were reviewed together with the strategies, standards, and regulations as well as the completed and the ongoing projects, research, articles and master theses produced by Palestinian universities regarding the Lower Jordan Valley and Eastern Aquifer.

B-Data and Measurements from the field

1- Specific Data of agricultural land cover and land use in the CSA:A field survey was conducted through filling a special form by farmers. The form contained the crop type, crop cycle and production, water consumption of each crop, the used irrigation method, production per dunom. The form also contained questions about benefits and quantities of fertilizers and pesticides used. (Full questioner attached in annex 10.1.)

2- Field measurement included soil water content, soil properties and texture and water salinity for irrigation during irrigation process. In addition to time series, metrological measurement in the CSA is essential. Measurement of soil water content, soil hydro chemistry and water hydro chemistry is high priority to have accurate prediction and simulation of future scenarios regarding the agriculture sector development. Basically, experiment design should be implemented into two directions, water sampling and soil sampling.

The main design of experiment well focused on; Climate parameter, soil texture and salinity, cropping cycle and irrigation system of each crop. Water for irrigation and soil sampling just take in consideration the crop cycle, in spring and summer seasons, this could be implemented for both, field and perennial crops.

Five places were selected as representative samples and were distributed into agricultural areas in irrigated and irrigable areas in the CSA (Fig 1.8).

1.7.2 Experiment Design Procedure

a-Identifying 19 sampling places in Auja area, Figure 1.7, located in the Agriculture area (irrigated and irrigable), and including perennial e.g. palm dates, vegetables, crops, vegetable crops including protected covered crops (French tunnel and green house), and unprotected irrigation system.

b-Choosing several crops taking into consideration the cropping cycles of these crops (one sample from each site to be representative of the growth phase during

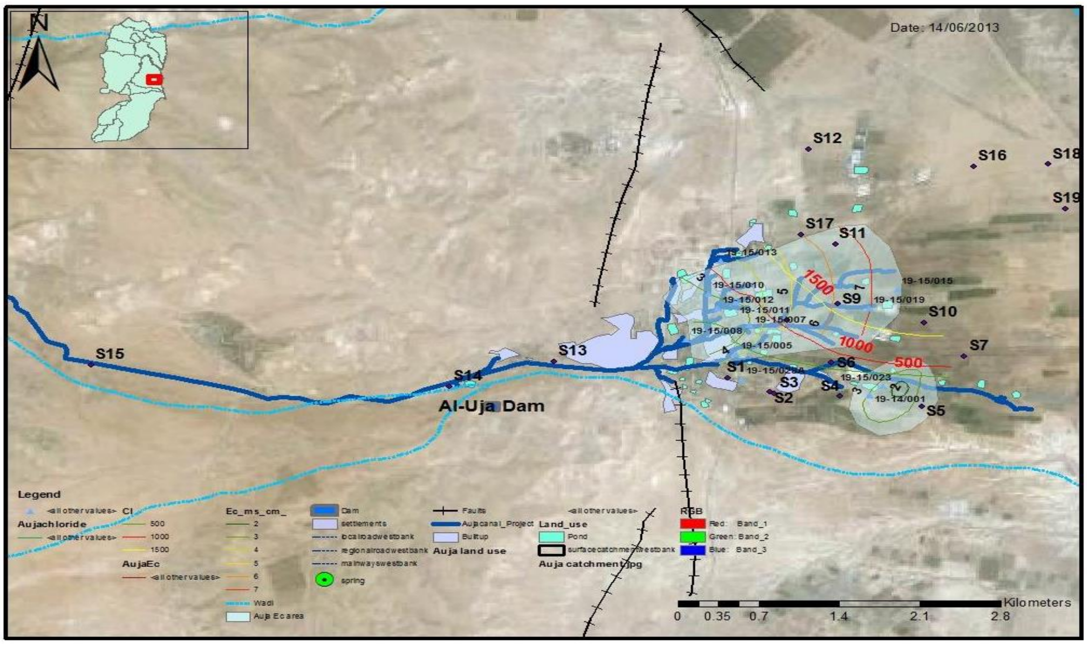


Figure1.7: Soil sample sites at Auja area

Cropping cycle), almost vegetable crops need 3-4 samples according to their cropping cycle during 4-6 months. On the other hand perennial crops phase cropping has longer time such as banana with 24 months' cropping cycle, citrus with 60 months. In this manner and regarding the several growth phases of the crop, several samples need to be taken of several crops of the same kinds in each growth phase. If that is available the results shall be calibrated with FAO index in arid and semi-arid areas (Mediterranean). This idea suggests implementing the sampling process in a short period (4-6 months).

c-Water for irrigation sampling: During the irrigation process and starting with each growth phase of different crops in the CSA, one sample of this water is taken for hydrochemistry analysis, and at the same time for electrical conductivity (EC) of this sample is measured with different field measurements, like temperature, dissolved oxygen, PH,…etc.

d-Soil water content of salinity and hydrochemistry measurements: In the depth of root zoon area, the required data during the sampling period include soil water content, soil hydrochemistry with total dissolved solid (TDS), and sodacity of soil all of which will be calculated as well as the soil physical properties including soil texture, soil permeability and electrical conductivity of bulk soil in several soil-water phases (soil water phase ECw, bulk soil phase ECa and saturated soil water phase (soil past) Esp.), (Rhoades 1972, Mass and Hoffman 1977, Mass 1986 and 1990). This methodology which is approved by the Food and Agriculture Organization (FAO) with extraction procedure of water from water soil paste, of course, with the sample weight at 800 gm, it should be divided into two parts each weighing (400 gm) and the first is for sieve analysis and the second (400 gm) is for soil paste and extraction. All specifications and theoretical details will be added in case this design is approved. There are several tolls and different procedures of sampling and measurement. This depends on the available type of instruments.

e- Underground (UG) wells: (10 wells of these are in Auja, Nui'meh and Quilt). They should be monitored by monthly sampling. Moreover , the relationship between salinity of these wells, the abstraction rate and water table level during the experiment time should be taken into consideration. Furthermore , water mixing of springs' water with brackish water coming from these underground wells should be measured.

f- Canopy Percentage and Dry Canopy in the field just estimated: This is important before starting and during the initial cropping phase. Therefore calculating Evapotranspiration (ET) should be effected by canopy percentage which makes it good in resisting potential soil evaporation.

g-Interpretation, Simulation and Results: Several kinds of software are suggested for simulating and calculating the output result and also the available data:

- For water quality interpretation, Aquachem software is suitable for simulation and interpretation of hydrochemistry data. It is good enough also to make water mixing interpretation (fresh with brackish). This interpretation provides characterization of soil salinity hazards and water salinity could be identified with Surfer Software support.

- Calculating Evapotranspiration (ET), irrigation schedule, and irrigation water quantifying of different kinds of crops is done by using (cropWat.8) software. This software model could calculate the normal quantities regarding the current situation of the quantity of the irrigation system; furthermore, different scenarios of irrigation system could be suggested to formulate the optimal kinds of irrigation strategies regarding crop kinds and irrigation system.

Depending on the output data from cropwat8 simulation, and according to resulting data by field measurements, Aqua crop, version 4 software**,** could predict several scenarios of water irrigation management and effect of saline water . This simulation leads to predicting different scenarios of water resources management in terms of crops productivity and water consumption by each donums taking climate conditions, soil, crop and irrigation as base for the simulation project. This kind of simulation models could be modified exactly according to all possible scenarios of water consumption and crop productivity. These scenarios are applied jointly with future findings according to water resource in the CSA area.

1.7.3 Characterizing the case study area

According to available data, and with regards to field plan survey, characterizing CSA could be defined under the following considerations:

1- Water resources in the case study area include (springs, U.G wells, surface run off and flood water from different wadis, and waste water effluents). These resources in quantity and quality are based on historical and updated PWA data, water table fluctuation (WTF) in order to calculate the discharge and recharge of springs and U.G wells respectively. Also total dissolved solids and physical properties have to be interpreted, especially saline and brackish water distribution in the entire CSA. This interpretation of water quality helps predict the irrigation water quality for future scenarios. In addition, Aquachem software could be used for this kind of interpretation.

2- Flood water of three wadis (Auja, Nui'meh, and Qilt) located in the CSA was calculated by different Palestinians and international establishments such as (PWA, JICA, Survey 2007, Al-Aghwar Development Plan (PWA,MOA), and Palestinian Agriculture Relief Committees' (PARC) Report about Lower Jordan valley in 2010. All these reports and surveys gave clear picture of flood and surface runoff water.

3- The waste water effluents help in characterizing water resource issue. These effluents have been discharged by villages of Auja and Nui'meh. This effluent discharge has no other kind of primary treatment and it indicates hazard impact on the CSA. Quantification of these effluents is given by the Palestinian estimation and Jericho Master Plan by PHG, 2011. Furthermore, This effluent forms around 90% of per capita water consumption in the CSA.

4- The second source of waste water effluent comes from Al-Bireh Waste Water Treatment Plant (BWWTP). This effluent is subject to secondary treatment phase and according to Palestinian Standards (PSM, 2010) of irrigation water quality. It is applicable to agriculture sector usage. It is worth noting that about 2 m^3 is discharged yearly into wadis without being used.

-Land use and Agriculture land cover**:** According to the Palestinian Ministry of Agriculture (MoA), Agriculture Census 2010, and(MoA), and the Ministry of Planning and Administration Development(MOP), Land Use Mapping Project, 2011, land use and agriculture land cover were characterized and classified in 2011. This classification could be used as main base of characterizing the CSA in addition to some field investigation during field work by stakeholders in the area and local authorities (Village Councils of Auja and Nui'meh**).**

- Soil characterizing would be classified by field work, using sieve analysis and hydro-chemistry laboratory analysis.

All the above-mentioned methodologies of the CSA characterization have to be represented by using Geographical Information System (GIS), Arc Map 10 software, and Surfer software in three dimension elevation model based on Gridding Palestinian Coordinates (1923).

1.7.4 Definition of socio-economic development scenarios

The Case study area has around 5000 people who depend mainly on the agriculture sector for their living and direct farming activities. About 50% of irrigable lands are cultivated but increased salinity of available water as water table depletion decreases its utilization. 24% of total available water reaches Jericho district though transportation.

With regards to the current situation, a creative model into the dimensions of main indicators of population growth and water demand together with choosing interventions and measures should be developed. In this regard driving forces represented by population growth and pressure variables like water depletion and salinity increasing should be formulated with joint combined measures and interventions to conclude several scenarios of socio-economic development.

In this approach, the overall socio-economic indicators should be defined and analyzed. These variables and indicators could be interpreted into multi-variant analysis using Stat graphics Centurion XV, 2009. The Software, and should be analyzed to predict the future socio-economic dimensions and scenario developing in terms of income benefits, agriculture productivity and agriculture water consumption

1.7.5 Water Resources System Analysis and Water Budgets

Usually, Water Resources System Analysis (WRSA) is more important in meeting demands and developing needs. This kind of analysis should give complete picture according to strategic planning as a main tool of Integrated Water Resources Management (IWRM). Manage Aquifer Recharge (MAR) with regards to several existing resources in the CSA, jointly with these water resources potential should represent the basic management key in this regards.

WRSA including resources, potential, water infrastructure and water demands in Auja area and Nui'meh are considered the main component of WRSA (B.Rusteberg, 2011 and 2012). Therefore, our CSA has been considered as one unit in this methodology in the form of one watershed with three sub-catchments; the overall drainage systems were collected towards the Jordan River. On the other hand, the CSA has agricultural land continuity which makes future demands planning more comprehensive and sustainable.

Application of Hydrologic Engineering Center (HEC-HMS 3.5) software model program in analyzing water resources system could reflect the current situation of overall basin of the CSA according to defining basin elements resources and jointly with Time series analysis of different metrological data in lower and upper aquifer. By HEC-HMS simulation, many hydrographs should be produced and used directly or in conjunction with software for predicting water availability, urban drainage reduction, flood plan regulation, water lands hydrology and system operation. Also, time series simulation model could predict future scenarios of precipitation and other metrological variables. This is useful in reflecting agriculture development scenarios with regards to predicting available water in future (Figure1.8).

Selection of the most appropriate technological measures and interventions is part of water development strategies as combined measures.

1.7.6 Definition of alternative water development strategies as combined measures

Selection of socio-economic and environmental indicators is a basis for Multi-Criteria-Analysis; application of mathematical models simulates groundwater flow and transport, underground storage of water, crop water requirements and soil salinity for impact assessment and water planning. (This thematic issue could be distributed into several parts of previous methodology such as characterization of the CSA as well as Water Resources Analysis System).

Evaluation of alternative agricultural development options with regards to the extension of irrigated areas is also used (included in characterizing the CSA with CropWat and Aqua crop software model)**,** and final strategy evaluation and ranking.

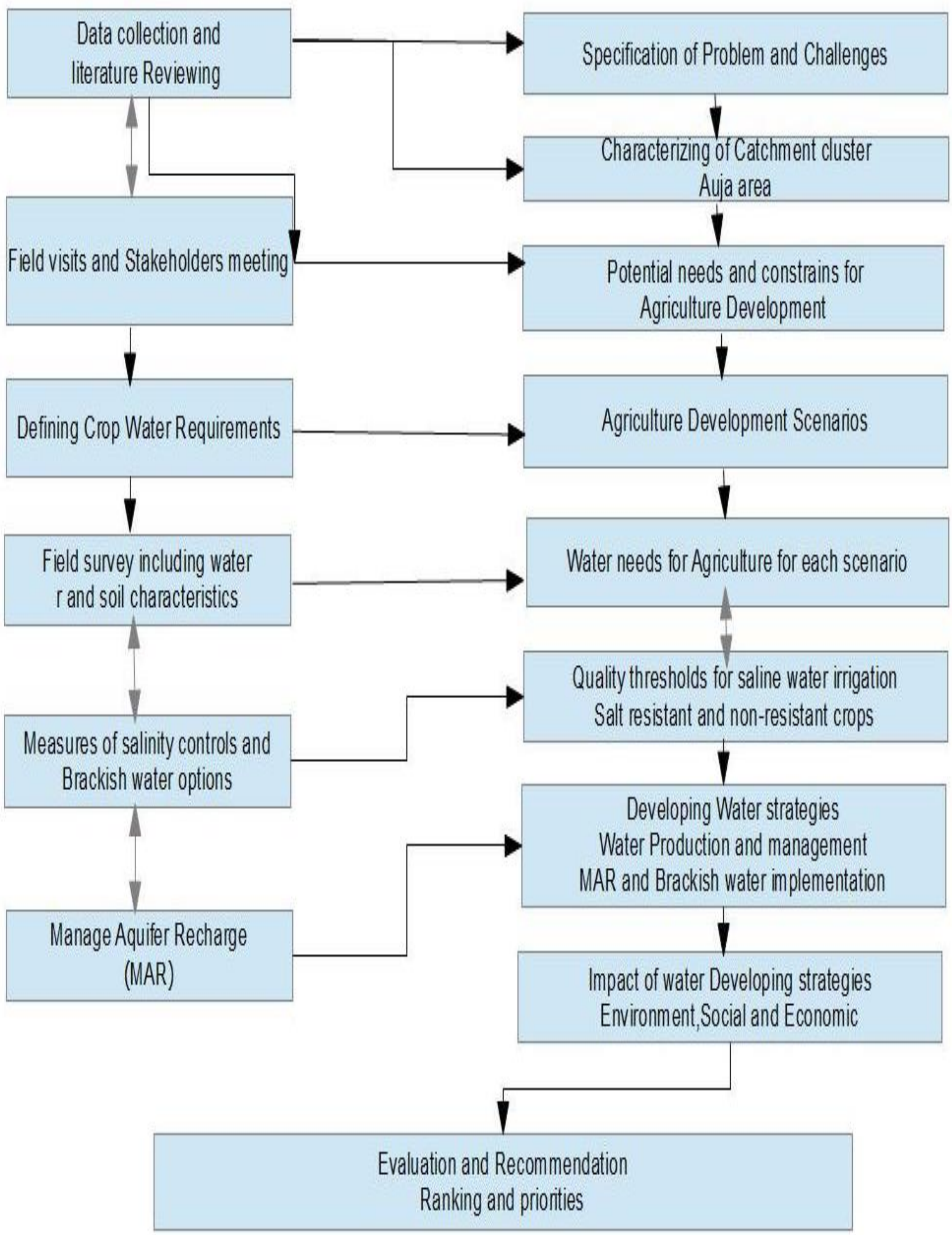


Figure1.8: Methodology Work flow Sheet

Chapter 2

The Study area in the Lower Jordan Valley

2.1: Delineation of study area

Auja village has 30,000 donums of arable lands out of which 12,000 donums of arable lands were irrigable until 2007 (MoA) but only about 4000 donums are irrigated now (District Office of the Ministry of Agriculture in Jericho City and Auja village Council, 2013). The rest is not cultivated, (JICA, 2008) (Figure 2.1). Drip irrigation is the prevalent irrigation method in the area.

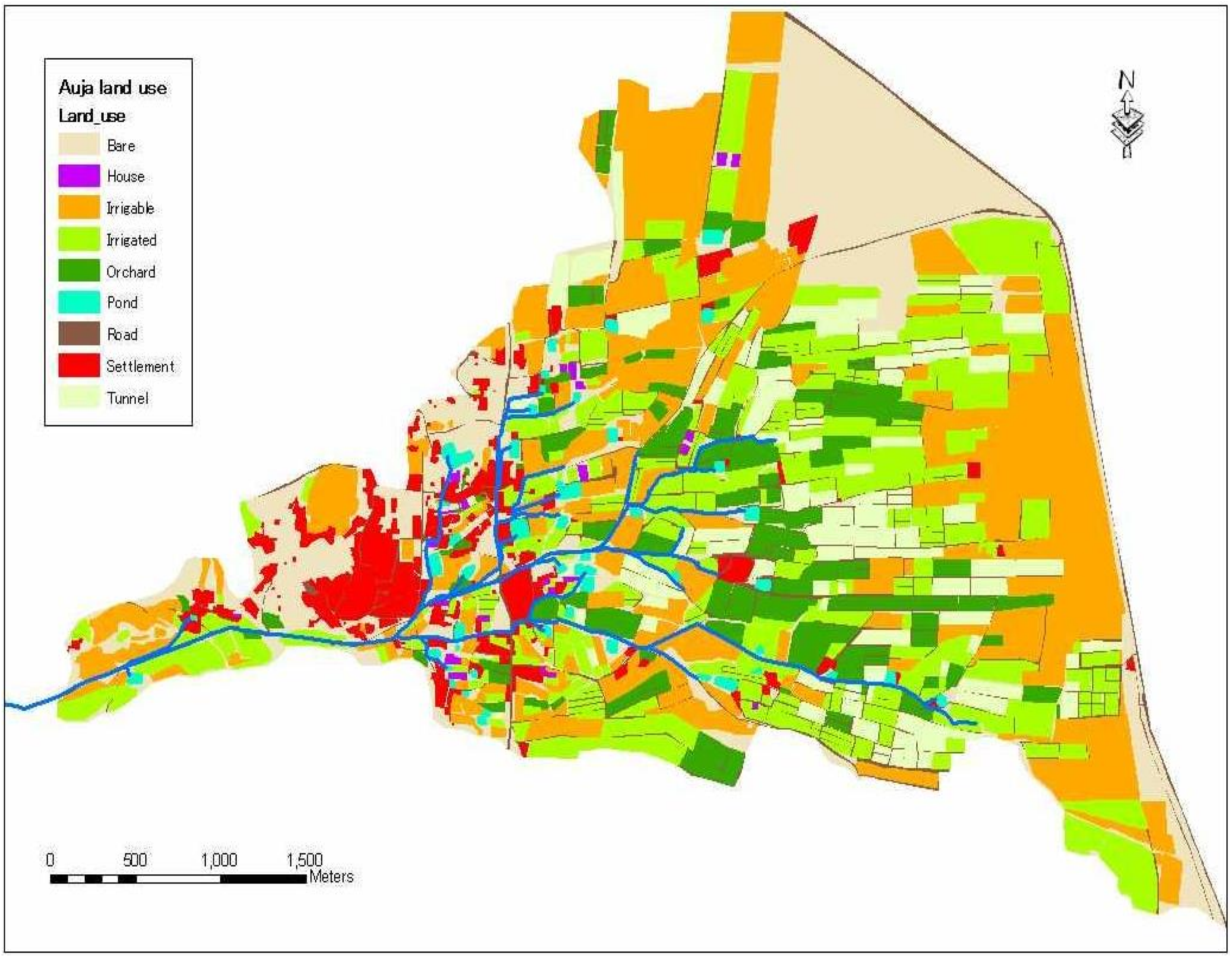


Figure 2.1: Auja Agriculture land use, MOA, 2007

In Auja village, annual water share from springs directly or water pools (52 pools storing from spring) during all crop seasons is 6,589,600 m^3 (Field Investigation, Ayman A.M. Shawahna, 2013), (Figure1.2). The pools are 37 units with total capacity of 294,580 m^3, and 5000 m^3 mean size. The average size of these pools is 7,961m^3 with different capacities ranging from 240 m^3 to 25,000 m^3.

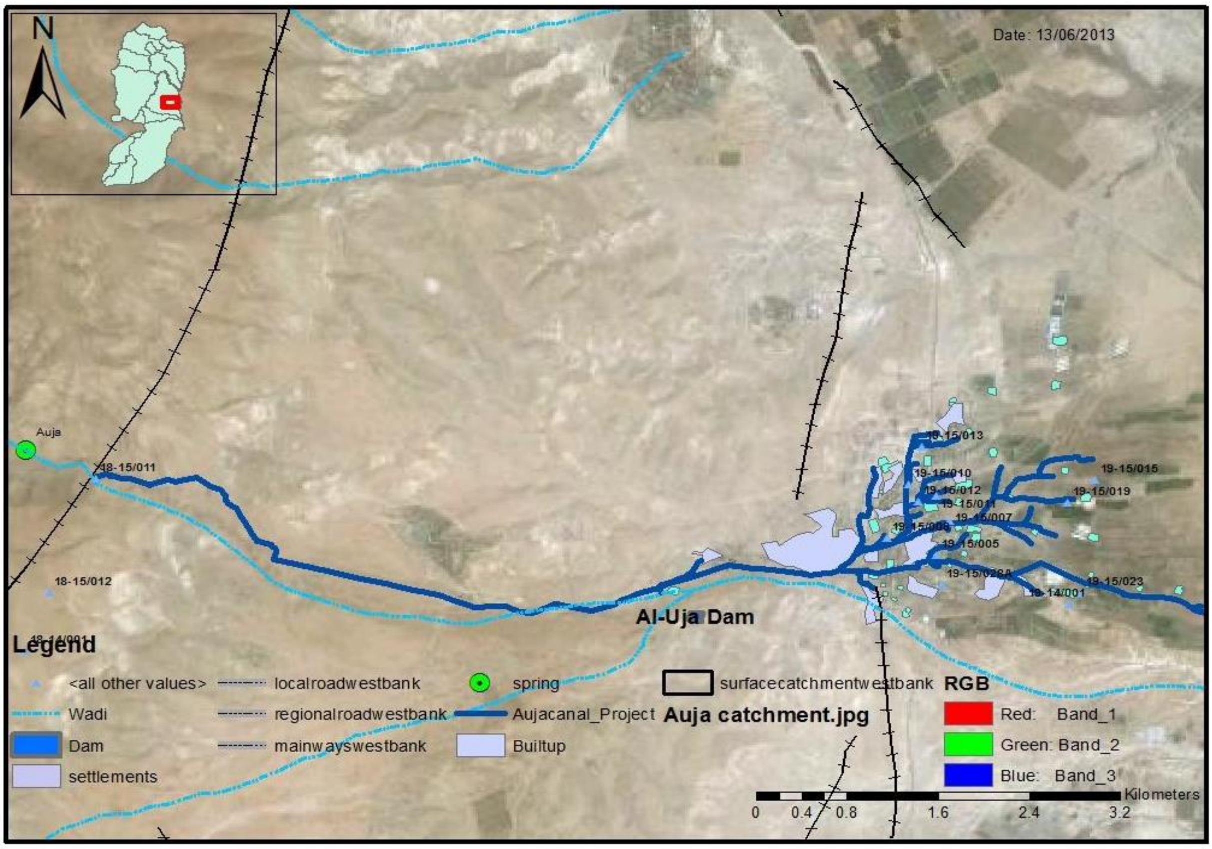


Figure 2.2: Auja Spring conveyance system and water pools distribution in cultivated area

2.1.1 Surface and Subsurface Water Divides

Figure 2.2 shows that Al Auja sub-basin is part of three sub basins forming the Auja-Jericho area. The three sub basins are Auja, Nui'meh and Quilt. Auja sub basin collects karstic spring drain water from the Mountain Aquifer system (Auja Spring). Its annual mean discharge in wet years is 10 Mm^3 and 2.5 Mm^3 in dry years. In addition to the spring,12 shallow boreholes tape water from the shallow aquifer system. The total annual mean of abstracted groundwater from this system is about 0.5 Mm^3, **(**2000-2009, Database, PWA**)**. The major Jordan Valley Dead sea fault system separates the Shallow Plio-Plistocene aquifer from the Mountain system where impermeable chalk unit partially crops on the surface. Direct recharge to the shallow system is limited to flooding during few days of winter months (Figure2.3).

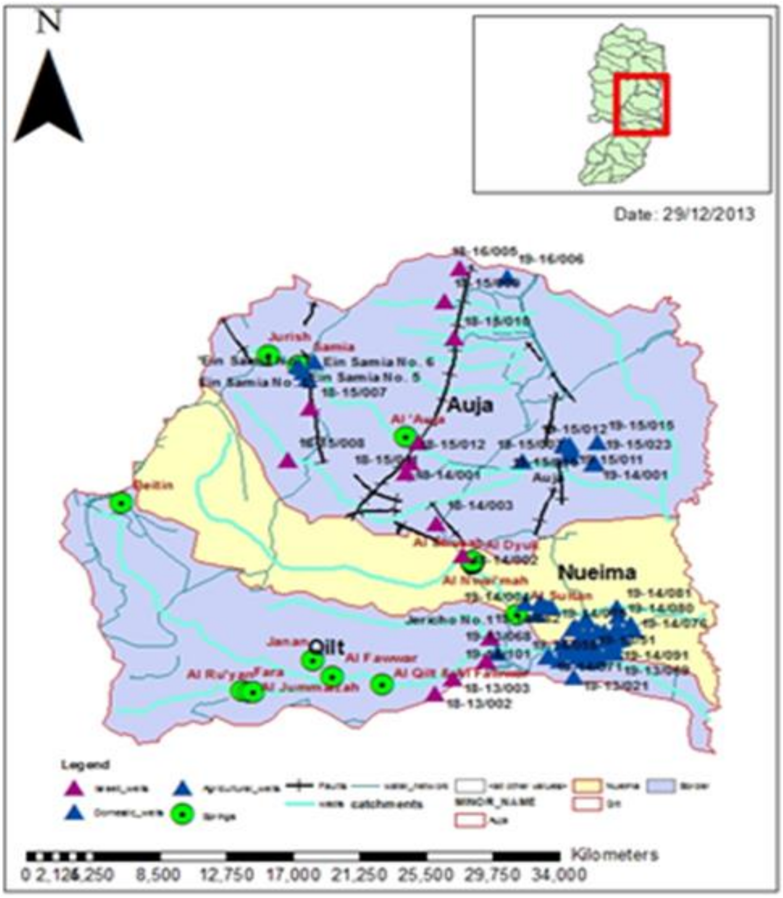


Figure 2.3: Al Auja sub basin and water resource in the area

At the eastern boundaries of Auja catchment surface water is divided into approximately north-south direction and runs parallel to the axis of the mountain anticline. Surface water in this sub catchment area drains eastward recharging the groundwater aquifers by infiltration, which flows eastward towards the Jordan Rift Valley. Figure 2.4 shows surface water drains by different branches from Wadi Auja and from Wadi Fasayel which is coming from the north.

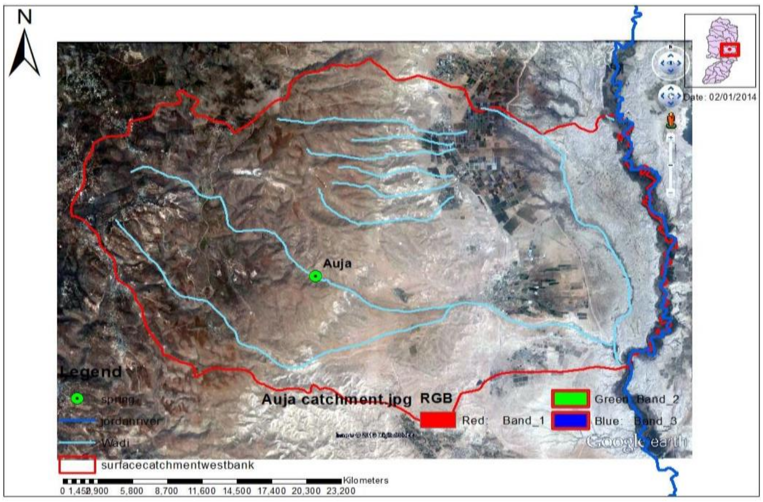


Figure 2.4: Surface water in the CSA

2.2 Land Resources, Land use, and Geology

In this section, topography figure 2.5 discusses and explains soil, land use and Geology.

2.2.1 Topography

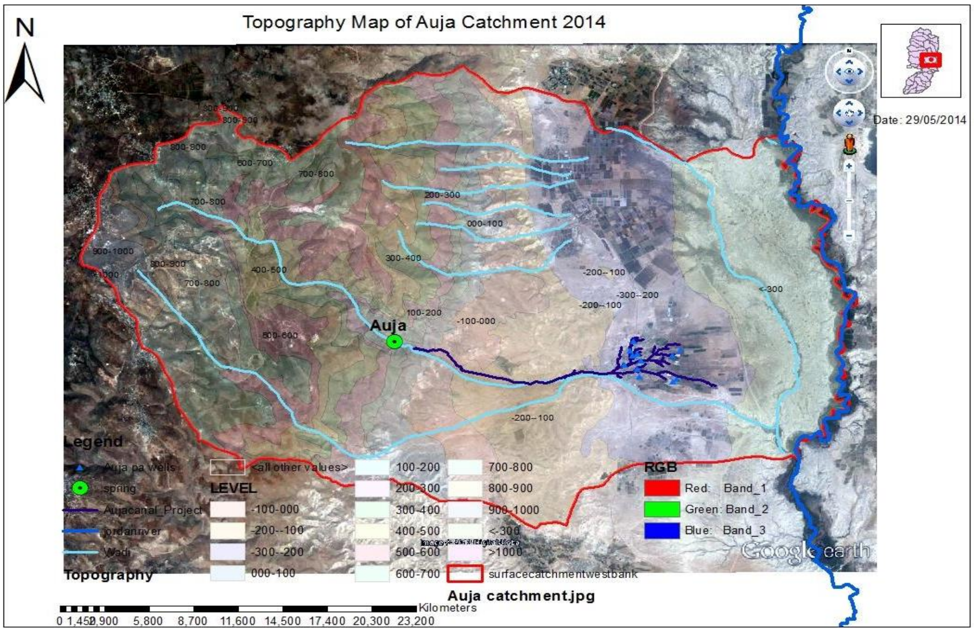


Figure 2.5: Topography map of Auja catchment

Topography and land scape conditions in the Auja catchment are categorized into three topographic zones: mountain areas, foothills and flat areas.

Mountains areas were extended on Ramallah anticline Surface Mountain including the western slopes towards Kafer Malik and Almazra’a village borders including Ain Samia spring. These slopes exceed 25% in gradient up to foothills of Auja Mountains. This upstream elevation is around 1,000 m above sea level (ASL) in Tal Asour Mountain. It decreases to 100 m ASL on foothill border. Foothill and steep slopes have an elevation between 0 m and 250 m ASL. It includes Auja Spring area. The flat area which is below sea level is the target site for this investigation. Its elevation extends from 0m to 300 m below sea level (bsl). Most of this flat area is for agricultural land use, it usually has high agricultural produce. The agricultural area in this flat zone is 30,000 donums (3 km^2) but it is no more than 4,000 donums cultivated now. Among the agricultural area there are also built up areas.

2.2.2 Soils

CSA soil map, figure 2.6, mentioned six main kinds of soil: the terra Rosa and Pale, rendzinas, Brown, Rendzina as Brown Litholsols, Loessial Serozims, Brown Litholsols and Regosols.

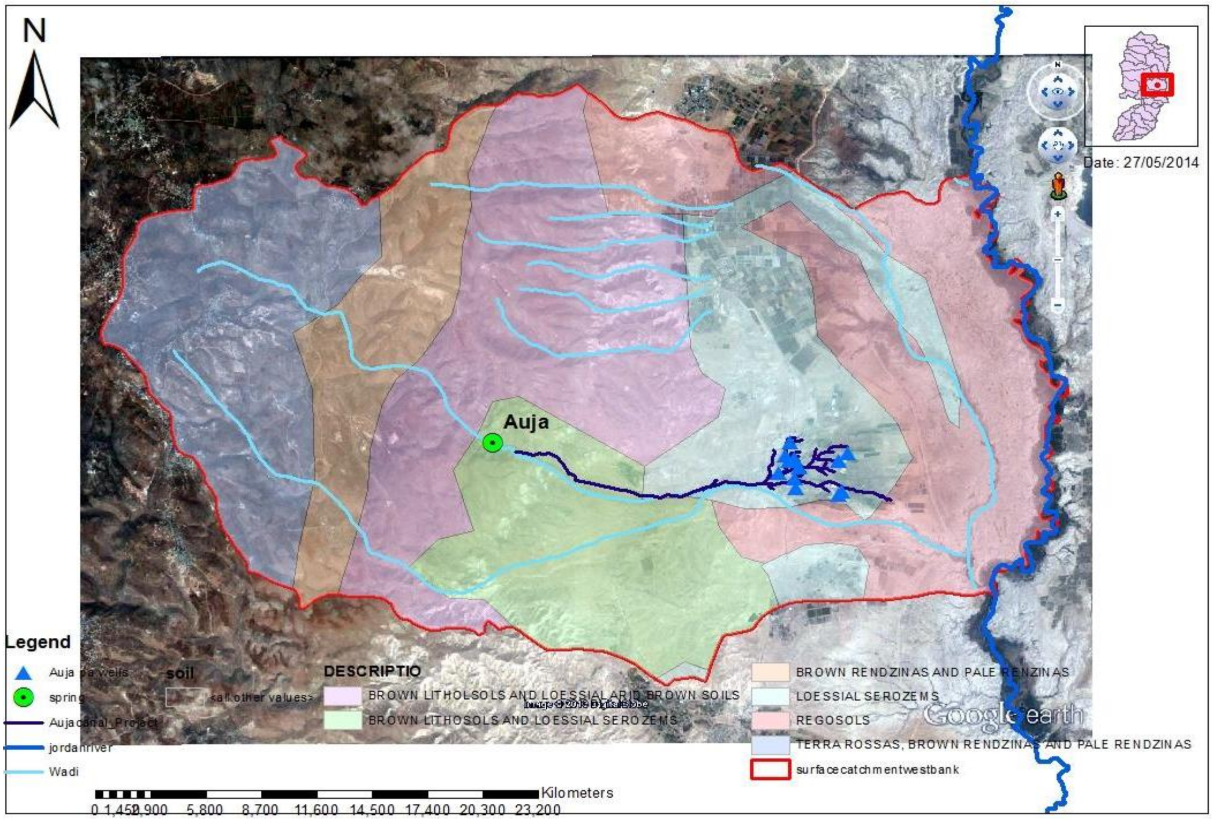


Figure 2.6: Soil map of the CSA, Auja Catchment (Ministry of Agriculture, 2012, Soil Map)

Lands in the CSA are divided into upper mountain soil, which is not cultivated, and lower alluvial deposit, which is considered the agricultural area in the CSA. So, alluvial soil deposit in the lower part represents cultivated area. This alluvial soil genesis in soil classification (U.S.D.A Classification) contains three main subsoil groups: the Lossiah serozems, the regosols and the brown Litholsols. Loessial Serozems soil is the main irrigated area in Auja catchment; it is described as aridic, and rarely as luvic calcisols. It has been classified with saturated complex and contrasting Pedo climate (5^{th}class of soil Isohumiques, sub class 3, 1975, French Classification). Regosols soil is the desert soil; it is raw mineral soil of deserts and is mentioned in some classifications as Yermic Gypsi soil, which is secondary accumulated Gypsum (World Reference Base, 2006). It is usually silty. Alluvial soils are found in depressions and are characterized by various sediments. They are unconsolidated deposits. The third kind of soil in the area is Brown Litholsols and Loessial Serozems soil. It is shallow brown Litholsols with numerous out crops and rendzinic. Inclusions of loessial sierozems are found in broad valleys and in small plateau. Loessial alluvium soils and stony desert alluvium cover narrow valleys.

2.2.3 Land covers use of the CSA

In figur2.7,and according satellite images and Palestinian ministry of agriculture (MOA)

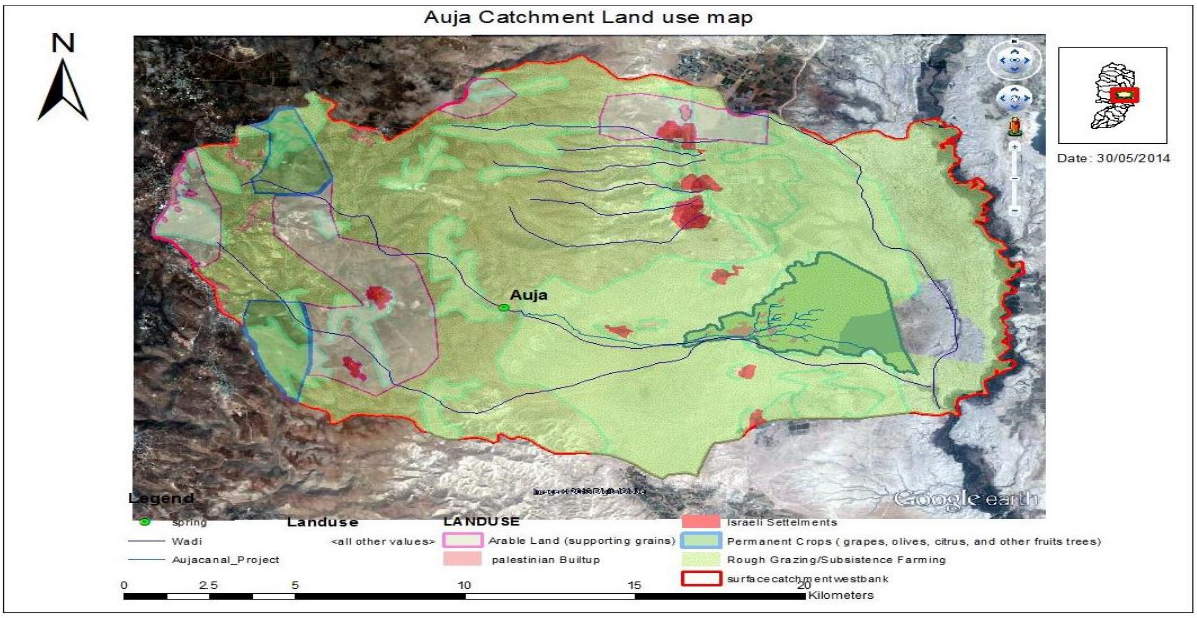


Figure 2.7: The CSA land cover use.

According to Census2010, the land cover use can be classified into four main areas: agriculture areas, Palestinian built up area, Israeli settlements and military bases, and rough grazing and random pastures areas.

Most of the CSA area (229.19 km²) is considered as rough grazing and random pastures (Table 2.1).It is distributed into upper stream mountains towards the west and also along wadi Auja shoulders, especially in the area of foot hills. Palestinian Built up area is in the lower stream and has one cluster of communication with around 5,000 capita. Auja village is located in the flat plane area of Auja catchment with 2.33 Km² in area. Auja municipal council plans to expand structure plan of Auja village to 4 Km².

Table 2.1: Land cover use in the CSA.

LANDUSE	Area (Km²)
Arable Land (supporting grains)	35.70
Palestinian Built-up area	2.33
Irrigated Farming (supporting vegetables)	8.73
Israeli Settlements	3.96
Permanent Crops (grapes, olives, citrus, and other fruits trees)	10.98
Rough Grazing/Subsistence Farming	229.19
Total catchment area	290.89

Israeli settlements built up areas occupy 3.96 Km² of Auja catchment mostly located along the flat plane of Auja catchment. Arable lands in the CSA is 35.7 Km² and the flat plane around the village is considered arable land. Some parts of these lands were owned by the government and others are private. Some of these lands grow some cereals like wheat and barley. Permanent crops like grapes, olive and citrus are distributed on the upper slopes of the western mountain of Auja area. Olive farms and others are on the flat plane alluvial deposit of the CSA. Permanent crops occupy around 11 Km² and the last kind of agricultural land covers is irrigated farms in the flat plane area, the irrigated area is 8.73 km² (2005).However, in different seasons, this area it does not exceed 4 Km² nowadays. So a lot of agricultural cover land use will be discussed specifically and with more details in Crop Water Demand and Agriculture Chapter.

2.3 Regional and Local Climate Conditions

The Occupied Palestinian Territory (oPt) climate is traditionally described as 'Mediterranean', characterized by winter rain and summer drought. However, there is great diversity in this climate which is modified locally by latitude and altitude. This is especially apparent in the West Bank. Climatic zones range from extremely arid to humid, according to the De Matron Aridity Index Classification for arid areas. (Figure 2.8) (Climate Change Adaptation Strategy of OPT, December 2009).

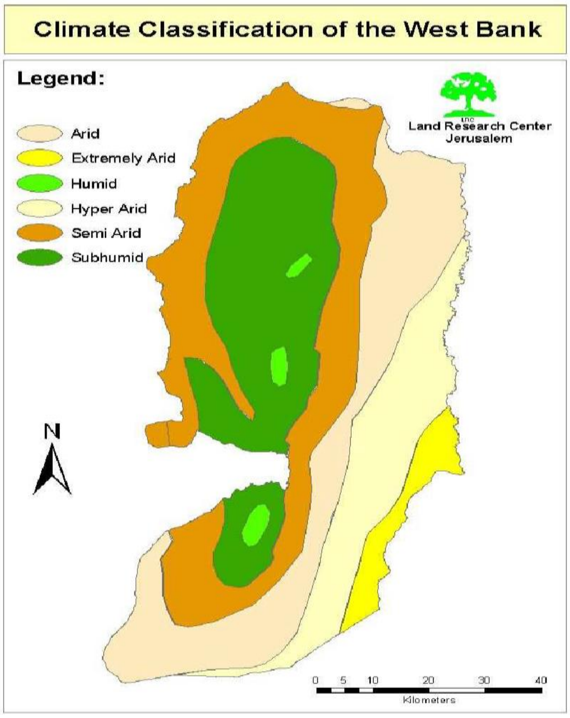
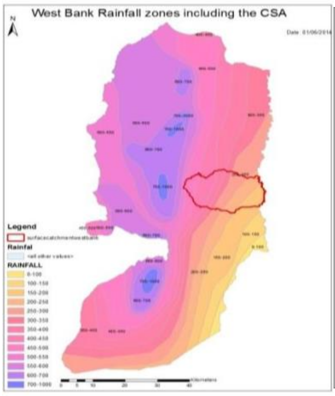


Figure 2.8: Climate zones in the West Bank in oPt, 208, Land Research Center, Jerusalem.

The Case study is divided into semi-arid zones in elevations of 200 ASL to 900 ASL in upstream area towards the west, and hyper arid zone in elevation between 200 ASL to -270 BSL in the eastern part close to the Jordan River area. This diversity in climatic zones in a small area has resulted in different elevations at short distances and makes pressure columns affect the rain fall, temperature, humidity percentage and evaporation in the area.

2.3.1 Rainfall in the CSA

Figure 2.9 a,b shows rainfall ranging from 100 mm/year in the eastern flat plane categorized as agricultural area, to 500 mm/a in the highlands and the western slopes toward Ramallah mountains.



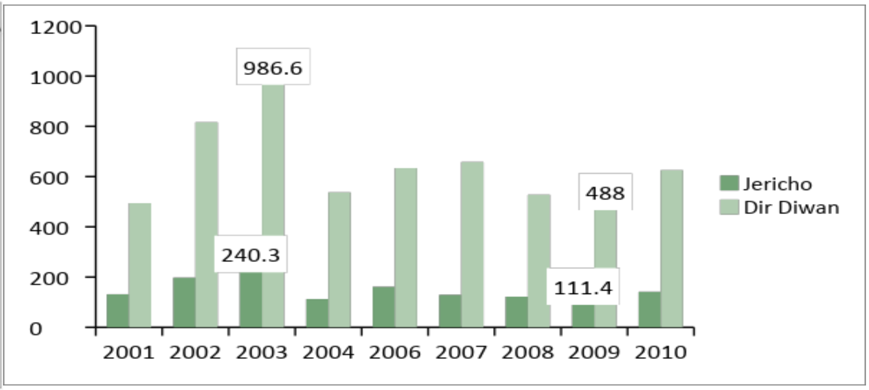


Figure 2.9 a : Rainfall Distribution map   Figure 2.9 b: Annual Rainfall un the CSA

Figure2.9 b Annual rainfall in the case study area including two rainfall gauge stations in high mountain levels in Dir Debwan Metrological Station and flat plane area of Jericho Metrological Station.

Just as rainfall is distributed in the West in specific months of the year with shorter winter and longer summer as well as in the CSA (Figure 2.10) where the mean monthly rainfall distribution seems obvious and clear between the months of October and April while in Jericho area, the mean monthly rainfall is limited between October and March which makes the CSA even drier especially during the high temperatures and evaporation along the year. Thus, the minimum mean of monthly rainfall in the CSA is 5.8 mm in November and is about 37 mm in December. CSA has a mean of 120 mm as total rainfall throughout the year, with 25 rainy days during the entire year in Jericho area ,PMD, 2000-2008, Climate Bulletin.

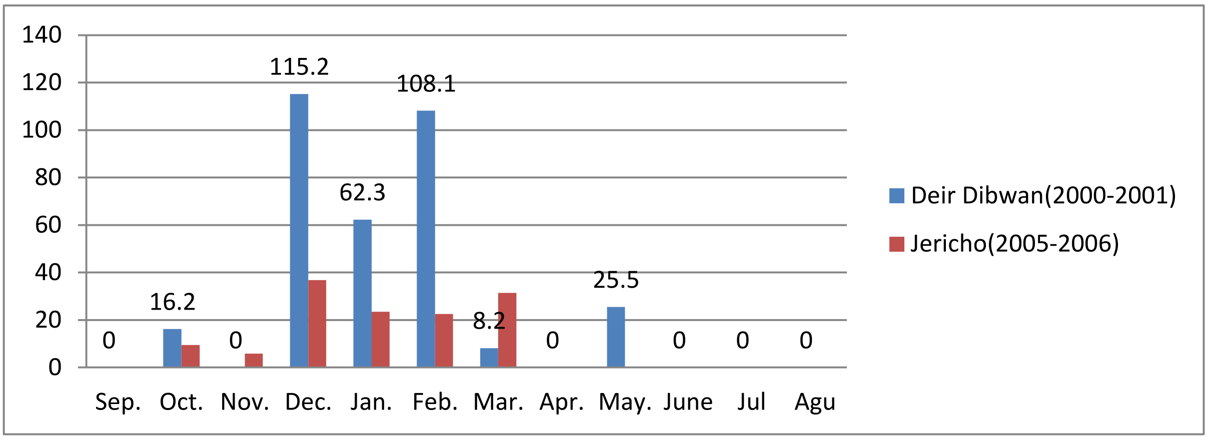
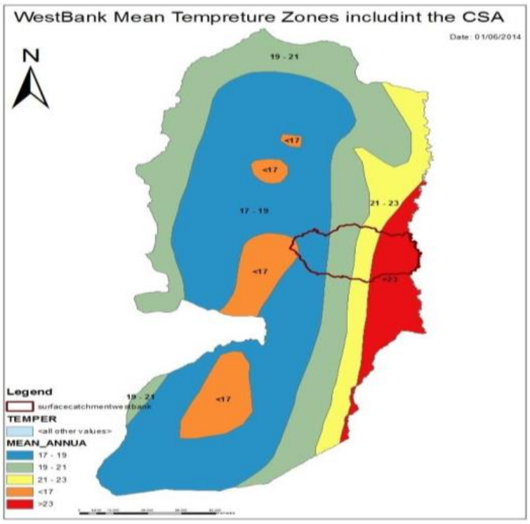


Figure 2.10: mean monthly Rain fall distribution in Dir Debwan Station and in Jericho

2.3.2 Temperature and Evaporation

In the case of arid and hyper arid areas in the CSA, proportional difference and metrological variables were obvious. The differences are very clear in the case of several topographical areas and diverse altitudes in small area, figure(2.11,a and b), show temperature and Evaporation zones respectively.



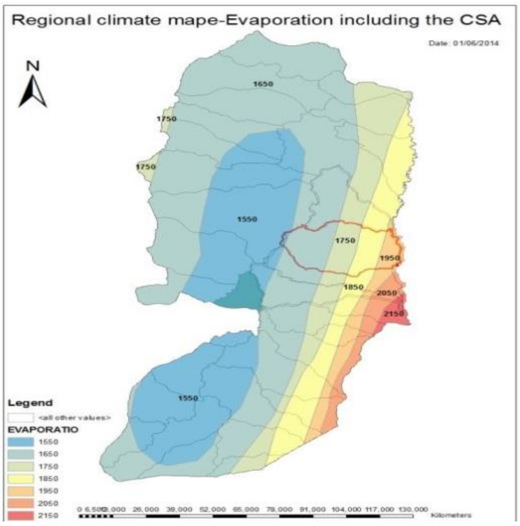


Figure 2.11, a: mean temperature zones Figure 2.11, b: mean evaporation zones

Table (2.2) shows all climate metrological data from Jericho Station in 2011. These climate variables explain the effects on drought situation in the area and the impact of this drought conditions on agricultural production and crop yields in case of water scarcity and integrated water resources mismanagement.

Table 2.2: Metrological data in 2011 from Jericho Station (PMD, 2011)

Met Variable Time	Temp.		R.H		Rain	Sun Shine	Evap.	WIND	Press.
	Max.	Min.	Av.	%	(mm)	(Hour)	(mm)	AV	(mb)
Jan					22.2		89.60		
	21.89	11.30	16.63	52.65		6.06	2.89	3.87	1047.79
Feb					17.20		87.90		
	21.97	12.29	16.94	58.04		5.98	3.14	5.07	1045.63
Mar					10.30		151.70		
	25.65	12.86	24.91	45.42		7.75	4.89	5.71	1048.60
Apr					16.70		188.40		
	29.01	16.49	22.63	42.60		8.36	6.28	5.53	1041.52
May					3.00		259.60		
	33.42	20.12	26.61	37.77		9.52	8.37	6.39	1041.56
June					0.00		306.30		
	36.89	23.41	29.57	40.10		11.74	10.21	6.67	1037.89
Jul					0.00		336.50		
	40.52	25.75	32.75	35.68		11.58	10.85	6.68	1034.37
Aug					0.00		303.90		
	38.92	26.11	32.12	41.10		10.95	9.80	5.65	1035.30
Sep					10.80		225.70		
	36.70	24.65	30.42	44.97		9.41	7.52	4.90	1038.35
Oct					0.00		172.46		
	32.52	20.61	26.44	42.48		8.56	5.56	3.81	1043.97
Nov					15.60		104.40		
	23.85	12.45	17.99	51.23		6.77	3.48	3.30	1048.34
Dec					3.20		89.54		
	22.04	9.37	15.84	44.87		6.46	2.89	3.42	1051.62

In the main season of non-protected agriculture growing during the period of March to July, the maximum temperature scored 40.5 C°. These elevated temperatures lead to high evaporation rates (up to 336 mm)and also high evapotranspiration rates, which leads to decreasing crop water yield. On the other hand, winter in the area favors natural greenhouse intensive agriculture. since the temperature is relatively moderate during the period ranging from September to February. Maximum temperature in this period is 36 C° in September and 21.5 C^o in February. The evaporation is 225 mm and 88 mm in September and February respectively. Figure (2.12) shows the differences between monthly maximum and minimum temperatures, plus, mean values of monthly evaporation in the CSA.

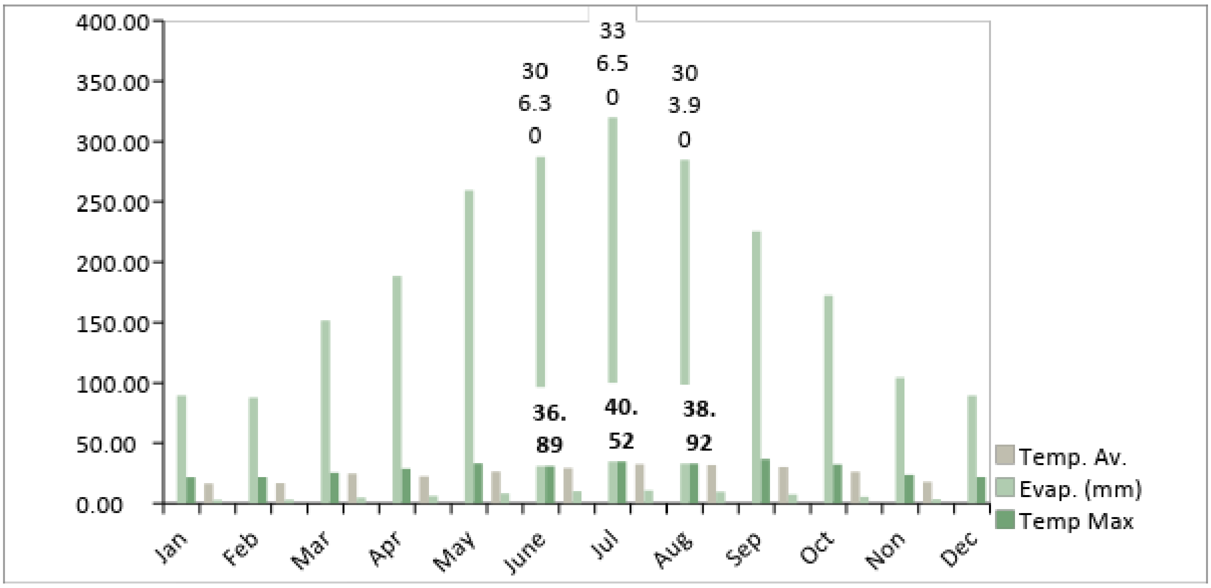


Figure 2.12: Maximum and minimum monthly temperature and mean monthly evaporation in Jericho Station (PMD, 1994-20011)

Regarding these regional climate conditions in the West Bank, four areas of Agro-climate zones were classified by the Ministry of Planning based on special plane maps of the West Bank in 2012. These areas are highly suitable for agriculture and are moderately sensitivity to agriculture. Figure (2.13) shows several agricultural sensitivity zones in the West Bank (including the CSA) categorized to sensitive agro-zone at the upper stream in mountain areas, the poorly suitable zones for agriculture towards the south west. The majority of irrigated and non-irrigated areas in the CSA flat plane has been classified as moderately suitable for agriculture. This moderately agro-zone area is the key area for developing sustained Agriculture Development Strategies (ADS). The strategy will be based on land extensions in addition to formulating more water production techniques coupled with compatible crop selection to efficiently cultivate the land.

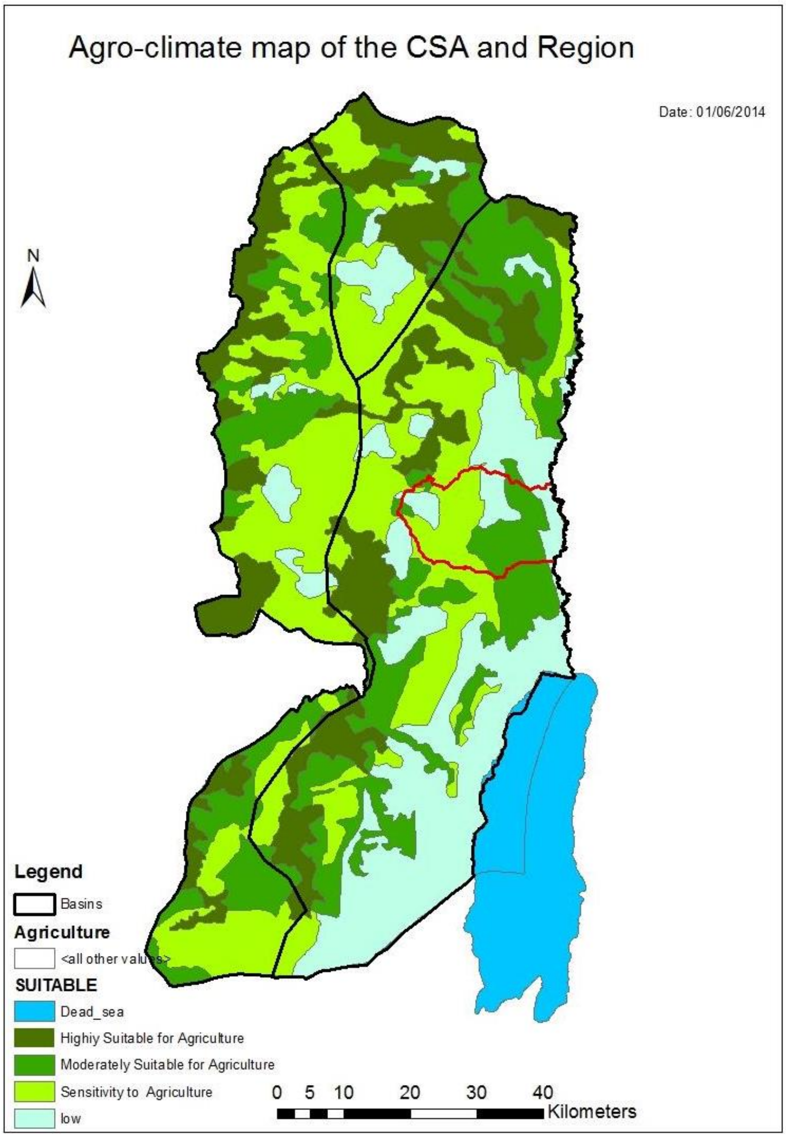


Figure 2.13: Agro-Climate Zones of the West Bank in OPT including the CSA (MOP, 2012)

2.3.2 Climate Projection and Related Risks

Several researches and different models pointed to the impact of climate change and different risks resulting from this change. Törnros, Menzel and Strakova in **(**2010**)** simulated the changes in water availability and irrigation demands in the Jordan River Basin. The simulation was based on reduced scenarios which resulted by Hemming, Betts and Ryall in 2007, according to precipitation in the Middle East and North Africa (MENA), in the 1990s. Figure 2.14, shows decreasing precipitation in the Lower Jordan Basin by 20% from 2020-2070. Glowa Project of the Lower Jordan Valley has confirmed this fact in the last conference held in 2011 in Limassol.

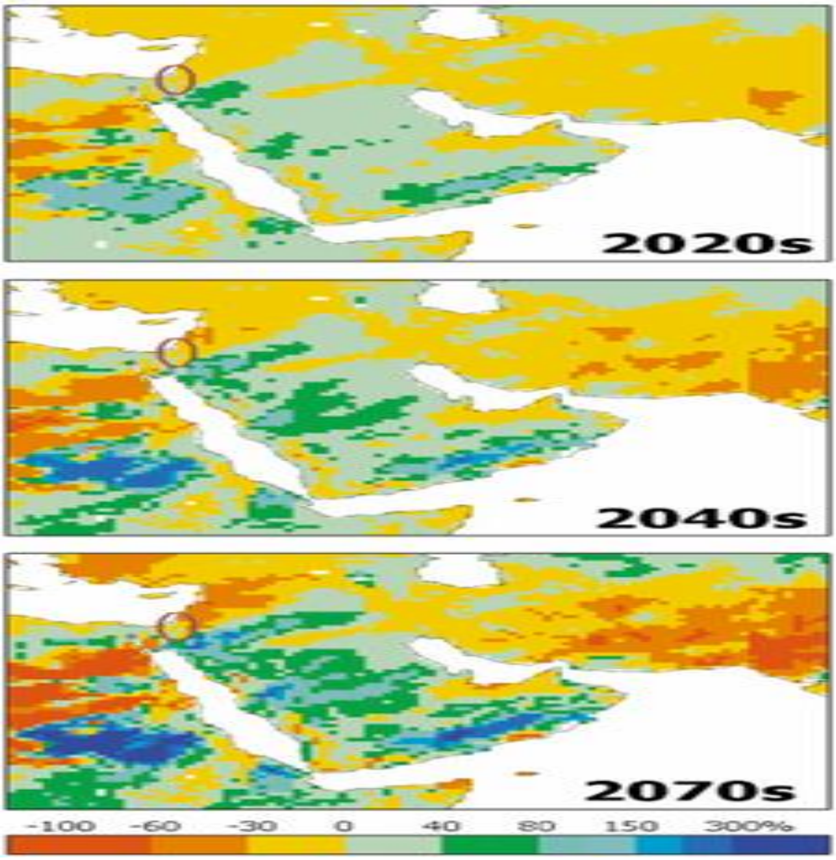


Figure 2.14: Precipitation changes based on 1990s predictions in MENA area, (Hemming, Betts and Ryall, 2007**)**

In spite of these simulation results of precipitation decrease in the forthcoming decades, Palestinian Desertification Strategy (PDS) in 2011 has identified „drought" as naturally occurring phenomenon that exists when precipitation is significantly below normal recorded levels causing serious hydrological imbalances that adversely affect land resource production systems. In this manner, annual precipitation rates are deemed likely to fall in the eastern Mediterranean –by 10% by 2020 and 20% by 2050 –with an increased risk of summer drought. Furthermore, there is a need for climate modeling and research capacity-building in the OPT tailored to Palestinian adaptation priorities in the face of future climate risks.

The water sector in the OPT justifies priority focus in terms of climate change impacts, and that agriculture is the Palestinian most sensitive economic sector to climate hazards, both now and in future.(Palestinian Climate Change Adaptation Strategy) (PCCAS, 2010**).** In addition, the World Bank in its report Number 64635 – MENA**-**in 2011, has indicated that 2008 marked the fifth consecutive year of drought for the basin of the River Jordan. Many Palestinians are deprived of water during summer months and rainfall is predicted to decline by more than 20% in the next 50–70 years. In light of this prediction of declining rainfall by 10% to 20% in the next 50 years, there will be more water scarcity in the Jordan River Basin. Therefore, several climate-induced risks to food production and water security should be taken into consideration.

Ziad Mimi and Sireen Abu Jamousindicated in 2010 that agricultural risks on crop areas change due to decreasing optimal farming conditions, decreasing crop productivity, increasing risk of floods, increasing risk of drought and water scarcity, and finally increasing of irrigation requirements.

Due to different risks in agricultural adaptation, water re-use and desalination in the CSA for irrigation, have priority at a sectoral level in climate change adaptation based on the infrastructure build-up and rehabilitation. This is evident when considering that many wells in the CSA stopped pumping because of high salinity in the abstracted water, leading to the reduction of irrigated lands by more than 60% in the last 10 years.

2.4 Availability of Water Resources and the Existing Hydro-infrastructure

2.4.1 Auja Spring

Auja Spring in the mountain foothill is one main water resource in the CSA. Part of the discharged water from the spring runs naturally into the wadi for about 700 m, after that the water is directed into open canals that are 7.5 km in distance. The canal then splits into two main branches, each main branch will then split out into multiple smaller canals Total conveying distance into these branches is 12 km. Figure (2.15) shows Auja Spring flowing into the wadi and the conveying system towards the irrigated lands in Auja Village.

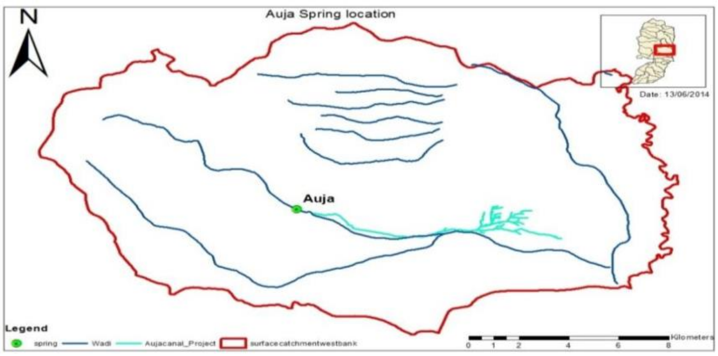


Figure 2.15: Auja Spring and water conveying system

Auja Spring has been classified as the greatest discharge spring in the lower Jordan Valley (LJV). The Spring discharge fluctuates sharply from 18 MCM in wet years to 0.5 MCM in dry years rendering water irrigation management very complex, and leading to unrest in agricultural production and instability in the implementation of plans for agriculture in the region. Thus preventing the achievement of sustainability in the agriculture sector.

Figure 2.16 shows time series discharge fluctuation of the Spring and the precipitation in the recharge area (Upper Aquifer) from 1973 to 2011.

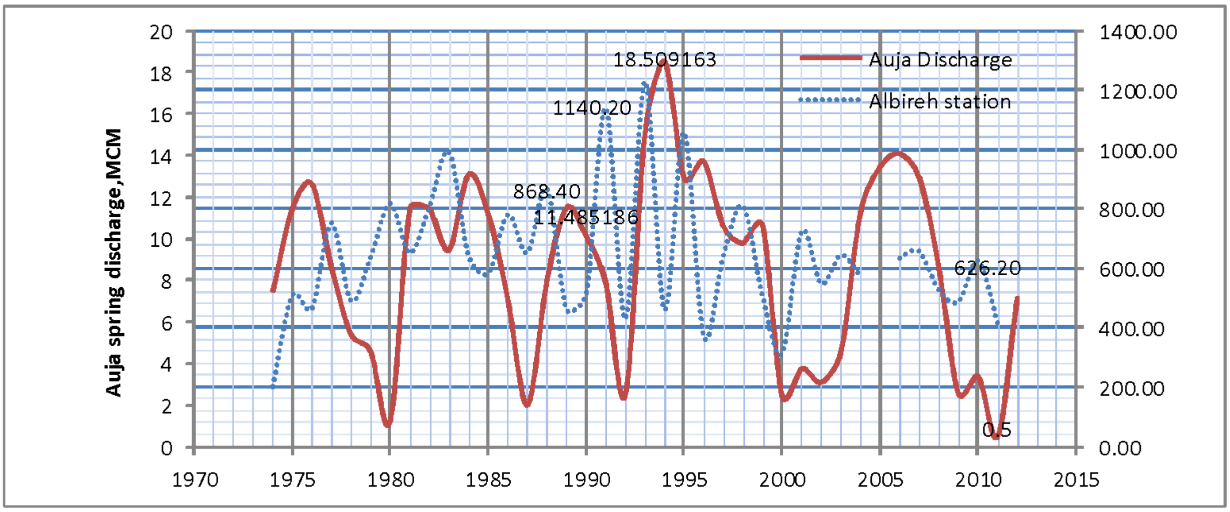


Figure 2.16: Auja Spring fluctuation and precipitation time series (PWA Data base, 2012)

The spring fluctuation and recession curve trend has 3 to 4 cycles; this trend cycle reflects precipitation effects on the upper catchment area without consideration to anthropogenic activities in the area like pumping and over-exploitation from deep aquifer wells (Israeli wells). In this manner, sharp and sudden changing of spring discharge makes sustained planning of agriculture development much more difficult and complex. Therefore, by the year 2013, all vegetable crops in Auja area are planted during winter season (starting in January). This cultivation season, according to farmers, is proper and meets their planting plans which are based on spring discharge decreasing up to drying in June. This is explained by spring drought and sharp discharge. Their effects will be detailed in The Agriculture Developing Chapter.

2.4.2 Surface Runoff

Slopes especially sharp slopes in the CSA catchment make surface water drains eastward or infiltrate to recharge the groundwater aquifers, which also flow eastward towards the Jordan Rift Valley. These slopes in figure (2.17) range from more than 63% in the upper mountain along the wadi Auja to 8% in flat plain area in the east towards the Jordan Riverwhilerainfall quantity starts from 600 mm in the Western mountains to 100 mm in the east of Auja catchment.

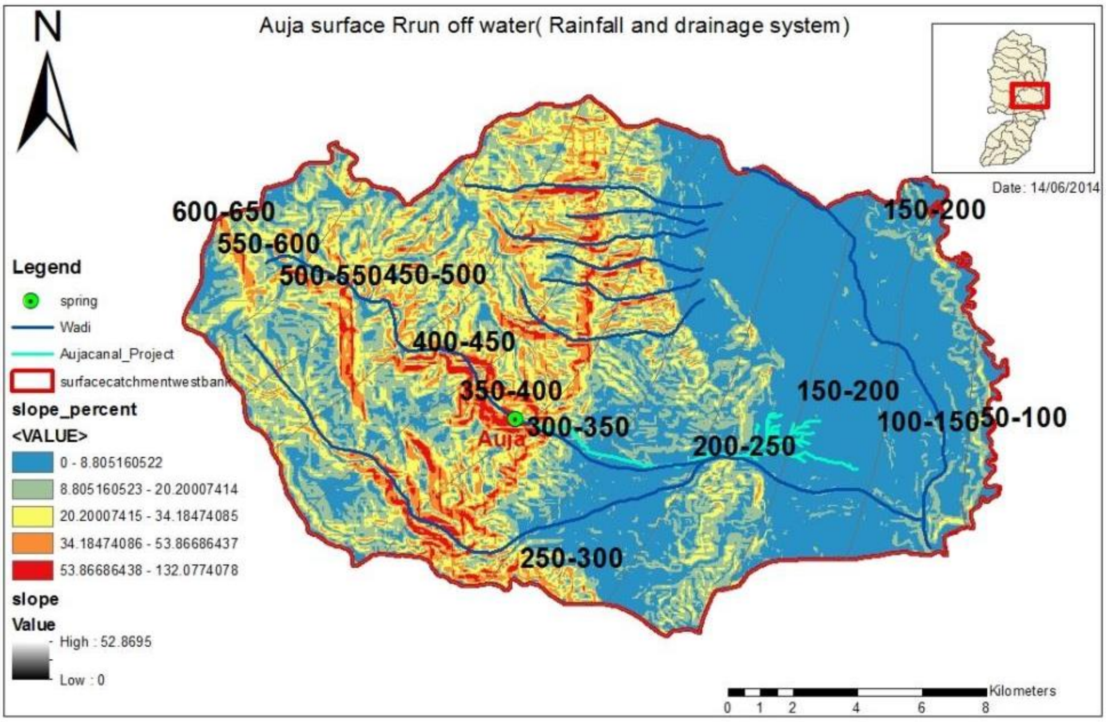


Figure 2.17: Surface runoff and rainfall distribution in the CSA

Two main components form the surface runoff in the CSA: stream flow, which is generated from Auja Spring (base-flow), and flood flow in winter. Stream flow (base-flow) originates from Auja Spring discharges on the ground surface in the form of springs and flows in a stream channel. The following statements describe the surface run-off situation in the CSA.

Auja Spring base-flow and the flood flow are the direct surface runoff generated and collected in stream channels after rainfall.

The number of rainy days per rainy season ranges from 43 days in the mountains area to 25 days in the Jordan Valley (Abadi, Almotazbellah A., 2006)

The flood flow is the direct surface runoff generated and collected in stream channels after rainfall events and ceases sometime after that. JICA estimated flooding in 2008 by 3 Mm^3 in dry years and 11 Mm^3 in Wet years.

Spring average discharges into the wadi flowing in stream channel is from 2 Mm^3 in dry years to 12 Mm^3 in Wet years. Therefore, base flow represents the surplus of the storage capacities of the ground water reservoirs of karstic aquifer in Auja Spring area**.**

The effective catchment area in the CSA is 133 km²; therefore the recharge water from surface water inside the study area is 9.2 Mm^3 and the flooding of Wadi Auja is between 3 Mm^3 in dry year to 11 Mm^3 in Wet years (JICA, 2008).

2.4.3 The Aquifer System

In Auja area, ground water is part of the Eastern ground water basin in the West Bank which is divided by the Ramallah anticline in the west and the Jordan Valley in the east. In the CSA, geological formation according to physical properties is classified by the hydrogeological system into Aquifer and Aquiclude. Figure 2.18 shows this classification of the Eastern Aquifer which includes the Lower Jordan Valley and Jericho Area. Aquifer in this formation stores and sends water into wells or springs and the low transmitting capacity with insignificant quantities into wells or springs is Aquiclude(Almotazbellah A. Abadi May, 2006). Therefore, according to this hydrogeological system, there is deep carbonate aquifer and Alluvial Shallow Aquifer.

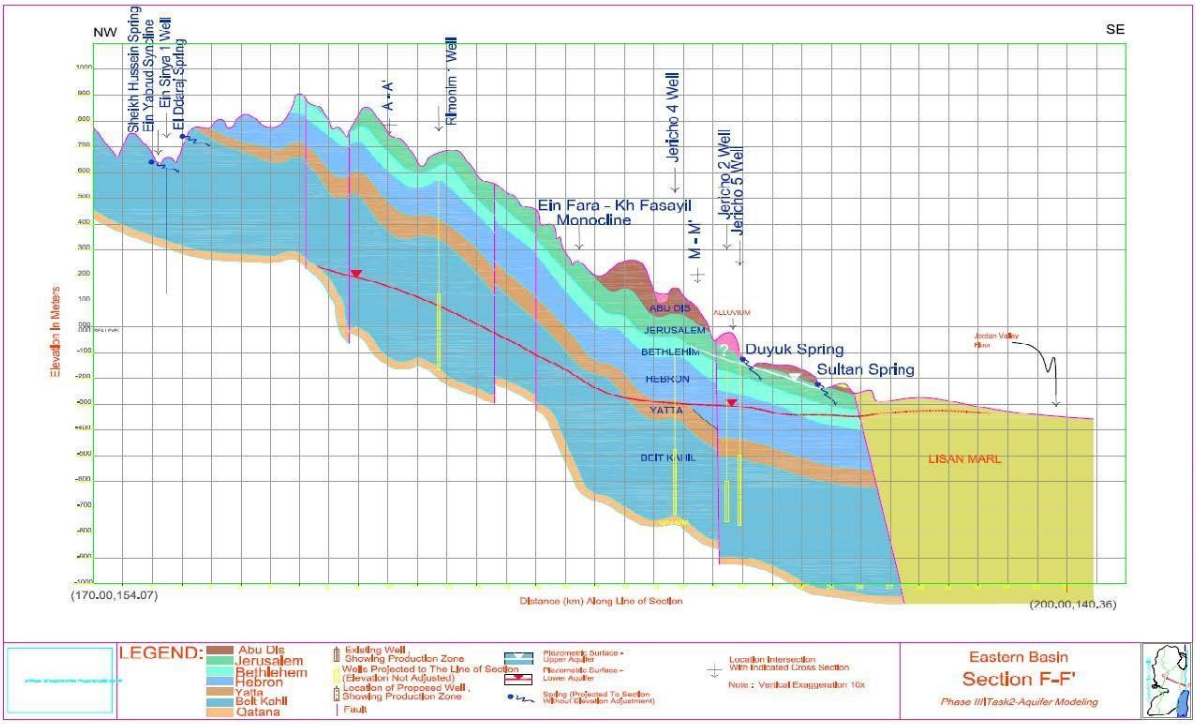


Figure 2.18: Hydrogeological cross section in Jericho area (Ground water Management Model, Task 7, The Jericho Model, CH2MHILL, 2001).

As it has been mentioned in chapter 1, two main Aquifer systems composed the Eastern aquifer, a largely phreatic upper Cenomanian-Turonian Aquifer, and a largely confined lower Cenomanian aquifer. These two aquifers are the most important available water resources in the central hills, the foothills and the Jordan valley. (SUSMAQ,2005) Different historical surveys and many several investigations said that these two Aquifers are not connected systems. However, other new investigations in last years approved some connectivity between these two Aquifers.

2.4.3.1 Deep Carbonate Aquifer

The mountain system layer manifested by Ein Samia and Ein Al Auja is exposed to the east of the lower upper cretaceous layer and in the Hebron anticlinal axis including further east, near the Jordan Valley and in the west by discontinuous fault escarpment reaching a height of 200 m near Jericho and becoming lower northwards. The valley bottom consists of lacustrine sediments, evaporates and alluvial outwash forming an arid, flat, plane land. Auja monocline strikes NNE south of wadi Samia and becomes NS northwards and dips up to 30˚E and ESE. It should be noted that Auja monocline is not a rift feature but is rather characterized by intensive fault systems, E-W directions. These fault systems are formed from grabens, horsts and step structures. This is shown by the continuity of the monocline, with almost the same dips from the immediate vicinity of the rift (Faria area) to more than 20 km far from the rift (Z.B. Begin, 1974).

Figure(2.19) shows PWA well drilled in 2011. PWA drilled this well to the west of fault system of about (496 m). This borehole penetrated the chalk unit of Abu Deis, Jerusalem, Bethlehem, Hebron and Upper Beit Kahel formations (Amer Marie,WP4.2: Hydro-geological Settings in the Western Part of the Jordan Graben/Case study: Wadi Al Auja Sub basin, 2013).

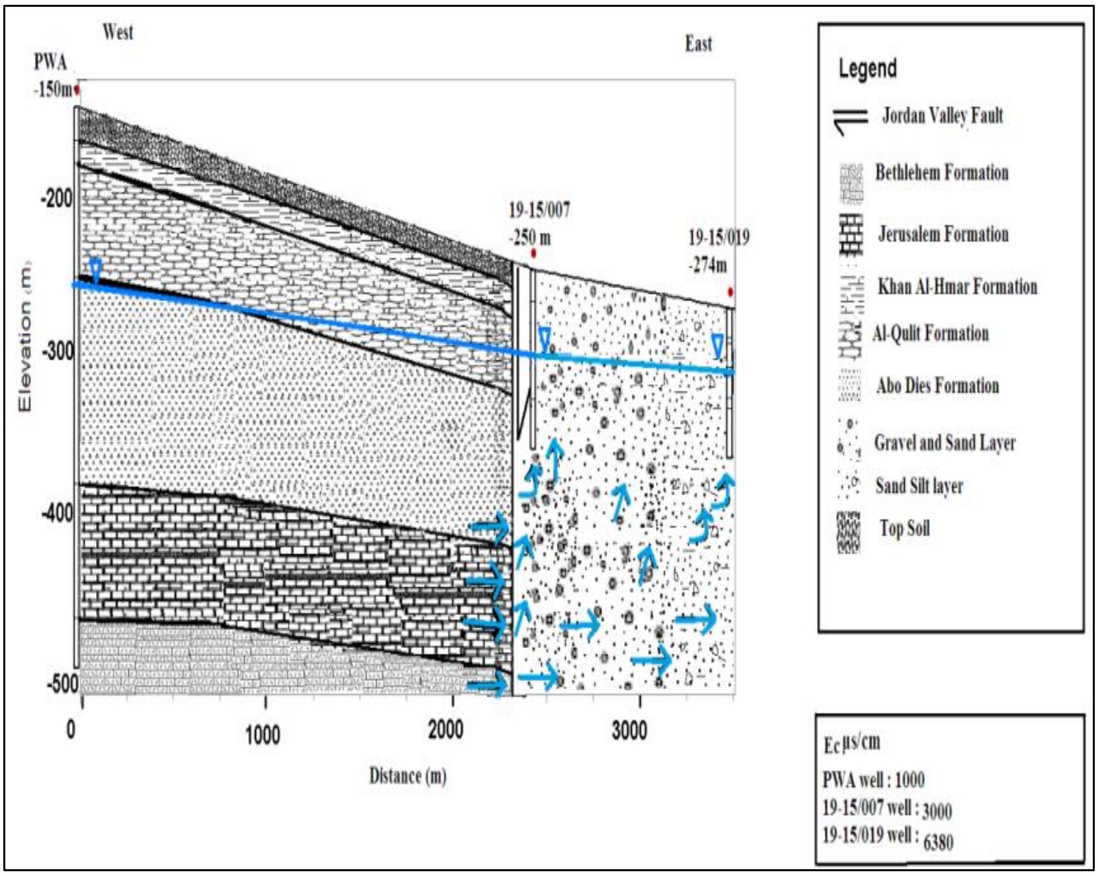


Figure 2.19: Cross section of PWA well to the well no.19-15/019, PWA, Amer Marei, 2013

The groundwater table in both aquifer systems, according to constructed cross section, shows flow gently eastwards with no evidence of high gradient. From this hydro-geological investigations, groundwater's flow from the mountain aquifer eastwards through the fault system and drains the shallow Plio-Plistocene aquifer system. PWA well and Mekerot No. 2 well are hydro-geologically connected and the static water table in PWA borehole falls gently eastwards into the Plio-Plistocene boreholes. This indicates a hydraulic connectivity of both systems and the fault and Abu Deis formation do not act as a barrier. Therefore, recharge of the shallow aquifer system takes place by lateral flow from the Mountain Aquifer into the shallow aquifer system due to the overexploitation up coning of fresh water from the lower layers into the upper layers of the shallow aquifer system. This causes mixing with salty layers as well as with salty water bodies within the shallow aquifer system and the connection between the two aquifer systems (Figure 2.20), Dr. Amer Marie, (2013).

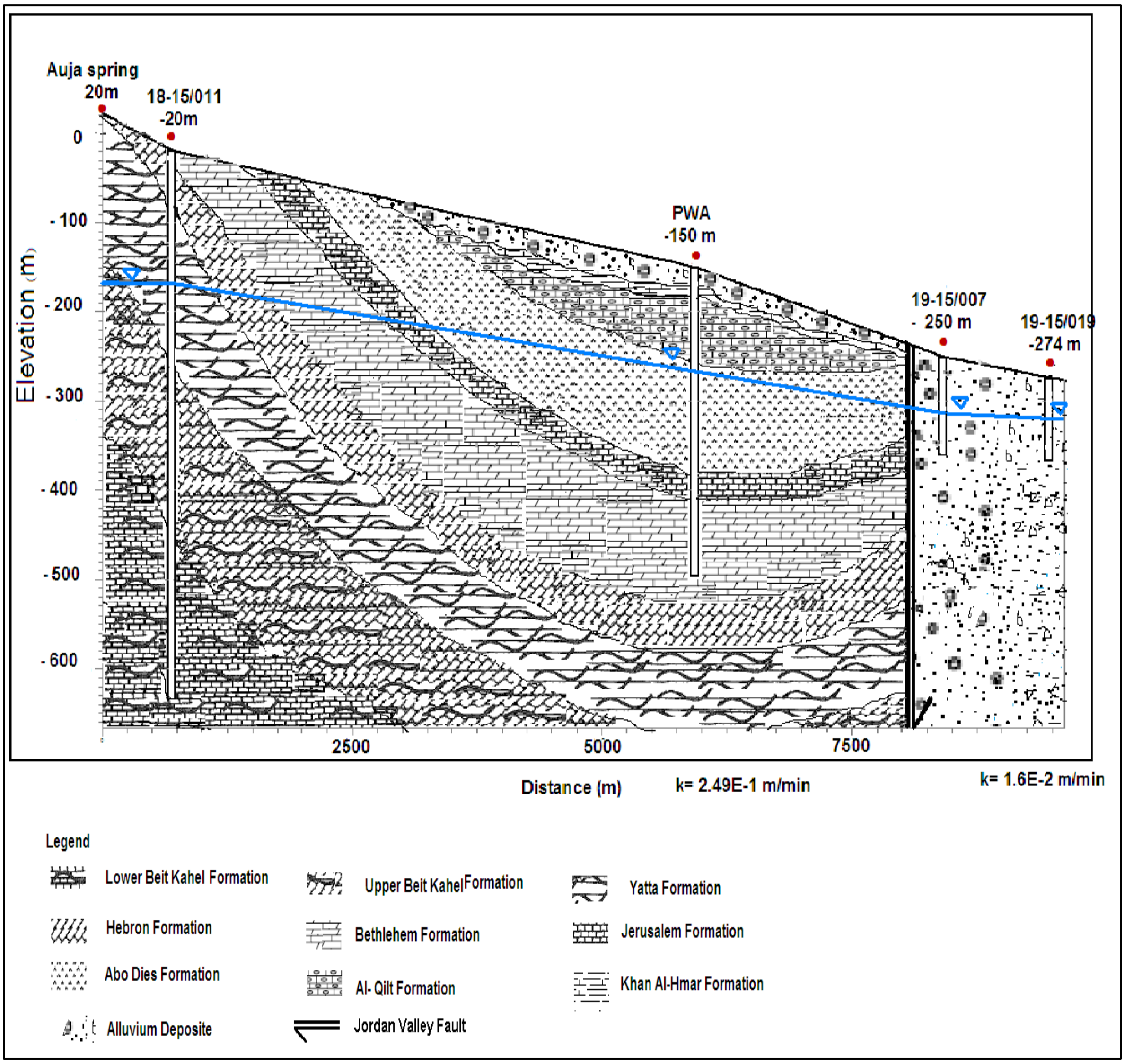


Figure 2.20: Hydrogeological cross section from west to east showing the groundwater table. PWA, Amer Marei, 2013.

2.4.3.2 Alluvial Shallow Aquifer

The lower aquifer is formed from Lisan (Pleistocene), gravel and alluvial fans (Holocene) formation. Lisan Formation (Pleistocene Aquifer) extends along the Jordan Rift Valley and near Jericho. It is lithological composed of valve marl which consists of thin layers of gypsum and limestone. It includes three members [Samra coarse clastic, Samra silt and Lisan] of the Pleistocene Samra aquifer which are lateral facies succession from terrestrial/fluvial to deltaic/limbic and limbic/brackish lake environments. The marl, gypsum and silt units were generally considered as aquiclude.

Alluvial and gravel fans (Holocene) are distributed in the Jordan Valley. They cover the flood plains of the Jordan River and are strongly related to the faulted areas which are subjected to erosion. They are unconsolidated in the Rift Valley where they are formed of laminated marls with occasional sands. Gravel fans are widely distributed in the Jordan valley and have the capability of transferring groundwater from the limestone aquifers. The alluvial aquifer often directly overlies the Pleistocene gravel aquifer and is hydraulically interconnected with this aquifer. (Figure 2.21) (Wolfer, 1998)

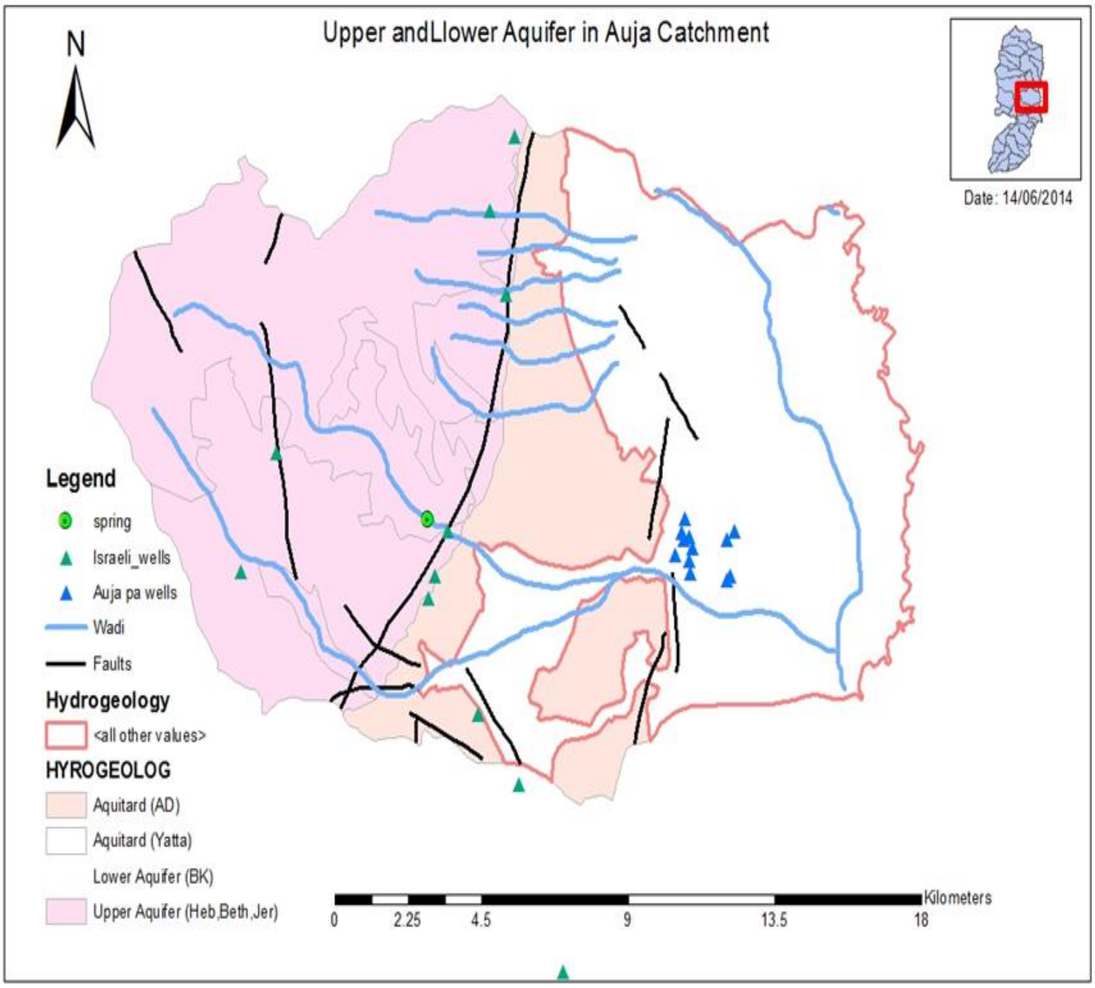


Figure 2.21: Upper and Lower Aquifer in the CSA catchment: the hydrological system.

2.4.3.3 Brackish Ground Water

Brackish water in Jericho District is one of the major obstacles which makes water utilization in irrigation and demotic use too complex and limited. This brackish water has increased causing serious problems.

Saline up coning along the Jordan valley resulted by steep dipping which caused deep circulation of the recharging ground water bringing it into contact with the salinity formation.

Currently, agricultural companies (Themar Company) practices flushing in the CSA with huge quantities of pumped water for long periods of time up to 14 hours in one time flushing.

In the CSA, water quality deterioration has increased during the last 30 years, with salinity becoming much higher by years in irrigated area. (Figure 2.22).

Figure 2.22:Water Salinity distributions in the CSA, Values of EC and Chloride concentration

Electrical Conductivity (EC) is greater than 2 MS/dm towards the North east of irrigated area, and also in the southern part of irrigated area close to Wadi, while in the middle of southern area, EC decreases to less than 2 MS/dm.

Chloride concentration starting 500 mg/liter in west and increasing to 1500 mg/lit, Figure (2.23) shows one example of increasing salinity concentration in term of Chloride in Well number 19-15/023, and also the increasing of Electrical conductivity during years (2003-2011).

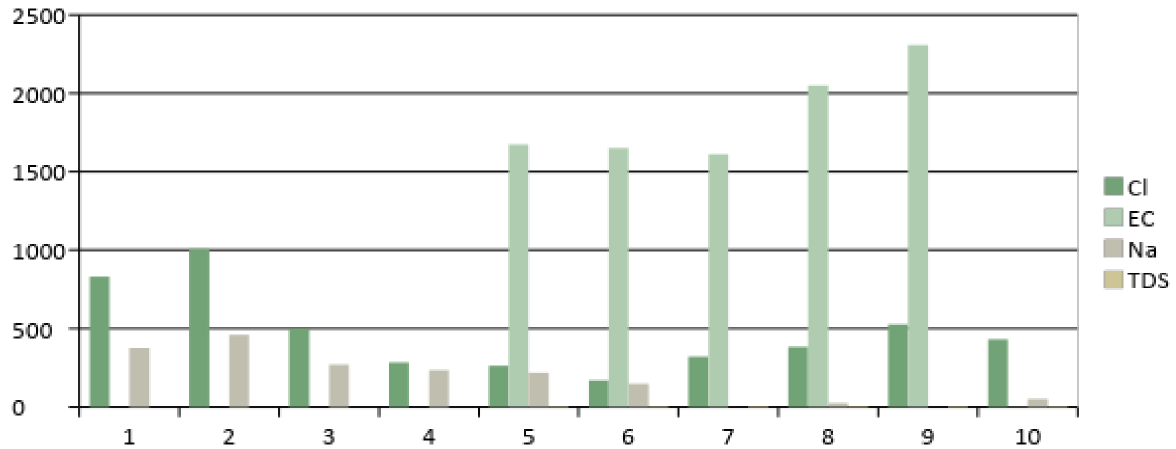


Figure 2.23: Chloride concentration and EC during years 2000-2009 ,well no. 19-15/023.

2.4.4 Waste Water

Waste water in the CSA is similar to many other areas in OPT. Disposal of waste water and its management is inadequate. In the Auja area about 500 houses have porous cesspits inside their home gardens. Cesspits constitute 45% as disposal method comparing sewage networks in OPT. Waste water is discharged in these cesspits until they are saturated. This takes 1-5 years depending on cesspits size, which ranges from 10 m^3 to 50 m^3. After cesspits become saturated, they are emptied by vacuum tanks, and are disposing of at the southern part of Wadi Auja. Waste water discharges were estimated at 81% of domestic water consumption in 2010, (S M.Y 1995). The annual total domestic water consumption in Auja is 141,426 m^3 **(**Auja Municipality Council, 20011&2012). Estimated disposed of quantity was 115,555 m^3/year. With high biochemical oxygen (BOD). Domestic water consumption ranges between 600 mg/L to 900 mg/L (Isaac, J. 1995). In addition, this waste water is rich in nitrogen .

In Jericho City, the Japanese funded a Waste Water Treatment Plant by US$ 32 million and began construction in June 2012 and finished it in March 2014. The goals of the projects focused on improving sanitary conditions and mitigating ground water contamination. Project maximum capacity is 9,800 m3/day of treated waste water and 25.4 km trunk of sewer pipes in Jericho City.

Another source for treated waste water is Al Bireh Waste Water Treatment Plant (BWWTP) located in Wadi Al-Ein, the eastern part of Al-Bireh City and built on an area of 2,200 donums. It was constructed in 2000 and cost US$ 15 million. It is secondary process design in the treatment operation which is aerobic sludge stabilization and sludge drying filter process. AL-Bireh WWTP treats daily flow of 5000m^3, which means 1.85 Mm^3 yearly. Treatment of waste water is compatible with irrigation standards. It was originally designed for a total of 60 orchard trees (25 different species), 15 date palms, 500 flowers and shrubs, 300 m^2 of grape stocks, (4 different species), and 600 m^2 were planted.

A nursery for annual cultivation of 80,000 seedlings of indigenous trees and cooked vegetables was built. The greenhouse is irrigated with high quality water from a tertiary treatment system that includes media filtration and chlorine disinfections (MEDAWARE, 2004**).** Table (2.3) shows the influent properties before treatment.

Table 2.3: Influent Properties of Al-Bireh waste water treatment Plant(WWTP)

Parameter	*Flow Rate (m^3/day)*
Average daily flow	*5,000*
Average daily design flow for dry weather	*5,750*
Average daily design flow for wet weather	*11,500*

2.4.5 Water Availability according to Source

Underground water in shallow aquifer and Auja Spring surface water are main water resources in the CSA.

There are 12 wells in shallow aquifer all of which are for agriculture irrigation usage. 2 of these wells stopped functioning completely; others work seasonally because of salinity increase in summer. Water table caused high concentration of chloride and increased Electrical conductivity values. (Table 2.4) shows that abstraction capacity of these wells is 1.155,000 Mm^3

Table 2.4: Auja agriculture wells with maximum capacity

Code	X	Y	Z	Depth (m)	Work	Max. Abstraction (m^3/a)(2012)	Abstraction capacity (m^3/hr).
19-14/001	195910	149990	-268	59	Yes	74000	80
19-15/005	194750	150440	-242	108	Yes	65000	50
19-15/007	194870	150760	-250	105	Yes	164000	100
19-15/008	194320	150600	-240	102	Yes	120000	90
19-15/010	194510	151100	-247	102	Yes	88000	50
19-15/011	194750	151000	-251	90	Yes	128000	50
19-15/012	194590	150940	-248	103	Yes	133000	100
19-15/015	196150	151140	-278	65	No	76000	(X)
19-15/023	196020	150090	-273	50	Yes	94000	50
19-15/019	195907	150936	-274	92	Yes	133000	100
19-15/028A	194800	150170	-246	90	No	(X)	(X)
19-15/013	194620	151450		100	yes	110000	80

Real abstraction during the period 2000-2009 decreases by 30%. In the end of 2010 water salinity increased in comparison with the year 2000. Table 2.5 illustrates the condition of the 7 wells of Auja area that were still working in that period before the rehabilitation of some of these wells. But others, like well number 19-15/015, are not working till know. By the year 2000 available abstracted water was 0.7 Mm^3 and by year 2003 it was 0.4 Mm^3.

Table 2.5: Auja wells abstraction in the period 2000-2009, $m^3{}_{/a}$

PMD_Code	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009
19-14/001	209152	146344	141423.8	115506.6	134424.8	125380	134885	149370	138608	107655
19-15/005	75959	57160	63182	63091	64848	62070	68385	64848	68592	65220
19-15/007	273455	166879	132847	73797.36	124507.8	110380	95978	154297	88557	67450
19-15/011	726	581	0	0	0	0	0	261	871	98360
19-15/012	8061	53053	55085	43479.29	40610	39410	45950	40058	9673	65140
19-15/015	16355		0	0	0	0	0	0	0	0
19-15/023	115936	99525	107733.2	89432.21	103156.6	99960	104624	103157	107319	101365
Total	699644	500271	500271	385306.4	467547.2	437200	449822	511991	413620	505190

Auja Spring, which is the second main source of water resources in the CSA, fluctuates between 18 Mm^3 in wet years and 2.5 Mm^3 in dry years. Lateral infiltration is about 700 m in wadi Auja 45% of which is infiltrated along cement open canal 11 Km long to reach the irrigated area. 40% of the remaining water passes the wadi through the canal and is lost as return flow. Total available water of the Auja Spring is around 6 Mm^3 in wet years and about 0.9 Mm^3 in dry years.

As a result, there is big difference in total available water according to sources in the area according to wet or dry years. In dry years, available water from the springs and wells is about 1.3 Mm^3 and is 6.7 Mm^3 in wet years.

2.5 Irrigated Agriculture

In the CSA, water system of the spring water is based on family shares. The system was designed and implemented in 1950 by Dr. Dawoud Al-Husainyduring feudalism era and influential families and clans that own the largest area of lands in the CSA.

2.5.1 Irrigation System and Irrigable crops

The irrigation system organized in the CSA regarding water rights and family shares is categorized as follows:

Spring water is conveyed by an open cement canal with a total length of 12 km including branches. The open canal is divided into two main branches: the northern branch divided into

17 part branches and the southern branch with 5 part branches. 'One hour' of spring water is 12 minutes; all of these branches make 4.5 km from the total 12 km of the Canal Project length.

Cost of water was about JD 2000-3000 per share in 1950. There were 35 water rights held by families or clans in the project area with a total number of nuclear families of about 235 with 39 of them living outside the project area. Rotational period is 8 days. Two families frequently receive the spring flow simultaneously. There are 54 ponds with total volume of 800,000 m^3 collect spring water flow. In 2012 the Ministry of Agriculture planned to establish 12 large ponds with 200,000 m^3 capacity each in the CSA. One pond was established.

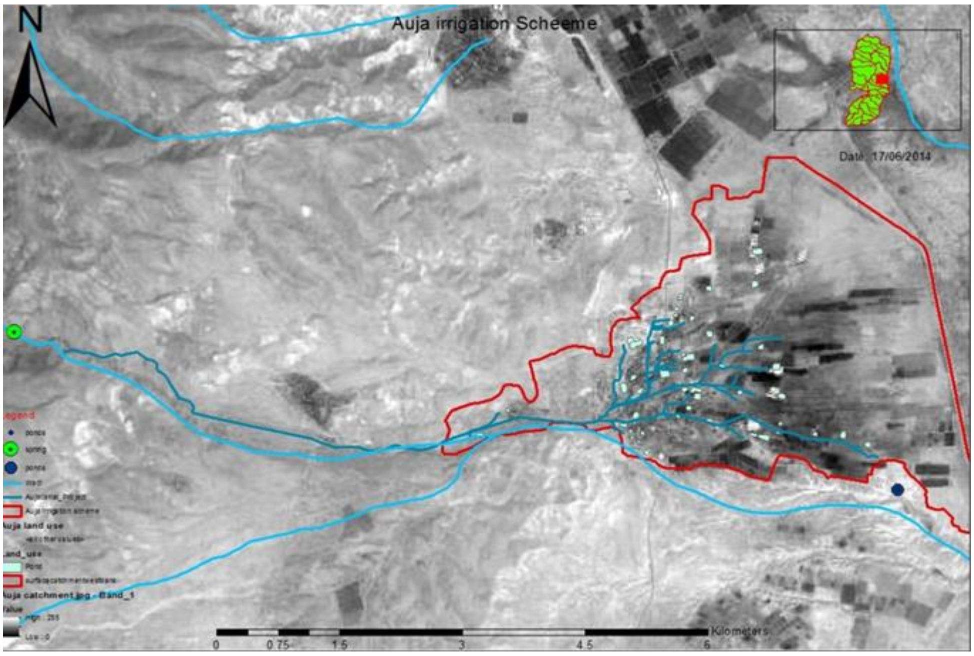


Figure 2.24: Irrigation system in the CSA, the Auja Canal Project and agricultural ponds

The irrigated area in the CSA is about 4,000 donums; it varies from year to year and from season to season based on rainfall quantity and sharp decrease or increase of spring discharges. Water table and salinity in these wells vary according to seasons. Usually, the main irrigated crops in the area are protected vegetables like tomato, cucumber, and eggplants, etc. and the main fruit trees were the banana until 2008. Banana consumes 23% of total irrigated area. There are no banana farms currently in the area, but there are new palm date trees instead. Corn which forms 31% of total irrigated area is also considered a main unprotected crop. Other main unprotected crop in the CSA is zucchini which consumes about 14% of total irrigated area. However, all crops specifications in the current situation will be explained in Chapter 3. Figure 2.25 shows irrigated crops percentage by the year 2007 (PARC, JICA, 2007).

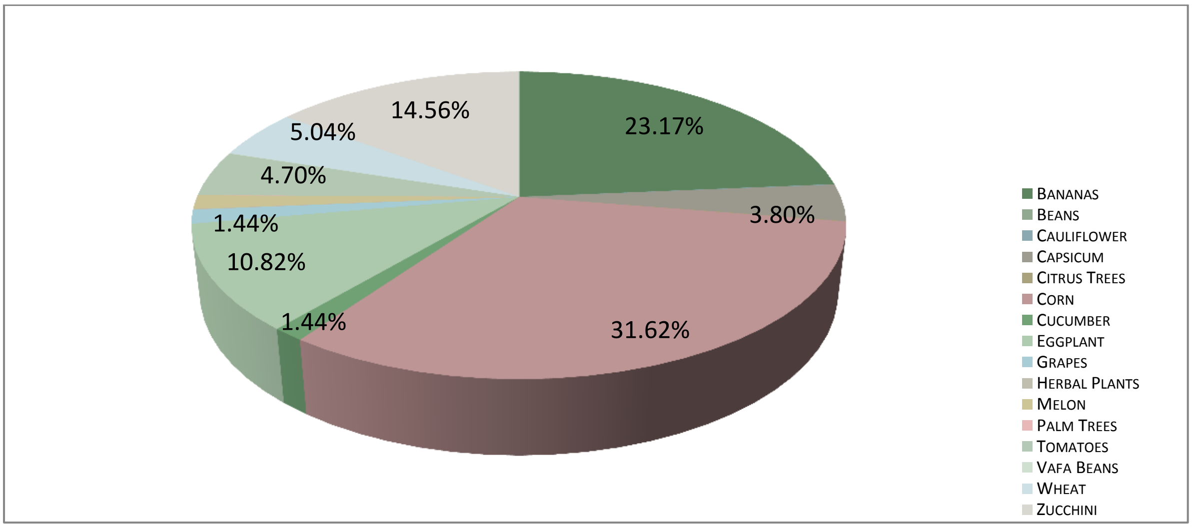


Figure 2.25: Irrigated crops in the CSA ,(2007) (PARC, JICA 2007)

2.5.2 Irrigation Planning and Crops' Water Consumption

In the CSA area, the main water resources for irrigation as mentioned above are Auja Spring and the shallow aquifer wells in Auja village. Irrigation system in the area takes the following water conveyance from the Auja Spring by an open 12 km long cement canal, including 17 branches in the irrigated area.

Fifty five artificial ponds owned by farmers receive 5,000 to 20,000 m^3 from spring water, from a total volume of about 800,000 m^3. During spring drought water is taken from 10 shallow wells in the area.

Growing vegetables in the CSA depends on drip irrigation, and so do fruit orchards. Other fruits are irrigated by surface irrigation. Winter cereals (wheat and barley), were sometimes irrigated by surface irrigation from the spring water.

Auja dam was constructed in 2011 with 600,000 m^3capacity (MOA, 2011). It was designed to receive surface runoff water (flooding rainfall and spring surface runoff) from wadis and conveyed water using pipes through Auja Canal for irrigation purposes inside Auja village.

In 2012, MOA planned to construct 18 large agricultural bonds in the LJV, each one with 20,000 m^3 capacity. MOA announced tender for the construction of Auja pond last April of 2014 in Auja area.

Irrigable crops in CSA could be divided into five main groups: orchards and fruit trees which include palm dates , grapes, banana, etc. Greenhouse vegetable crops classified as protected intensive irrigable crops and include tomato, cucumber, and capsicums, etc. The third group is the intensive greenhouse medical herbs crops like the Rose Mary, fennel, lettuce, etc. The forth group is the corn group and the last group is regular unprotected vegetables. Tomato and cucumbers are the main crops constituting this group in addition to others. However, water consumption of irrigable crops at present may be summarized as follows:

- Total irrigated area throughout the year with 2 usual seasons for vegetables is 4,000 donums, and total water consumption is 3.83 Mm^3year.
- Palm date trees consume one-third of total water consumption and occupies about one-third of irrigated area.
- Intensive vegetable greenhouses consume 1.392 Mm^3/a for 745 donums, while medical herbs consume 0.257 M m^3/a for 650 donums.
- Banana is the highest water consumption crop as one dunom consumes about 1,500 m^3/a, and is classified as high sensitive crop for less water. Figure 2.26 shows crops' water consumption in the CSA and average values of water consumption (JDOMOA, AMC , 2013).

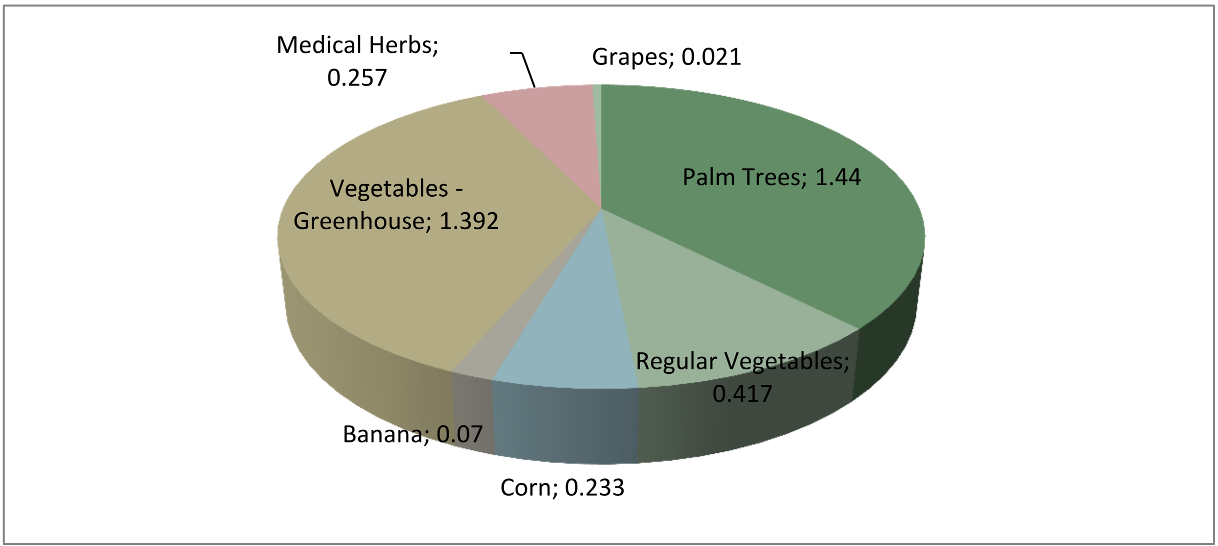


Figure 2.26: Crop water consumption in the CSA, 2013

2.5.3Yield and Crops Production

Crop yield in different literature is defined as measurement of the amount of a crop that was harvested per unit of land area. It is normally measured in metric tons or kilograms per hectare. Yield is highly relevant in CSA Evapotranspiration. The area is distinguished by high temperature and high evaporation values. FAO addressed the relationship between crop yield and water use in the late seventies proposing a simple equation where relative yield reductions are related to the corresponding relative reduction in evapotranspiration (ET). Yield response to ET is expressed as:

$$(Ya/ Yx) = Ky (1-Eta/ETx) \quad (2.1)$$

where Yx and Ya are the maximum and actual yields, ETx and Etta are the maximum and actual evapotranspiration, and Ky is a yield response factor representing the effect of a reduction in evapotranspiration on yield losses. Equation (1) is a water production function and can be applied to all agricultural crops, i.e. herbaceous, trees and vines.

Table 2.6 shows some of actual yields relevant to crop production and crop water consumption of some crops in Auja area. The difference between intensive greenhouse productions like tomato 20 is five times of the regular tomato. Therefore, yield

Table 2.6: Yield of some crops in the CSA

Crop	**Productivity (Kg/dunom)**	**Yield**
Date Palms (Fruit)	1,500	1.5
Grapes (Fruit)	2,500	2.5
Citrus (Fruit)	1,500	1.5
Zucchini (Regular)	2,000	2.0
Cabbage (Regular)	1,600	1.6
Tomato(Greenhouse)	20,000	20
Tomato (Regular)	4,000	4
Rose Mari	13,000	13

Factor (Ky) is a crucial issue in defining the crop sensitivity for water reduction. Banana in CSA has 1.25 average Ky. This approves the high crop sensitivity of water reduction which explains the disappearance of banana farms in Auja area.

2.5.4 Agriculture and Environment

Agriculture and environment have interaction relationship in terms of natural effects of several climatic directions towards the agro-zones areas. Further, agricultural activities affect environment in terms of soil toxicity and water resources pollution.

In a work carried out by JICA (2008), qualitative analysis of the pesticides, fertilizers and plastics used in Jericho is shown in Table 2.7. About 1,190 tons of these hazardous materials were indicated.

Table 2.7 Part1 : Hazardous materials in agricultural activities in Jericho, JICA, 2008

Description of annual consumption	**Annual consumption (kg)**
Irrigation network	293,850
Nylon for ground agriculture	674,880
Nylon for external coverage	24,527
Solid fertilizers bags	41,595

Table 2.7 Part2 : Hazardous materials in agricultural activities in Jericho, JICA, 2008

Liquid fertilizers bottles	35,082
Nets	7,937
Threads	3,648
Total	1,190,944

Considering the CSA as part of semi-arid zone in MENA (Middle East And North Africa) area, drought is one key issue which threatens the agricultural sector in the CSA. Drought means the naturally occurring phenomenon that exists when precipitation has been significantly below normal recorded levels, causing serious hydrological imbalances that adversely affect land resource production systems (Palestinian Desertification Strategy (PDS), 2011). Increase in soil erosion and soil salinity are the clearest indicators of nature's threat to agriculture.

On the other hand, anthropogenic activities such as using pesticides and fertilizers causes high toxicity in soil profile when inefficient and efficient drainage system exist. These persistent and toxic pollutant are transferred into the unsaturated zone and end up polluting the shallow aquifer system. In the CSA, found no good agricultural practice in the area, which currently leads to threatening soil and water in future.

Different kinds of Persistence Organic Pollutants (POPs) are still used, like organic-phosphate and Oregano-chlorine. No specific surveys according to quantities and quality effects of pesticides on soil and water were carried out. Percentage of pesticides and fertilizers expenditure out of the total expenditure of crop cycle is about 30%-50%. Huge quantity of plastic waste from plastic cover of green houses and piping system network were spreading randomly in the irrigated lands. Irrigation using brackish water increased salinity built up into soil profile.

2.5.5 Agricultural Wells and Management System

Majority of these Palestinian wells were drilled between 1955 and 1966 with a total depth of 50 m-145 m. Pumping rates are between 40 CM/h and 80 m^3/h with a mean of 10 hours pumping. Pumping in summer usually reaches 20 hours per day.

These wells were made of cast iron and plastic piping and fittings. With years of pumping, screens have clogged with high silt accumulation at the bottom of the well, and penetration.

Corrosion of cast iron inside these wells appeared. Due to this tragic case, more than 20 wells in Jericho District, including the CSA, stopped pumping causing increased salinity and in some cases water table depletion resulted by mechanical and hydro geological reasons. The economic productivity aspects of these wells was another factor.

Wells were dug in shallow aquifer at the eastern part of catchment area at 200 m-300 m elevation below sea level (bsl).Maximum allowable abstraction of wells is 1,109,000 m^3/a. All of these 12 wells were privately owned.

Ten of these wells are still operating with a capacity range between 50 and 100 m^3/hr. and with 0.5 Mm^3 as yearly abstraction mean. Two wells stopped working because of reduced water table and higher saline water.

During the period 2001-2011, total abstraction decreased from700,000 m^3 to 500,000 m^3.

Wells water table reduced by 1m/year compared to the historical observed data of water table and physical properties of shallow aquifer,(Shawahna,AM.,2010) **.**

Figure (2.27) shows agriculture wells in the CSA and abstraction during the years 2001-2011.

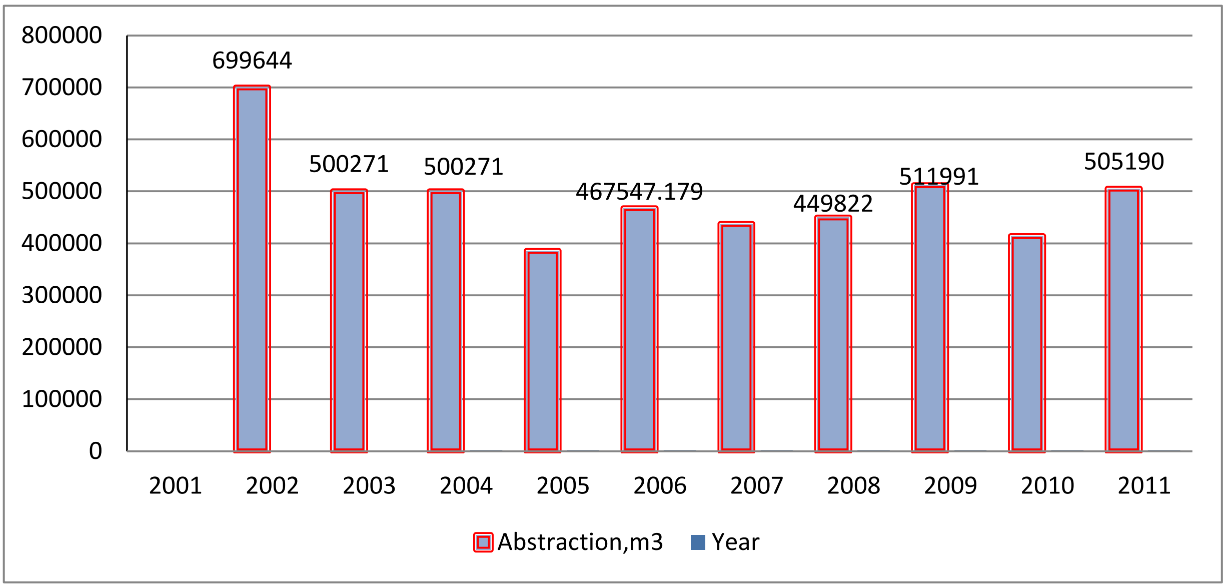


Figure 2.27: Auja shallow wells annual abstraction during the period 2000 to 2011

In Addition to water table depletion and mechanical defects of Auja wells, salinity of chloride concentration and electrical conductivity became higher making irrigation system more complex in the CSA. Brackish water is considered as one main obstacle to agriculture development and sustained development in the Jericho District.

Water for irrigation in the CSA is supplied by Auja Spring surface water and shallow aquifer wells in the area as mentioned before.

Spring water rights are divided among 35 owners by 'hourly' division. Each 'hour' is only 12 minutes, and farmers' pools receive water five times per week.

Spring water constitutes one of the important water resources in the study area. It decreases sharply in summer but it remarkably increases in winter. Thus, spring water volume varies depending on the rainfall amount as well as the available ground water.

52 pools collect spring water mixed with abstracted water from shallow wells. The capacity of these pools varies from 2,000 m^3 to 20,000 m^3. These pools usually leak the water and cause high evaporation rate of the water they contain.

The owners annual water share received by pools is 6.5 M m^3 in wet years and 1.300 Mm^3 in dry years and the total time sharing during one year is 14,410 minutes, or practically 1,200 hrs.

The owners shallow-aquifer wells pumps water into their pools and sometime mix water of brackish water from wells and fresh water from the spring.

Drip irrigation is used for all different kinds of vegetables and orchard trees. Some cereals like wheat and barley are irrigated by traditional surface irrigation.

Figure 2.28 , shows the irrigation system in the CSA

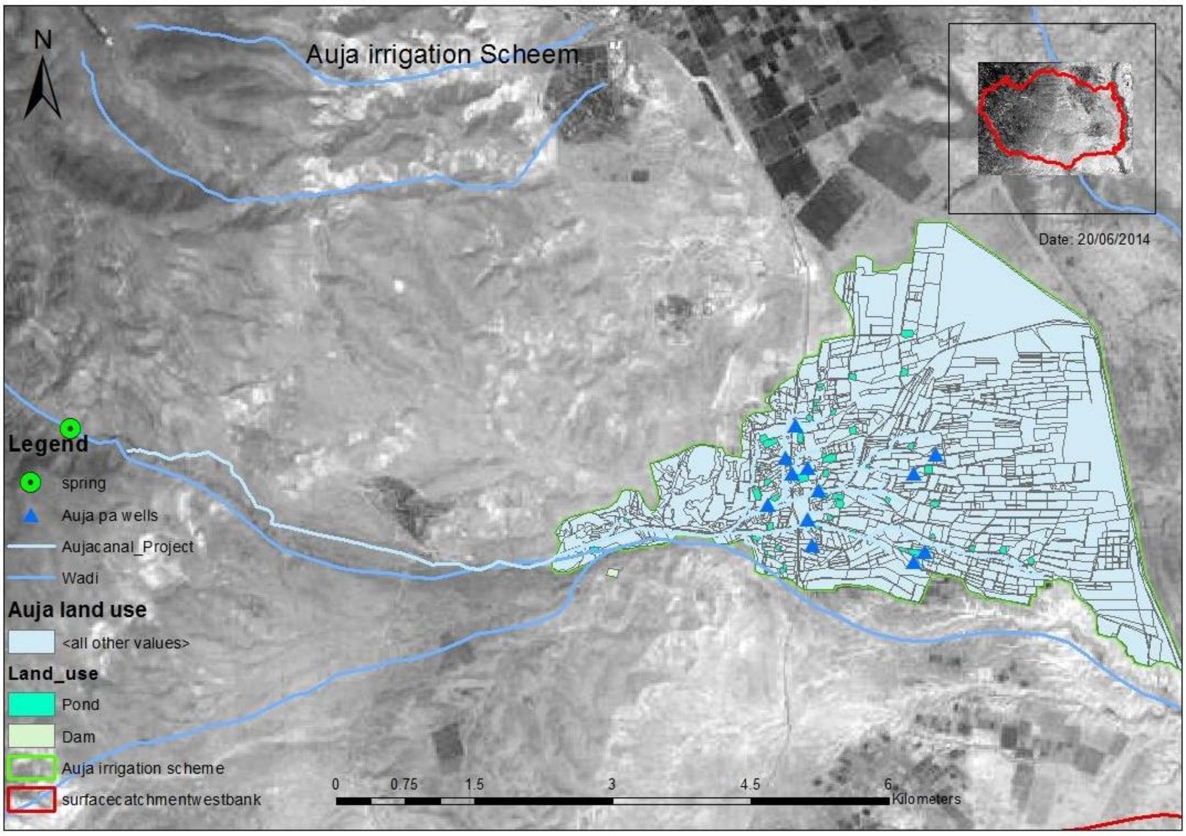


Figure 2.28: Irrigation System including water resources supply and conveying system in the CSA.

2.5.6 Challenges of the Agriculture Sector in the CSA

The following challenges were observed in the agricultural sector in the CSA:

-Absence of a comprehensive agricultural planning in the study area and regulations and the control of this sector;
-Lack of control over the markets and the lack of storage capacity for agricultural products.

-The inequitable distribution of water resources of Auja Spring water, regarding crop water requirements and irrigated lands areas

-The contradiction between the need for irrigated agriculture in the dry summer months and the lack of water available

-High salinity in Auja wells and depleting water table to 1m yearly

-Mismanagement and absence of optimal exploitation of water for irrigation

-Lack of periodic maintenance for shallow aquifer wells

Chapter 3

Agricultural Land Cover Use and Crop Water Demand Calculations in the Case Study area: field Survey and CropWat Model

3.1 Introduction

the total agricultural land in the oPt is about 1,854,000 donums, being 21% of the total area of the West Bank and Gaza Strip. From which, 90% is in the West Bank and 10% is in Gaza Strip. Area of rain-fed land constitutes 81% and the irrigated land constitutes 19% of the total cultivated area. (PCBS, 2010-2011, Census of Agriculture)**.**The volume of the water used in agriculture was 146 MCM in 2011. About 44% (60 MCM) of total water used in agriculture goes to the West Bank and the remaining 56% (86 MCM) is used in Gaza Strip (Palestinian Sectorial Strategy of Agriculture) (PSSA , 2014-2016).

LJV is part of the Eastern Aquifer in the West Bank (Figure 3.1) and it includes two main cluster population districts: Toubas District in the north east of the LJV and Jericho District which is in the middle towards the eastern south of the LJV (close to the Jordan River and the Dead Sea). The irrigable area was estimated at 87,900 donums (PCBS,2010-2011-Census of Agriculture).

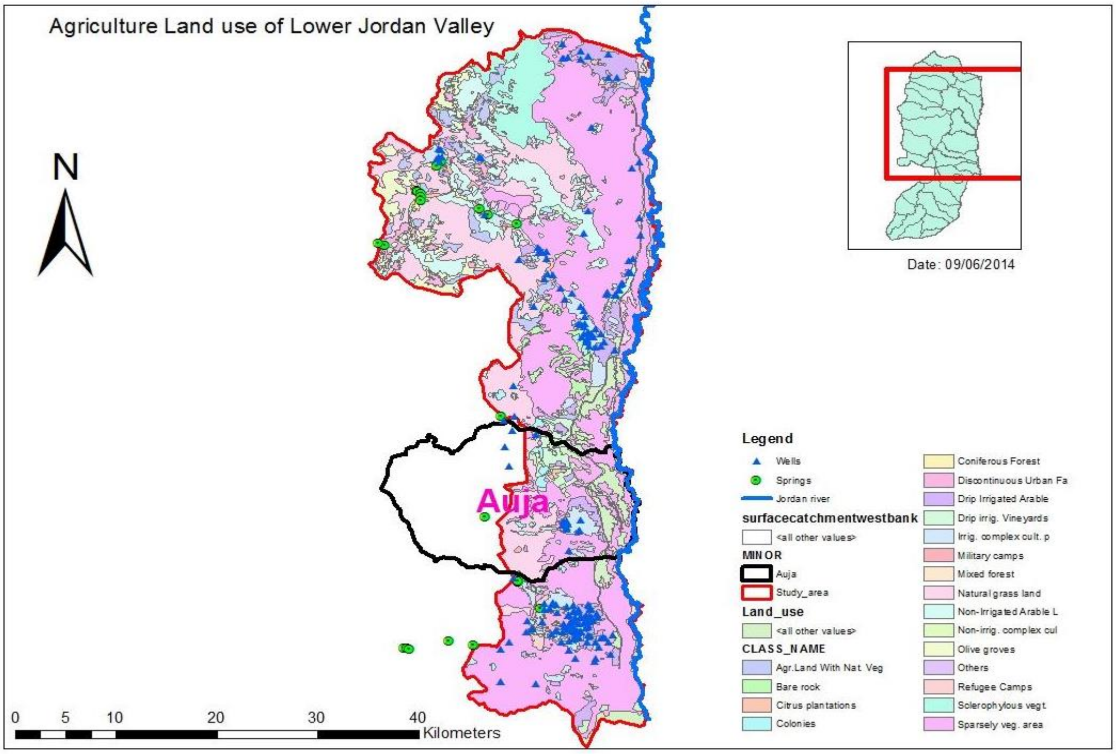


Figure 3.1: Land Cover Modified Map of LJV including Auja catchment (MAO, 2007)

In 2012, Marwan Hadad mentioned that the total cultivated area in the JLV was 150,332 donums, of which 63,875 donums are rain-fed area and 86,456 donums was irrigated area. The extent of the rain fed farming in the Jericho and Auja area is reduced by time due to limited rainfall, but is still common in the north part (Tubas area) of the LJV because rain is sufficient (more than 300 MM), while in Jericho and Auja area it is about average (120 mm/a). Therefore, irrigated lands in Auja area decreased by about 50% during the last ten years (2003-2014). The reduction of irrigated area in the CSA was due to several reasons such as the climate, water and soil salinity build-up.

In the context of this agriculture situation, more understanding of what happened in the LJV and what will happen regarding reduction of irrigated lands in the LJV is needed. Auja area was selected as representative of the CSA for the entire of LJV to evaluate agricultural current situation relevant to soil and water resources in the area. This investigation is based on field measurement of soil and some surface water measurements. In addition, agricultural land cover was investigated to have a clear idea regarding some promising scenarios that should be implemented for complete criteria analysis of agriculture development scenarios (ADS) in the CSA. Those scenarios are based on extension of available irrigated area on the one hand and using brackish water for irrigation on the other hand.

In this chapter, crops water requirements have been calculated regarding field survey in the CSA since 2013. CropWat software and FAO Paper No.56 were used for all these calculations which relied on average climate variable according to historical metrological data from PMD and also on metrological data of Auja metrological Station in 2013 by Fabian Reese. Moreover, the grown crops and irrigated lands were mapped also for 2013. In addition, soil hydrochemistry and soil texture were evaluated by integrated sampling of treated soil (irrigated area), and control areas (non-irrigated lands). Our conceptual model in this work could be summarized as following:

Mapping of irrigated area was based on Palestinian MoA classification. The area was classified and categorized by field work in 2013.

Selecting soil sampling sites regarding the irrigated and non-irrigated areas in the CSA.

Handling of water resources data in terms of quality and quantity according to historical data of PWA-Data Bank. In addition, some measured water data was carried out.

Calculating crops water requirements has been referenced by Auja area crops vapor-transpiration using FAO Penman-Monteith Equation, 1990**.**

Irrigation depends on fresh water and brackish water regarding crop salt resistance.

3.2 Methodology

Defining scenarios for Agriculture Development in this investigation has been carried out in two directions:

A-The available data from stakeholders including ministerial bodies, non-Governmental organizations (NGOs), Auja Village Council, farmers and agricultural lands owners. Also, some relevant publications like the Palestinian Agriculture Relief Committees (PARC) in 2007, the Japanese International Cooperation Agency (JICA) were also used. Survey of the water resources and management in the LJV in 2008, the LJV Developing Plan in 2005 were also utilized.

B- During 2013, field survey of agriculture land cover, soil, and surface water measurement were begun. Geographic Plan System (GPS) was used for agriculture land cover mapping; soil sampling of nineteen sites of irrigated lands (treated) and Non-irrigated lands (control) was implemented and the selected samples were referenced with Zig Zag methodology (Pennock D. ,Yates T., 2006). Auja Spring discharge along the Auja Wadi was measured using the Salt Dilution method (Benischke, R. and T. Harum (1984). Figure 3.2 illustrates the implemented methodology.

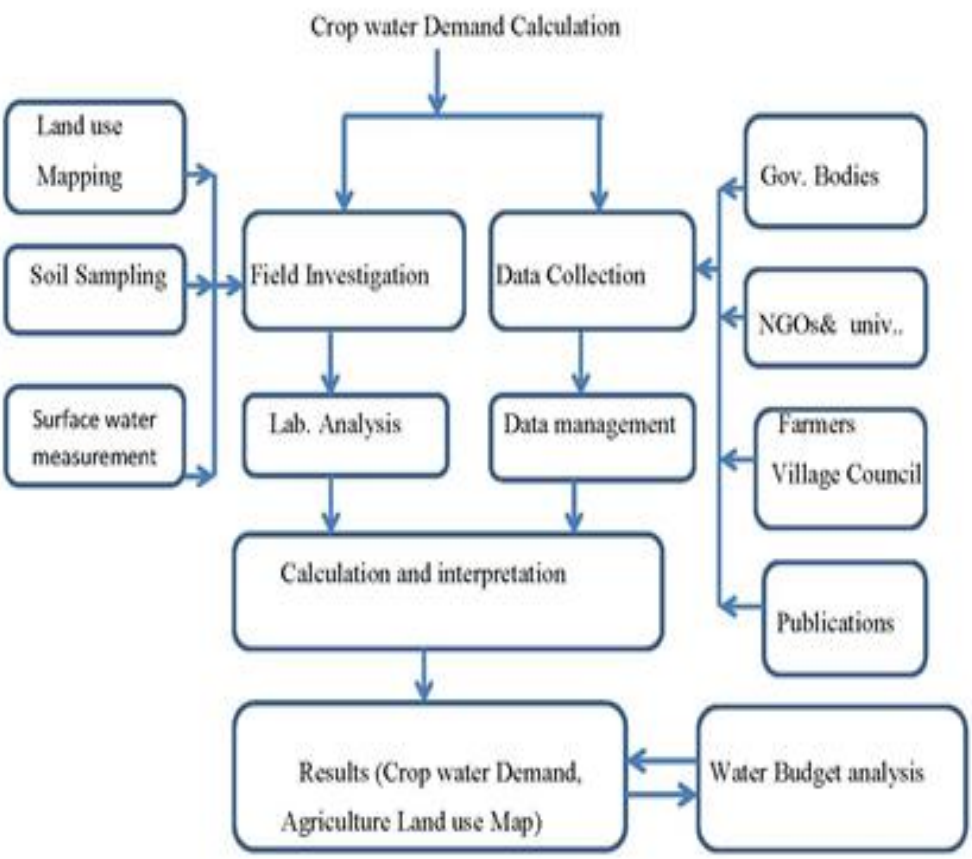


Figure 3.2: Schematic flow diagram of crop water requirements calculation

The planned tasks in our methodology have been carried out as following:

1-Reviewing many relevant surveys and articles about LJV and Auja CSA; these surveys included feasibility studies of water resources development in the LJV by JICA in 2008;

-Detailed survey on agriculture water use in Jericho and Auja catchment by PARC, 2007; evaluation of agricultural water management options in the LJV by Dr. Marwan Hadad in 2012;

-Water Resources Developing Plan of LJV in 2010 by PWA and MoA;

-Agriculture Census 2010;

-Water Master Plan for Jericho City by the Palestinian Hydrology Group (PHG, 2010);

-Land Use and Land Cover in LJV by MoA in 2011;

-Some aspects of irrigation systems performance in Palestine: a case study of Gaza and Auja by Issam Nofel, 2007;

-Several SMART publication Projects in the LJV until 2014, Glowa Project Publication, 2008;

-Many publications and a lot of literature were reviewed since 1970 till now, all of which will be listed under references.

2-Several meetings were held with governmental bodies/ministries relevant to water sector during years 2011, 2012 and 2013: Palestinian Water Authority (PWA), Ministry of Agriculture (MOA), Ministry of Planning (MOP), Environment Quality Authority (EQA), and Palestinian Metrology Department PMD). Data was collected from these establishments about various climatic variables in the CSA, historical abstraction readings, coordinates and water table of underground wells and spring. Some of the data go back to 1967 until 2000. Historical qualitative data of water hydro chemistry analysis was collected for all water resources in the CSA. Other Kinds of qualitative data were collected from Al-Bireh Waste Water Treatment Plant (BWWTP). Its treated effluent consists with agriculture Palestinian irrigation standards.

The data collection also targeted universities such as (Al Quds University) and NGOs (PHG). Agriculture irrigation water quality data was brought from Al-Quds University. PHG provided Socio –Economic data from its publication Jericho Master plan and the Socio-Economic report in the Environment Lab., 2011.

Following data collection steps, several meetings were carried out with Auja Village Council, farmers, and agricultural companies working in the region. Village councils provided the structural plan and the area for agriculture activities in the Auja village, while, farmers and agriculture private companies provided irrigation quantity data, irrigated lands area, and crops grown in the area throughout years in different seasons. Anyway, Table (3.1) illustrates all kinds of data and resources that were collected during research time.

Table 3.1: Data Quality and Resources of the CSA Survey

Data	Data Type	Data Source	Remarks
Auja wells	Quantitative Historical Data	PWA	Historical Data(Abstraction, water table, and coordinates)
Auja wells	Qualitative	PWA	focus on chlorides conc. And E.C
Auja Spring	Quantitative Historical Data	PWA	Discharge (monthly and yearly)
Auja Spring	Qualitative	PWA	Salinity and Hydrochemistry
Jericho District Wells	Quantitative Historical Data	PWA	Historical Data (Nui'meh and Qilt in addition to Jericho City Sub-catchment)
Jericho District Wells	Qualitative and Physical Properties	PWA	Hydrochemistry Analysis
Jericho District Springs	Qualitative	PWA	Discharge of Al Duke and Qilt Spring
Treated Effluent of BWWTP	Qualitative	PWA/BWWTP	Dally Analysis of Effluent
Jericho Sub catchment Maps	Hydrological and Catchment Shape Files	PWA	Including Wadis and Wells
Metrological Data	Quantitative Historical Data	PMD	Der Debwan Station and Jericho Station
Metrological Data	Qualitative	SMART(Schmidt S.,Reis F.)	2012 and 2013 of Kafer Malek and Auja Rainfall Stations
Land Use and Land Cover of LJV Maps	Shape Files	MOA	LJV -Mapping Project, 2010
Digital Elevation Mode (DEM) of West Bank	Model GIS Data	MOA	Including Elevation in slopes and Percentages
Auja Canal Irrigation Scheme Map	Shape Files	MOA	Including Ponds Distribution
Agriculture Census 2010	Quantitative Data of Agriculture in LJV	MOA and PCBS	Including Auja Cluster
Special Plan of West Bank 2012	Shape Files Data	MOP	Including Sensitive Agriculture Zones
Agricultural Irrigation Water Quality	Qualitative Data	Environment Lab/Al-Quds Uni.	Hydro chemistry Analysis
Jericho Master Plan	Quantitative Data	PHG/SMART Project	Socio-Economic Data
Land Use, Agriculture Lands, Lands and Water Ownerships	Quantitative	Auja village Council	Agriculture and land dues data
Crops, Agriculture Area	Quantitative	Fresh Gate Com., Themar Com., Farmers in the area	Visiting Five sites with 12 farmers

All collected data have been managed and evaluated in different excel sheets. The metrological data was used as mean value for calculating crop water demands. Others were used for water budget calculations and the land areas were used for agriculture land cover mapping.

3- Field working in the CSA

In this phase of work three kinds of field measurement and investigation were applied: agriculture land use and land cover, sampling from irrigated and non-irrigated lands, and Auja measurement of discharge along wadi.

Agriculture land use and land cover is based on (FAO, 1976), approved by the Palestinian MOA as methodological framework for land cover classification in Palestine. It is concerned with land performance when used for specific purposes likes different kinds of crops.

Land cover and crops in the area are grouped into six main groups: palm dates, banana, protected greenhouse vegetables, protected greenhouse medical herbs, non-protected regular vegetables, and corn. Some cereals like wheat, which were observed as irrigated crops in a very small area (2 donums). It was neglected as irrigated crops in the area. The investigation evaluated this case as excess water quantity wasted by the owner and resulted in non-planned wheat cultivation.

Filed work was conducted in two time periods, i.e. one from February 2013 to April 2013 and another from September 2013 till November 2013 in the Auja area using Geographic Plan System (GPS), referenced under Universal Transverse Mercator Coordinate System UTM1947 , and then converted into Palestinian National Grids (PNG 1923) to build up GIS layers in agriculture land use mapping.

Nineteen soil sample sites of flat plan in the CSA were selected with 0.5 relative error (RE) design size and 100% coefficient of variance (CV). Four to five depths in each point site, were carried out using 10cm diameter Auger. Selected sites were distributed in the irrigated area and the suggested extension area in Auja Agriculture lands. Distribution was based on slopes and targeted lands according the Zig Zag method mentioned above (Pennock D. ,Yates T., 2006), Figure 3.3.

Texture sieve analysis was analyzed using the Sieve Analysis Test (USDA), in Environment and Earth Sciences Department at AL Quds University in Palestine.

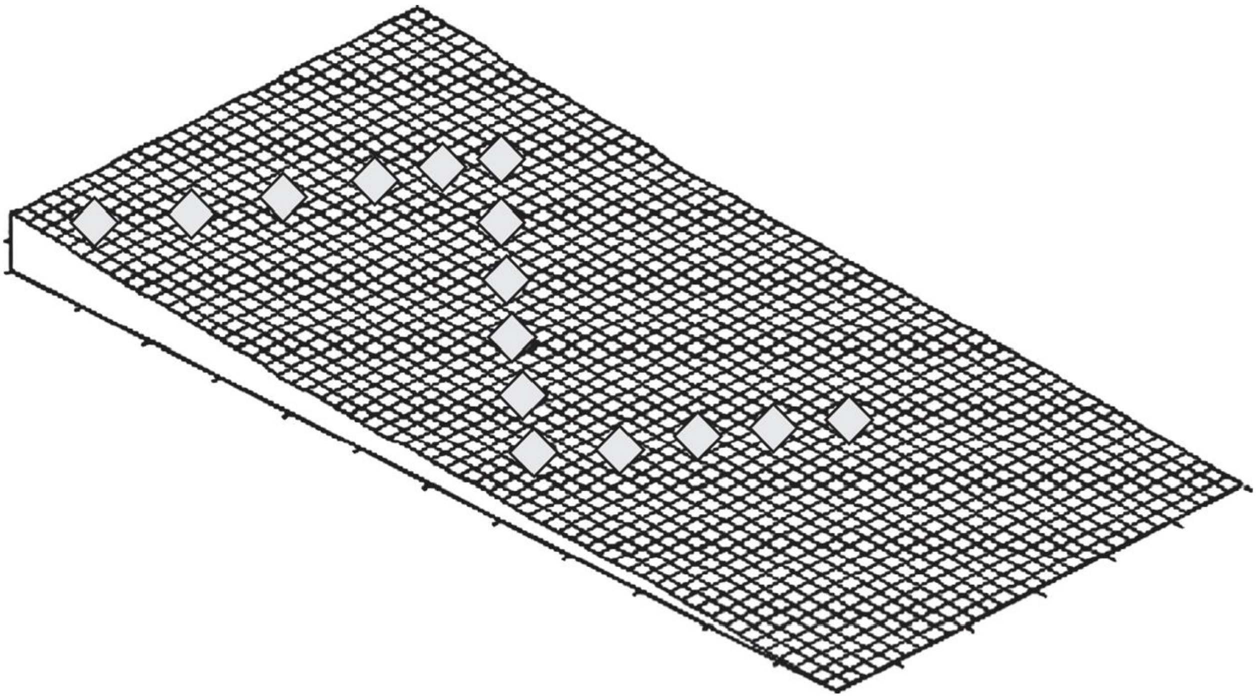


Figure 3.3: Zig-Zag method for selecting soil samples in arid zones.

Auja Spring Discharge and losses were measured using Salt Dilution Method along Wadi Auja (670 m), in three points (Starting point 100 m away from Auja Spring, in the middle of wadi and its end). Water lost by infiltration could be calculated by this methodology.

3.3 Building of CropWat Conceptual Model

CROPWAT version 8.0 windows is a decision support tool developed by the Land and Water Development Division of FAO. It calculates crop water needs and irrigation schedule based on climate, soil and crop data. It is important to know that the program allows the development of different management conditions in case of developing an irrigation schedule in seasonal or different cropping time period. In accordance with CropWat calculation was based on the following :

Calculation procedures used in CROPWAT 8.0 are based on the two FAO publications namely, Paper No. 56 "Crop Evapotranspiration - Guidelines for computing crop water requirements" and Paper No. 33 titled "Yield response to water".

Feeding input data included historical average of climatic data, soil properties and crops relevant to different crop growth phases and crop factors. Crops parameters in the model referenced FAO crops index parameters. Crop yields were projected regarding water quality used for crops in different phases.

FAO Penman-Monteith equation is the basic calculation method used in CropWat model. It was developed by FAO in 2004.

CropWat model was built up by FAO and is referenced on the following considerations:

- It is a combined method adapting between heat and mass balance of surface soil heat flux and evapotranspiration in soil and also into crop during all several cropping periods.

-The method overcomes the shortcomings of the previous FAO Penman Method and provides values more consistent with actual crop water use data worldwide.

- FAO developed this new formula of evapotranspiration relations based on original Penman-Monteith Equation and the aerodynamic and surface resistance equations.

- The FAO Penman-Monteith method could calculate reference evapotranspiration (ETo) values for each crop based on climatic parameters.

The equation uses standard climatological records of solar radiation (sunshine), air temperature, humidity and wind speed. To ensure the integrity of computations, the weather measurements should be made at 2 m (or converted to that height) above an extensive surface of green grass, shading the ground and not short of water.

The Expert Consult agreed to use the hypothetical reference definition of the FAO Penman-Monteith equation as the definition for grass ETo when deriving and expressing crop coefficients.

By using the FAO Penman-Monteith definition for ETo, one may calculate crop coefficients at research sites by relating the measured crop evapotranspiration (ETc) with the calculated ETo, i.e., Kc = ETc/ETo. The Kc factor serves as an aggregation of the physical and physiological differences between crops and the reference definition.

Associated equations for aerodynamic resistance(ra), and soil surface resistance(rs) against evaporation, is used to enable accounting for variation in ET due to variation in height of the grass measured. Variations in measuring height can significantly change LAI (Active sunlight leaf index). It should be noted that local environmental and management factors, such as watering frequency, also affect ETo calculation regarding observed climatic parameters.

Figure (3.4) illustrates the heat flux and evapotranspiration balance which Penman-montieth equation referenced by this heat and misbalance combination.

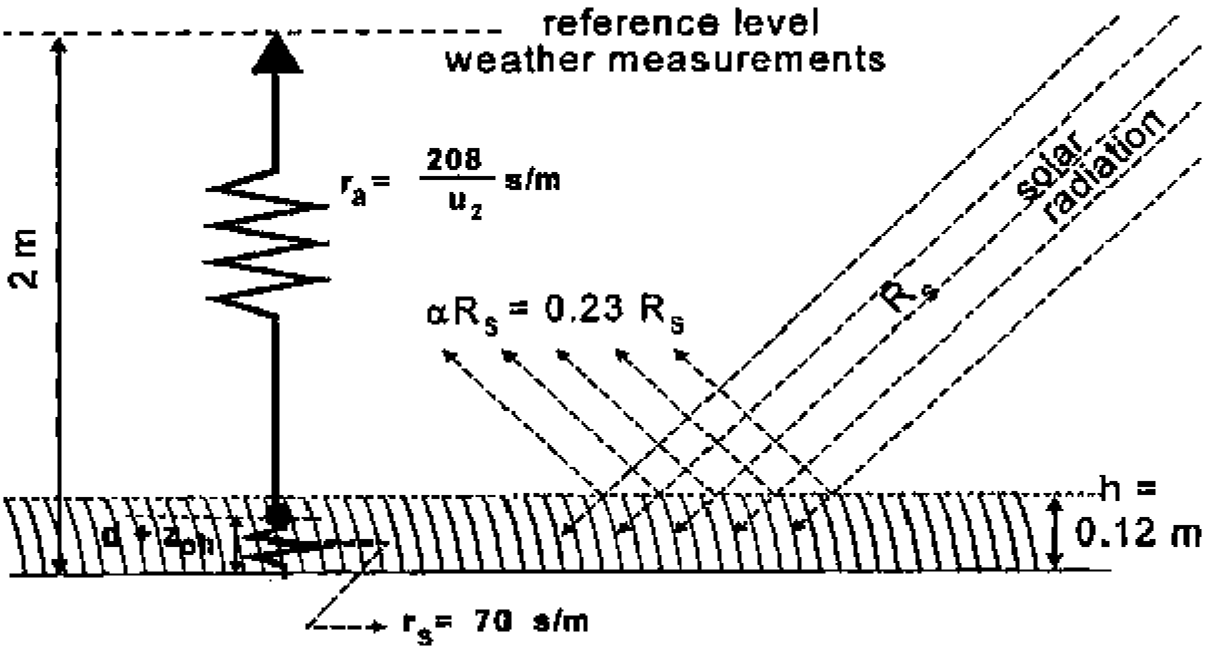


Figure 3.4: Characteristics of the hypothetical reference crop, FAO,1990.

Equation No. (3.1) explains the compensation of heat and mass balance in Penman-Montieth equation which joins wind speed, which is based on actual and referenced saturation vapor pressure, with net values of soil flux and crop surface radiation.

$$ET_o = \frac{0.408\Delta(R_n - G) + \gamma \frac{900}{T+273} u_2 (e_s - e_a)}{\Delta + \gamma(1 + 0.34u_2)} \quad \text{........................(3.1)}$$

Where:

ETo=reference evapotranspiration [mm day-1],

Rn=net radiation at the crop surface [MJ m-2 day-1].

G=soil heat flux density [MJ m-2 day-1].

T= mean daily air temperature at 2 m height [°C].

u2=wind speed at 2 m altitude [m s-1].

Es=saturation vapor pressure [kPa].

Ea= actual vapor pressure [kPa].

Es= ea saturation vapor pressure deficit [kPa].

D=slope vapor pressure curve [kPa °C-1].

G=psychrometric constant [kPa °C-1].

3.4 Output Results from Field Survey

This field work could be divided into land cover mapping, soil texture and hydrochemistry analysis, and Auja Spring discharge measurements.

3.4.1 Agricultural Lands Cover in Irrigated Area in the CSA

Land cover survey in the CSA was implemented in the period from February to October, 2013. The field survey included:

- Several meetings with Auja Village Council, Themar Agriculture Company, Fresh Gate Agriculture Company, farmers who owned larger irrigated areas, and seven other farmers, agriculture expertise, engineers in Auja area, and engineers of Palestinian MOA in Jericho District.
- Using the Geographic Plan System (GPS) was referenced on international coordination UTM in the field, and transformed to Palestinian Grid System 1923 by the Geographic Information System Application.
- Taking into account seasonal cultivation of different irrigated vegetables in the area, all crops in the area have been divided into seven main groups: palm dates group, green house vegetables, green house medical herbs, regular vegetables, other orchard fruits like grape and citrus, corn and banana fruit .
- Crops data relevant to growing phases is based on FAO Data adapted to filed observation and seasonal cultivation in one year ,2013.
- Total irrigated area in all seasons is 3,945 m^3/a. Seasons means for regular vegetables and green house vegetables that have 1.5 and 2 seasons in one year respectively.
- Theoretically, for regular vegetables there are three seasons in one year according to the agriculture cycle from November till February, from March till June, and from July till October. The one from July till October season has been cancelled by farmers because of water shortage and spring drought in summer season.
- New and promising crops in the area are the greenhouse medical herbs. This companies-owned activity makes production sustained in the area on the one hand and may cause negative impact on farmers in the area on the other. Area of these medical crops is 650 donums.
- Intensive agriculture using greenhouse technology for several kinds of vegetables in the CSA, increases irrigated area to 867 donums in a year while regular vegetables area is 906 donums in two seasons of one year.

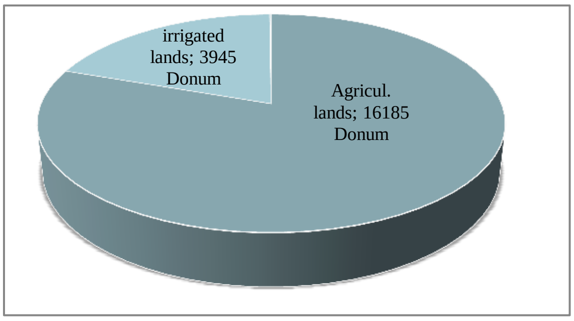
Corn crop is more import to farmers because of its resistance and more benefit. The French tunnel (plastic tunnel) was used by covering seeds. The cultivated area is 244 donums.

Banana and some medical herbs are highly sensitive to brackish water irrigation while palm dates are highly resistant to brackish water irrigation. Table (3.2) shows all crops grown in the CSA in 2013.

Table 3.2: Irrigated crops in the CSA area in one and all seasons

Crop	Irrigated area for each crop in one season, (Donum)	Irrigated area in one season for each group, (Donum)	Irrigated area in all seasons, (Donum)	Irrigated area% per year	Crop duration (Years /months)	Crop Group
Palm dates	1200	1200	1200	30.4%	5 years	Palm Dates
Grapes	20	33	33	0.84%	2 years	Orchard Fruit
Citrus	13				3 years	
Eggplant	138	453	906	22.97%	6 months	Regular Vegetables, 2 Seasons
Tomato	20				5 months	
Wheat	128				7 months	
Zucchini	129				4months	
Cabbage	38				5months	
Capsicum	197	578	867	21.98%	6months	Green house vegetables,1.5 seasons
Cucumbers	261				6 months	
Eggplant	90				9 months	
Tomato	30				8 months	
Basil	90	650	650	16.48%	12 month	Green house Medical herbs
Chamomile	100				7 months	
Fennel	50				12 months	
Rose Mari	50				12 month	
Thyme	120				9 months	
Sage	150				12 month	
Lemon Palm	20				9 months	
Lettuce	40				12 month	
Aniseed Plant	20				12 month	
Mint	10				12 months	
Corn	244	244	244	6.19%	4 months	Corn
Banana	45	45	45	1.14%		Banana
Total	3203	3203	3945	100%		

Arable lands of Auja catchment consist of 16,185 donums; 24% (3,945 donums) of arable lands are irrigated, mostly by drip irrigation system. Parts of arable lands are sometimes cultivated by cereals like wheat and barley which are rain-fed. Figure 3.5 (a and b) shows the arable lands and percent of irrigated lands respectively according to field observation.



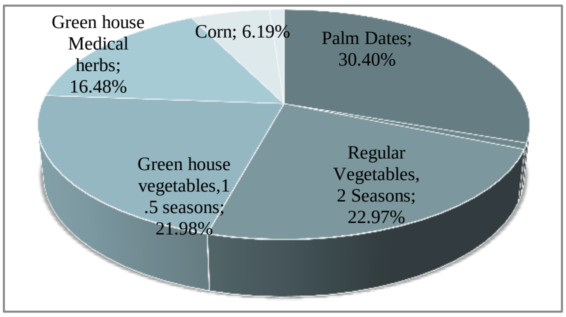


Figure 3.5 a: Total arable lands Figure 3.5 b: Irrigated crops percent in the CSA

There is discontinuity in irrigated lands in the area caused by water scarcity and water poor quality. In the last ten years irrigated lands decreased from 10,000 donums to only 3,945 donums in 2013. Figure (3.6), shows the irrigated land cover in the CSA in 2013 including several groups of irrigated crops. Besides, companies of Themar and Fresh Gate were identified on the map. These companies represent greenhouses of vegetables and medical herbs while banana is included in Themar Company irrigated area.

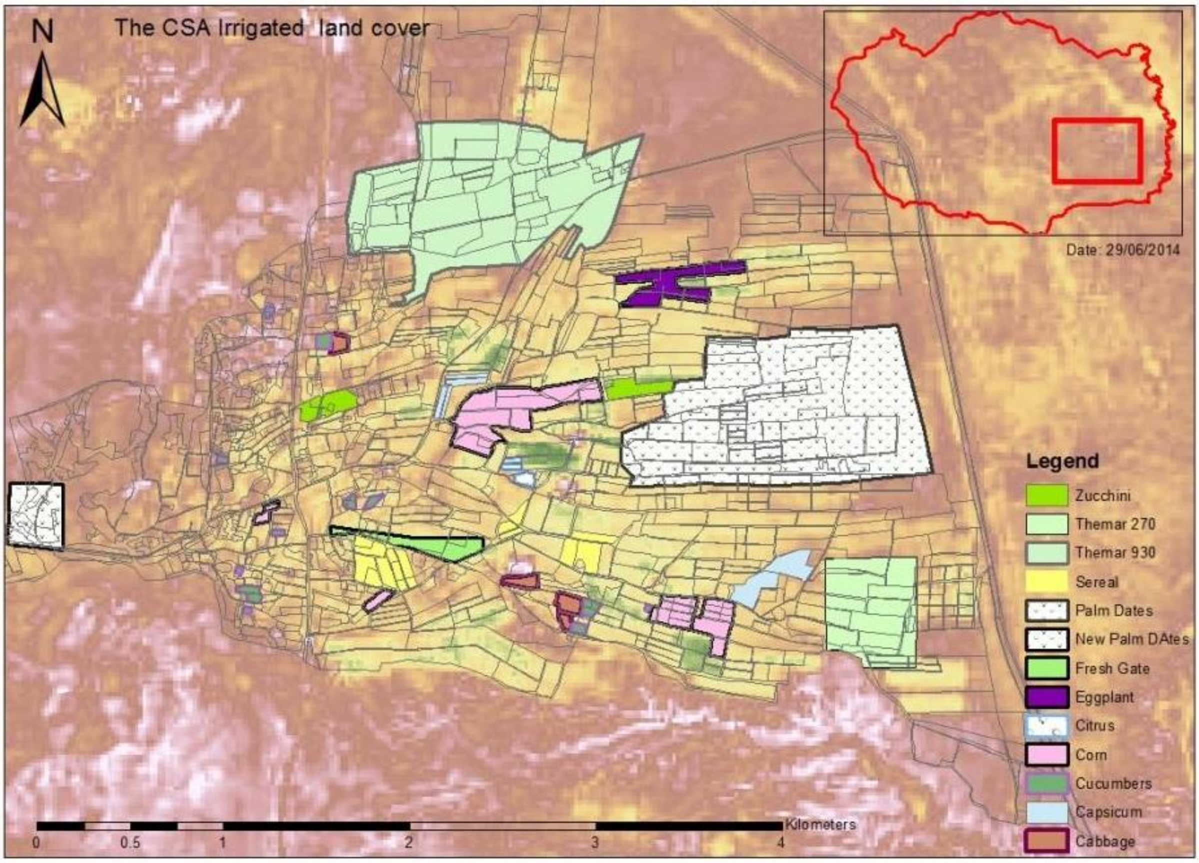


Figure 3.6: Irrigated land cover map in the CSA-Field survey 2013

In the context of crops production, it was observed that intensive agriculture including greenhouse vegetables and greenhouse medical herbs have higher productivity compared with regular vegetables. Their production is 15 and 12 tons/dunom for vegetables and medical herbs respectively. Such values are average values. All production data was collected directly from farmers in the field and modified by MOA, JICA 2008 and Census 2011. Several fruit groups production ranged from 1 to 4 tons/dunom. The observed regular vegetable production is 3 tons/dunom. Corn is considered the highest productivity crop giving 3 tons/dunom. Finally, water quality and the planting time between winter and summer season have direct impact on crops productivity as observed in the field. Figure 3.7 shows crops production values in the CSA.

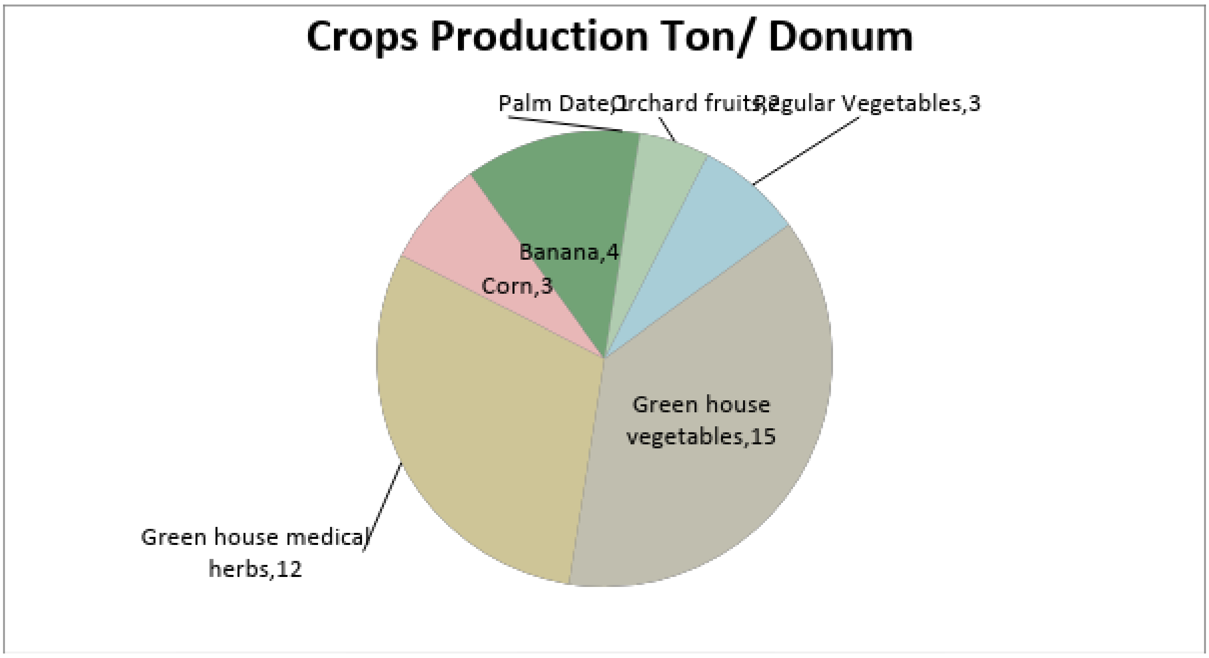


Figure 3.7: Average Crops productivity in the CSA regarding groups' classification (Field Observation, 2013)

3.4.2 Soil Physical Properties and Hydrochemistry

3.4.2.1 Soil Sampling

Soil sampling in the CSA was based on land division into treated (irrigated) and Control lands (non-irrigated).soil investigation in the CSA shows that soil sampling of arable lands included 16,185 donums, with 3,945 donums irrigable.

Nineteen site samples were selected in arable lands in the CSA. Samples from sample code S1 to S11 are located in the treated lands while samples from S12 to S19 are placed in control lands. Each site was sampled into four to five varying depths: 0 cm -20 cm, 20 cm -50 cm, 50 cm-70 cm,70 cm-100 cm. Depths of some samples were 100 cm-120 cm. Depths took into consideration crops' root zone in the CSA. Samples weight was about 1 kg each.

Soil sampling was done for texture and hydrochemistry analysis which included hydraulic properties of soil, soil salinity in terms of Sodium Absorption Ratio (SAR), Exchangeable Sodium Percent (ESP), and Leaching Fraction (LF) of soil in the CSA.

Figure 3.8 (and b) shows selected soil samples in the CSA. Fig.3.8.a is the sample distribution according to lithological classification of soil. Majority of samples were selected in Loessial Serozems soil; some samples were in Regosols and Brown Litholsols soil. Figure 3.8-b shows the soil sample selection into irrigated and non-irrigated area.

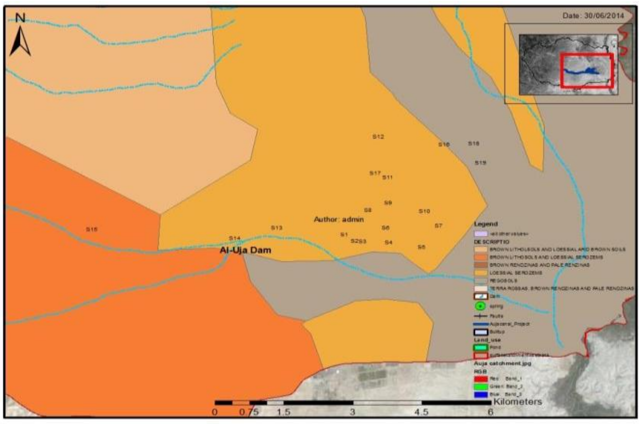


Figure 3.8a: Soil samples with soil lithology

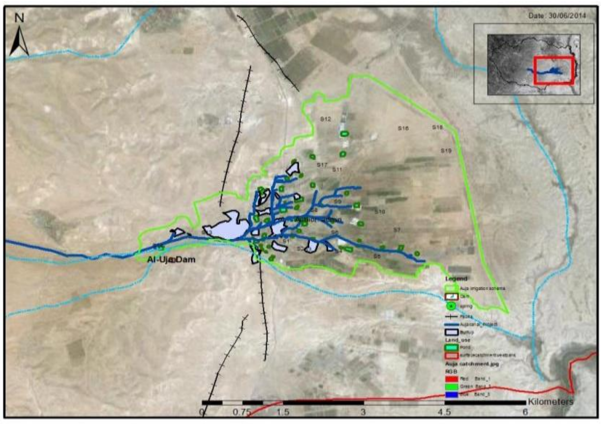


Figure 3.8b: soil samples with scheme Irrig.

3.4.2.2 Soil Texture Analysis

By 10 cm diameter and 1.2 m long Auger, seventy seven samples from nineteen sites were collected; each sample weighs about 500 gm. Soil texture and soil hydrochemistry were analyzed. Texture refers to the size of the particles that make up soil. These particles are defined by sand, silt and clay being the larger size particles. Silt, being moderate in size, has a smooth or floury texture. Clay, being of smaller size particles. Analyses of the samples proceeded as following:

1- In AL Quds university, Environment and Earth Science Laboratory, samples were dried in an oven at 100c°.

2- Twelve meshes were used in sieve analysis smaller than 2 mm and bigger than 63 mm.

Regarding analysis method, USDA soil classification 1987 was applied based on diameter size of soil particles, with clay<0.002 mm, silt smaller than 0.05 mm and larger than 0.002 mm, and sand between 0.05 mm and 0.2 mm. This classification was considered as fine earth in soil classification.

It was observed that, the soil retained percent is similar in soil layer depths of 50-70cm and 70-100 cm. Table 3.3 shows sieve analysis results (Sand is yellow, silt is grey and clay is brown). (Sample No. 6). Results are in appendix 10.1.

Table 3.3 Part 1: Sieve analysis results of four intervals; soil depth sample no. 6 (example)

s6(0-20)					s6(50-70)				
Diameter	mass of empty sieve	mass of sieve and soil retained	soil retained	soil retained %	Diameter	mass of empty sieve	mass of sieve and soil retained	soil retained	soil retained %
2mm	511.3	514.9	3.6	0.72	2mm	511.3	697	185.7	37.26671
1.6mm	507.7	607.9	100.2	20.04	1.6mm	507.7	526.1	18.4	3.692555
1mm	450.6	492.6	42	8.4	1mm	450.6	496.2	45.6	9.151114
710Mm	395.7	430.7	35	7	710µm	395.7	434.1	38.4	7.706201
500Mm	432.6	465.8	33.2	6.64	500 µm	432.6	465.5	32.9	6.602448
250Mm	413.3	486.7	73.4	14.68	250 µm	413.3	476.9	63.6	12.7634
200Mm	413.1	489.4	76.3	15.26	200 µm	413.1	449.3	36.2	7.2647
160Mm	324.2	415.1	90.9	18.18	160 µm	324.2	355.7	31.5	6.321493
90Mm	387.5	396.8	9.3	1.86	90 µm	387.5	424.2	36.7	7.365041
75Mm	365.3	382.8	17.5	3.5	75Mm	365.3	370.8	5.5	1.103753
63Mm	360.1	371.6	11.5	2.3	63 µm	360.1	362.6	2.5	0.501706
<63Mm	304.5	311.6	7.1	1.42	<63 µm	304.5	305.8	1.3	0.260887
			500	100				498.3	100
S6(20-50)					S6(70-100)				
Diameter	empty sieve	(sieve+soil retained)	soil retained	Soil retained %	Diameter	empty sieve	(sieve+soil retained)	soil retained	Soil Retained %
2mm	511.3	697	185.7	34.78179	2mm	511.3	692.5	181.2	36.2617
1.6 mm	507.7	562.1	54.4	10.18917	1.6mm	507.7	532.5	24.8	4.96297
1mm	450.6	496.2	45.6	8.540925	1mm	450.6	508.6	58	11.6069
710 Mm	395.7	434.1	38.4	7.192358	710 µm	395.7	440.6	44.9	8.98539
500 Mm	432.6	465.5	32.9	6.162203	500 µm	432.6	465.5	32.9	6.58395
250 Mm	413.3	476.9	63.6	11.91234	250 µm	413.3	479.2	65.9	13.1879
200 Mm	413.1	449.3	36.2	6.780296	200 µm	413.1	447.3	34.2	6.84410
160 Mm	324.2	355.7	31.5	5.899981	160 µm	324.2	348.1	23.9	4.78287
90Mm	387.5	424.2	36.7	6.873946	90 µm	387.5	411.7	24.2	4.84290

Table 3.3 Part 2: Sieve analysis results of four intervals; depth of soil and site sample number

75Mm	365.3	370.8	5.5	1.030155	75 µm	365.3	371	5.7	1.14068
63Mm	360.1	362.2	2.1	0.393332	63 µm	360.1	362	1.9	0.38022
<63 Mm	304.5	305.8	1.3	0.243491	<63 µm	304.5	306.6	2.1	0.42025
			533.9	100				499.7	100

USDA: Criteria for soil classification (USDA Soil Classification Criteria) included twelve textural classes regarding Sand –Silt-Clay percentage in soil composition. Usually, these percentage values classify soil classes and soil properties distributed into sand with low percent of silt and clay, or silt with low percentage of sand and clay, or clay with low percentage of sand and silt. Table 3.5 shows soil samples could be divided into three classes: samples from S1 to S12, samples from S13 to S15, and samples from S16 to S19. The first class has about 40-50% sand at a depth of 0-20 cm. This percentage increased to 75% at a depth of 100-120 cm. The second class starts by 60% of sand composition at a depth of 0-20 cm, then it decreased to 55% at a depth of 80-100 cm. The third group is random in sand composition percentage between 75% at a depth of 0-20 cm and 22% at a depth of 80-100 cm as shown in Table (3.4).

Table3.4: Soil Texture composition of all interval depths and samples.

Depth	**0-20 cm**			**20-50 cm**			**50-70 cm**			**70-100 cm**			**100-120 cm**		
ID	**Sand**	**Clay**	**Silt**	**Sand**	**Clay**	**Silt**	**Sand**	**Clay**	**Silt**	**Sand**	**Clay**	**Silt**	**Sand**	**Clay**	**Silt**
S1	49.2	24.33	26.47	55.94	17.51	26.55	51.7	16.04	32.3	61.8	4.2	34.01	65.27	19.57	15.17
S2	36.6	34.1	29.22	24.66	39.32	36.02									
S3	49.1	20.16	30.66	67.67	9.66	22.67	77.89	1.11	21	79.4	2.94	17.66	78.03	1.54	20.43
S4	31.2	22	46.8	52	17.85	30.65	53.25	15.28	31.48	39.96	30.93	29.1	54.3	25.18	20.52
S5	78.3	1.46	20.24	87.61	0.58	11.82	95.08	0.28	4.64	92.64	3.63	3.73			
S6	36.1	27.62	36.58	60.7	14.44	24.86	57.82	15.55	26.63	61.82	11.57	26.62			
S7	36.8	41	22.2	42.1	30.6	27.3	53.1	30	16.9	50.26	10.94	38.8	52.92	19.25	27.83
S8	39.5	24.64	35.78	17.19	26.71	56.1									
S9	41.1	25.47	33.39	54.95	7.59	37.46	53.97	8.33	37.7	48.99	17.98	33.03			
S10	54.4	20.53	24.99	55.98	7.52	36.5	59.03	6.9	34.07	56.37	3.8	39.82	51.4	9.16	39.44
S11	57.8	15.1	27.09	40.15	37.15	22.7	55.95	7.84	36.21	59.4	5.36	35.24			
S12	42.3	18.66	39.01	43.49	17.59	38.92	43.91	30.8	26.01	70.52	16.01	13.47			
S13	65.5	15.38	19.07	57.31	21.16	21.53	57.1	25.2	17.7	56.77	23.28	19.95			
S14	38	37.9	24.1	62.67	14.46	22.87	67.03	8.13	24.38						
S15	61.3	17.88	20.67	85	0.9	14.1	77.14	4.24	18.62						
S16	75.8	0.38	23.76	77.2	0.6	22.2	51.42	0.56	48.02	42.3	1.35	56.35	22.89	3	74.21
S17	40.5	23.95	35.55	45.76	11.63	42.61	53.58	6.48	39.94	55.53	5.26	39.21			
S18	32.5	20.7	46.8	39.52	20.45	40.03	21.4	38.9	39.7	64.79	2.69	32.25	64.79	2.69	32.25
S19	18.98	57.33	23.69	22.13	48.61	29.26	12.09	35.41	52.5	64.3	16.25	19.45	66.67	1.06	32.27

Soil texture classified with using Texture Auto Lookup (TAL) program. Texture Windows, by linking results in table 3.5 with TAL program, figure 3.9a,b shows all soil texture kinds according to USDA classification into all depth intervals for all samples. By these Texture charts, it was made clear that there are soil layer textures in the area, the first is 40 cm thick, the second is only 20 cm thick and an interval depth of 50-70 cm, and the third one is 30 cm thick at 70-100 cm depth. The third soil layer, sometimes mixed with less than 20 cm of soil profile(it has direct contact with Lisan formation).

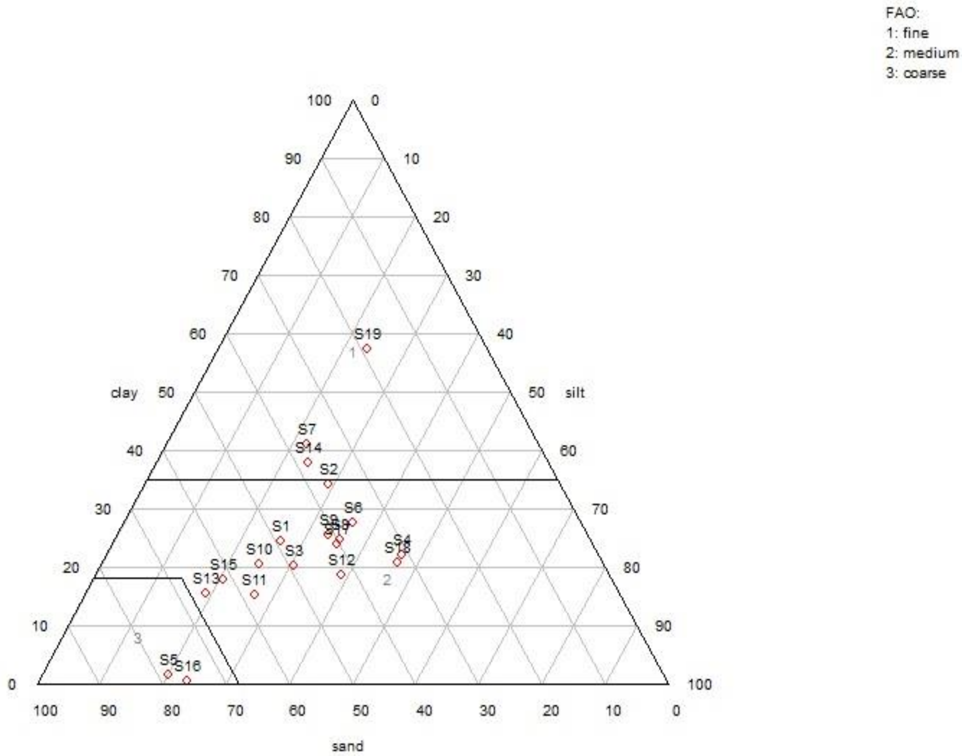


Figure 3.9 a: CSA Soil texture charts, including all samples and all interval depths

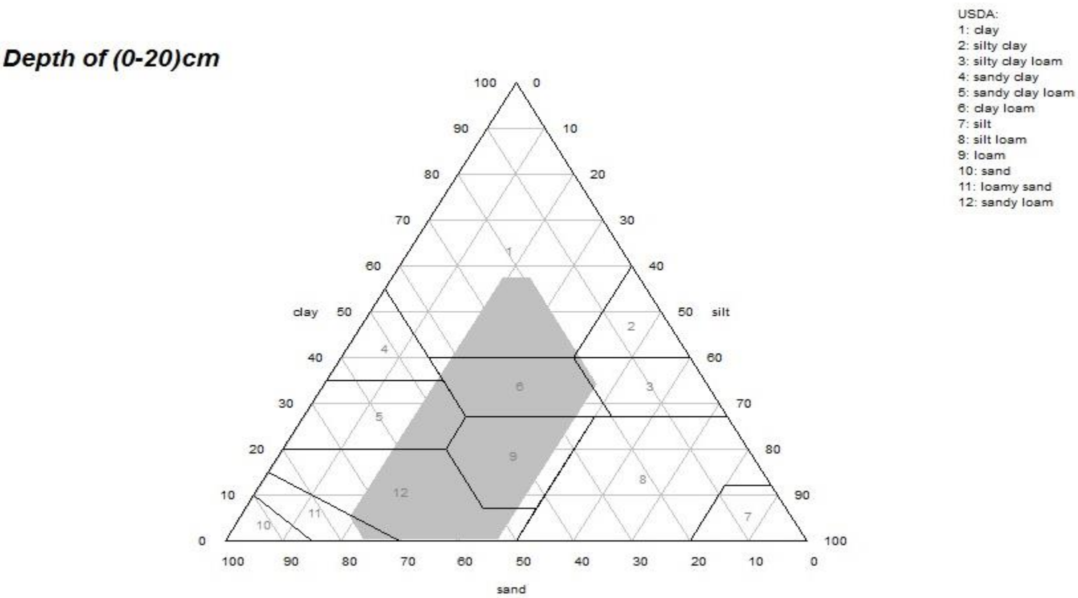


Figure 3.9 b: CSA Soil texture charts, depths of 0-20 cm

Table 3.5 explains the following results:

In all CSA arable area and at an interval depth of 0-50 cm, the main texture composition is clay loam in irrigated area. The dominate composition is sandy loam in the western part of the arable area (non-irrigated area), and clay in the non-irrigated northern east part of the arable area.

The second soil layer is 20 cm thick and at an interval depth from 50 to 70 cm. The main texture composition is sandy clay loam in the irrigated part. Clay loam appeared in the north eastern part of the non-irrigated area. Sandy loam was also observed in the western part of the non-irrigated area. The third layer is 30- 50 cm thick and is of sandy loam texture.

Table 3.5: Soil profile layers in the CSA.

Layer Thickness	**Sub-area 1**	**Sub-area2**	**Sub-area** 3
50 cm (0-50 cm)	Clay	Clay loam	Sandy loam
20 cm (50-70 cm)	Clay loam	Sandy clay loam	Sandy Loam
50 cm (70-120 cm)	Sandy Loam	Sandy loam	Sandy Loam

3.4.2.3 Soil Particle Size, Frequency Curves (PSF) and Hydraulic Properties

A particle-size frequency curve is plotted on a graph where the logarithms of the particle size are shown on the horizontal axis; this logarithms plot shows:

- The particle size decreases toward the right and the cumulative percentages of occurrence of the particle size are shown on the vertical axis.

- Two scales are shown on the vertical axis. To the left, percentages relate to particles passing through sieves of a particular size in the left vertical axis. Percentages increase from zero at the bottom to 100% at the top. Particles that do not pass through sieves of a particular size are on the right side and the percentages accumulate and increase from top to bottom.

- Cumulative percentages of occurrence for each given particle size is calculated starting with the largest size. In our Case, cumulative particle size starts from fine sand <2 mm and coarse sand was neglected and cancelled (Appendix 10.2).

Table 3.6: Accumulated diameter weight of sample number 16 (Example).

Diameter	Mass of empty sieve	Mass of sieve soil retained	Soil retained	Soil retained%	Acum. D.W (%)	Sand , clay & silt
2 mm	511.3	547.2	35.9	7.1201904	7.1201904	
1.6 mm	507.7	514.1	6.4	1.2693376	8.389528	
1 mm	450.6	472.4	21.8	4.3236811	12.713209	
710 mm	395.7	447	51.3	10.174534	22.887743	**Sand**
500 mm	432.6	608.4	175.8	34.867116	57.754859	22.88774
250 mm	413.3	595.5	182.2	36.136454	93.891313	**Silt**
200 mm	413.1	429.3	16.2	3.2130107	97.104324	74.21658
160 mm	324.2	331.7	7.5	1.487505	98.591829	
90 mm	387.5	393.3	5.8	1.1503372	99.742166	
75 mm	365.3	365.8	0.5	0.099167	99.841333	
63 mm	360.1	360.5	0.4	0.0793336	99.920666	**Clay**
<63 mm	304.5	304.9	0.4	0.0793336	100	2.895676
			504.2	100		

Table 3.7: Accumulated diameter weight of sample number 16 and sieve analysis.

Sieve Size(mm)	Acum. D.W(%)	Acum. D.W(%)	Acum. D.W(%)	Acum. D.W(%)	Acum. D.W(%)
2	44.28969359	35.16612073	16.54404454	10.82454084	7.12019
1.6	50.31834461	42.46607394	19.30801352	12.34857366	8.389528
1	67.36967768	61.06691624	33.00855041	20.53536538	12.71321
0.71	75.8654994	77.21104352	51.42175383	42.30168034	22.88774
0.5	87.78352567	95.10996724	84.9671903	79.62094568	57.75486
0.25	99.24393156	98.64295742	99.18472857	95.97499023	93.89131
0.2	99.62196578	99.41506785	99.44322927	98.65181712	97.10432
0.16	99.76124154	99.672438	99.58242195	98.90582259	98.59183
0.09	99.90051731	99.85961628	99.90057666	99.74599453	99.74217
0.075	99.94031039	99.90641086	99.94034599	99.84368894	99.84133
0.063	99.98010346	99.95320543	99.96023066	99.92184447	99.92067
0.01	100	100	100	100	100

Calculating the effective sizes and the uniformity coefficients from the fives-curves according, and shown in figure (3.10).

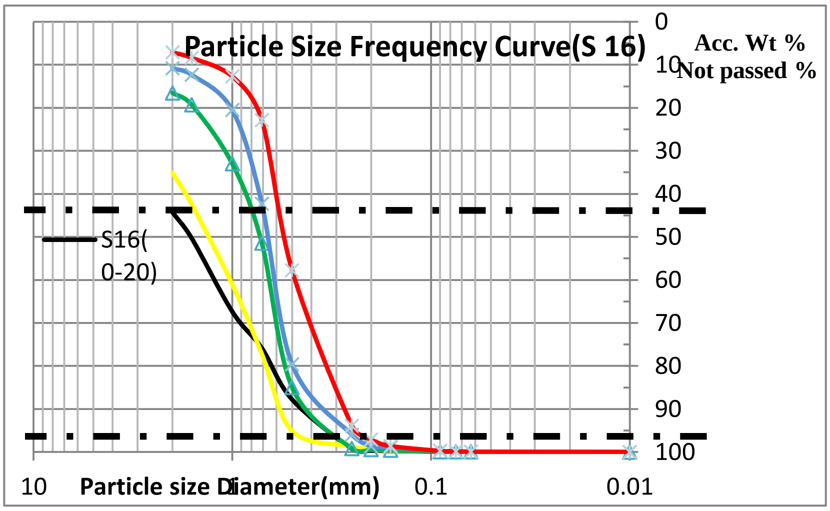


Figure 3.10: PSF-Curve of Site 16 samples with all soil depth profile

Effective accumulated weight should be marked by 10% of passed weight (D10), and accumulated weight 60% (D60) should also pass through the sieve test. This test represents the weight between 10%-60% passing through the sieve meshes. Meaning that 50% of effective accumulated weight passes through meshes. The two drown lines which intersect the several curves (e.g. if the blue cure which represents the sample depth of 70-100 cm have taken). D10 is 0.45mm which resulted by intersect of dotted line of 10% by the blue curve and have the reading perpendicular to X-axis. Also, the same goes for D60,it is 0.8. the uniformity U = D60 ÷ D10, so U in this example is 1.78. The more vertical the PSF-curve (U closer to 1), the more uniform the soil sample is. This calculation is introduction to calculate the hydraulic conductivity of the soil**.** Appendix 9 illustrates all tables and PSF-curves.

Hydraulic conductivity (K) of soil in the CSA could be calculated according to effective grain size range (D 60 and D 10) of soil particle size in PSF-Curves. Many empirical equations formulae were established for this purpose and were concerned with uniformity, effective porosity and effective grain size. The following illustrates these formulae and how to conclude the suitable one for selecting the K value from calculation:

Vukovic and Soro (1992) ,(Odong J.,2013) summarized several empirical methods from former studies and presented a general formula:

$$K= (g/ \nu)*C*f(n)*d^2_e \quad (3.2)$$

K = hydraulic conductivity; g = acceleration due to gravity; **ν** = kinematic viscosity ;

C = sorting coefficient; **f(n)** = porosity function, and **de** = effective grain diameter.

The kinematic viscosity (ν = μ/ρ) is related to dynamic viscosity (μ) and the fluid (water) density (ρ)

Hazen equation which identified (K) in term of porosity, fluidity and effective diameter grain size d_{10}.

$$k=g/ \nu \; 8.3*10^{-3} (n^3/(1-n)^2) d^2_{10} \quad (3.3)$$

This formulae is designed for uniformly graded sand, and is also useful for fine sand to gravel range, it is conditional with uniformity coefficient U< 5, and 0.1< effective grain size<3 mm, The Kozeny-Carman equation ,

$$k=g/\nu*6*10-4*(Log 500/U)*d2 10 \quad (3.4)$$

It is one of the most widely accepted and used derivations of permeability as a function of the characteristics of the soil medium. It is not appropriate for either soil with effective size above 3 mm or for clay soils (Carrier 2003) Breyer equation as

k=g/v*6*10-4* (1+ 10(n-0.26)*d10 2)…………………………………………………...(3.5)

Breyer formulae did not consider porosity and therefore porosity function takes no value. It is often considered most useful for materials with heterogeneous distribution and poorly sorted grains with uniformity coefficient between 1 and 20, and effective grain size between 0.06 mm and 0.6 mm.

Based on limitation of different conditions for each hydraulic conductivity equations, and regarding the field texture results and PSF-curves, several K values have concluded according to the uniformity and limits of effective grain size values.

Table (3.8) shows three soil samples selected from three sites in the CSA. (All K values of overall samples are in appendix9).Hazen equation is implemented on S1 at a depth of 100 cm. But on the last 20 cm after 100 cm depth, Kozeny equation was implemented on S1, while Breyer equation was implemented on S15 and S19. This variety of soil layer texture, K values of S1 are $1*10^{-4}$ mm/s, and on the other hand, K value of S15 and S19 is in order of $_{10}{}^{-2}$mm/s.

Porosity decreases from the top soil along soil horizon depth; it ranged between 0.3 to 0.4 into all samples and depths. S1 porosity in irrigated area seems larger than in non-irrigated area, while K values are smaller. This is explained by uniformity of soil that has direct effect on soil effective porosity. It is clear that S1 area is more uniform by the calculated results than other areas. (Table 3-7)

Table 3.8: Calculated hydraulic conductivity and effective Porosity of selected Soil.

SAMPLE	D60 mm	D10 mm	U=D60/ D10	Breyer equation: k mm/s	Hazen eqation:k,mm/s	Kozeny eqation:k,mm /s	Porosity n=0.225(1+0 .83^u)
S1 (0-20)	0.40	0.09	4.44	$8.58*10^{-5}$	$1.13*10^{-4}$	$1.45*10^{-4}$	0.43
S1 (20-50)	0.60	0.11	5.45	$1.23*10^{-4}$	$9.18*10^{-5}$	$5.4*10^{-5}$	0.31
S1 (50-70)	0.50	0.13	3.85	$1.84*10^{-4}$	$1.53*_{10}{}^{-4}$	$1.10*10^{-4}$	**0.34**
S1 (70-100)	0.75	0.26	2.88	$7.81*10^{-4}$	$6.98*10^{-4}$	$5.50*10^{-4}$	0.36
S1(100-120)	0.80	0.11	7.27	$1.15*10^{-4}$	$7.49*10^{-5}$	$3.63*10^{-5}$	0.28
S15(0-20)	1.05	0.11	9.55	$1.07*10^{-2}$	$6.43*10^{-3}$	$5.10*10^{-3}$	0.26
S15(20-50)	2.00	0.50	4.00	$2.71*10^{-2}$	$21.93*10^{-2}$	$11.10*10^{-3}$	0.33
S15(50-70)	2.00	0.30	6.67	$8.71*10^{-2}$	$65.04*10^{-3}$	8.37*10-3	0.30
S19(0-20)	0.20	0.07	2.86	$5.67*10^{-3}$	$5.06*10^{-3}$	$17.03*10^{-3}$	0.36
S19(20-50)	0.20	0.09	2.23	$9.83*10^{-3}$	$8.79*10^{-3}$	$19.12*10^{-3}$	0.37
S19(50-70)	0.21	0.07	3.00	$5.62*10^{-3}$	$4.81*10^{-3}$	$15.10*10^{-3}$	0.35
S19(70-100)	1.10	0.19	5.79	$3.61*10^{-2}$	$26.10*10^{-3}$	$8.37*10^{-3}$	0.30

a-Hydrochemistry and Soil Salinity in the CSA

In cooperation of AL Quds University Laboratory seventy seven soil samples were analyzed. The analysis validated measurement of electrical conductivity (ECe) of saturated soil Pasta and PH, the major cations (Sodium (Na), Magnesium (Mg), Calcium (Ca) and Potassium K), in addition to the Chloride concentration. The following analysis steps were followed:

-Screening the samples of 40 gm each with 2 mm mesh.

-Mixing the soil sample with 200 ml of deionized water and stirring every 10 minutes for 2 hours.

-Extracting the soil –deionized water solution- by filter papers and measuring ECe and PH;

-Analyzing Chloride concentration by titration methodology using this Equation:

(Cl)mg\L= (Volume of $AgNO_3$ * Normality of $AgNO_3$ *1000 *35.45/ Volume of Sample).

-Analyzing procedure of Cation has been applied by diluting 1:10 of sample, then instrumental analytical method by atomic absorption spectrophotometer was implemented based on calibration curve which is prepared before starting for every cation.

-Sample analysis at a depth of 70 cm (20 cm thick) was conducted. Results are in appendix 10. Regarding Tables 3.9 and 3.10, the following observations were made:

- Saturated soil electrical conductivity ranged from 0.1 ms/cm-0. 6 ms/cm in irrigated area
- Two ranges in non-irrigated area: from 1 ms/cm-9 ms/cm, the eastern area of arable lands of Auja catchment and;
- From 0.1 ma/cm to 0.45 ms/cm in the western area of arable lands of Auja catchment.
- In irrigated area, ECe decreases at a 20 cm-70 cm depth but again increases at 100 cm depth by the impact of leaching through irrigation at 1m depth.
- Sodium concentration was observed at high value in all areas; nevertheless, it is higher in irrigated area than in non-irrigated area. This negative impact indicates sodic toxicity and effect of irrigation water in the CSA.
- Chloride concentration in some irrigated areas reach more than 3,000 mg while in irrigated area it ranges between 17-200 mg/L at different depths, with no big difference and variety in soil layers depth.
- Calcium and Magnesium behave like Sodium in depth and in different areas; but Potassium decreases with layer depth and has higher concentrations in non-irrigated areas than in irrigated area (Appendix 10.3).

Table 3.9: Soil Hydrochemistry in the CSA by 20 cm (0-20 cm depth) layer thickness.

Sample Code	Na(mg/L)	Mg(mg/L)	Ca(mg/L)	Cl(mg/L)	[K] mg/l	ECe(ms/cm)	PH
S1(20)	21.32	13.79	11.91	17.73	20.54	0.233	8.65
s2(20)	34.45	18.19	13.79	124.08	7.27	0.3	8.71
s3(20)	46.3	31.12	24.42	141.8	20.96	0.694	8.49
s4(20)	56.3	49.59	387.5	1418	39.89	4.5	8.18
s5(20)	44.05	7.89	4.7	141.8	29.06	0.524	9.19
s6(20)	29.04	33.37	24.06	81.54	28.52	0.469	8.53
s7(20)	28	18.65	14.6	31.91	21.17	0.263	8.75
s8(20)	13.61	19.29	16.38	35.45	12.8	0.258	8.04
s9(20)	42.35	27.61	27.89	99.26	21.76	0.564	8.47
s10(20)	15.32	20.91	12.33	177.25	29.17	0.315	8.51
s11(20)	25.53	26.36	19.57	70.9	23.71	0.407	8.52
S12(20)	31.32	25.26	18.47	106.35	12.12	0.455	8.67
s13(20)	30.64	17.27	10.7	42.54	12.23	0.286	8.67
s14(20)	17.9	26.35	22.06	141.8	12.22	0.434	8.8
s15(20)	49.06	7.86	0.12	35.45	6.21	0.12	9.05
s16(20)	17.33	25.64	22.81	3013.25	32.12	8.57	8.09
s17(20)	52.7	47.55	110.18	35.45	15.53	0.401	8.89
s18(20)	50.09	41.34	77.49	531.75	22.43	1.544	8.51
s19(20)	33.75	13.24	12.12	70.9	26.66	0.327	9.07

Table 3.10: Hydrochemistry of soil in the CSA by 20cm(50-70 cm depth) layer thickness.

Sample Code	Na(mg/L)	Mg(mg/L)	Ca(mg/L)	Cl(mg/L)	[K] mg/l	ECe(ms/cm)	PH
S1(50-70)	10.9	10.08	11.22	17.73	11	0.108	8.92
s3(50-70)	40.9	8.82	6.53	49.63	8.83	0.271	9.02
s4(50-70)	56.85	49.07	100.5	1099	31.48	3.85	8.23
s5(50-70)	44.28	7.48	2.03	70.9	15.08	0.373	9.3
s650-(70)	24.78	17.57	13.22	28.36	9.44	0.186	8.84
s7(50-70)	15.87	18.13	10.69	21.27	9.61	0.158	8.83
s9(50-70)	43.37	14.07	13.04	70.9	13.96	0.364	8.91
s1050-(70)	10.82	22.3	9.78	35.45	13.5	0.223	8.59
s11(50-70)	17.73	17.12	13.63	17.73	19.66	0.189	8.92
S12(50-70)	45.64	42.27	30.77	354.5	21.25	1.12	8.53
s13(50-70)	15.53	9.57	8.29	21.27	6.24	0.12	8.83
s14(50-70)	47.87	16.88	5.96	212.7	6.24	0.72	9.04
s15(50-70)	20.41	30.18	30.44	70.9	3.94	0.294	8.72
s16(50-70)	59.8	52.17	576.9	1878.9	22.26	5.36	8.29
s17(50-70)	21.48	28.86	26.5	35.45	5.85	0.166	9.09
s18(50-70)	54.42	44.16	44.01	1063.5	16.57	3.06	8.44
s19(50-70)	51.57	37.81	23.05	779.9	21.48	2.27	3.62

b-Soil salinity in the case study area:

In the CSA, irrigation water contains a mixture of naturally occurring salts in the shallow aquifer wells, while discharged water from Auja Spring is fresh. Soil irrigated with saline water contains a similar mix of salts but usually at a higher concentration rate than in the applied water. Buildup of soil salinity and salt accumulation in the soil depend on water quality. Irrigation management and efficiency of drainage system are main factors that affect soil salinity, in addition to natural soil texture composition. Therefore, several measurements of saturated soil electrical conductivity (ECe) were conducted. Sodium absorption ratio and exchangeable sodium percent were calculated for all CSA sampled sites. Soil salinity and sodicity have been evaluated by laboratory testing and salinity control becomes more difficult as water quality becomes poorer. As water salinity increases, greater care must be taken to leach salts out of the root zone before their accumulation reaches a concentration which might affect yields.

-Electrical Conductivity (EC): It is the ability of soil solution to conduct electricity which is expressed in decisiemens per meter (dS/m)=(mS/m), because pure water is a poor conductor of electricity. Conductivity increases in soluble salts and results in proportional increases in the solution EC. Salinity testing is to measure EC of a solution extracted from soil wetted to a "saturation paste". (U.S. Salinity Laboratory Staff (1954), FAO,1998**)**

-Total Soluble Salts(TSS): It is the total amount of soluble salts in a soil-saturated paste. Extract is expressed in parts per million or milligrams per liter (ppm or mg/L). Relationship exists between TSS and EC within a certain range that can be useful to closely estimate soluble salts in a soil solution or extract. The. Sodium chloride, the most common salt, has a TSS of 640 ppm per dS/m. So if EC is known, TSS can be estimated using the formula below:

TSS (mg/L)=EC(dS/m)*640……………………………….…………………………(3.6)

c-Sodium Adsorption Ratio (SAR)

SAR index is used for characterizing soil sodicity, which describes the proportion of sodium to calcium and magnesium in soil solution. SAR formula is given below, with concentrations expressed in mill equivalents per liter (meq/L) analyzed from a saturated paste soil extract. Sodic and high sodium concentration cause soil particles to repel each other and prevent the formation of soil aggregates.

$$SAR = \frac{[Na^+]}{\sqrt{1/2\ ([Ca^{2+}] + [Mg^{2+}])}}$$ ……...…………………………………………………(3.7)

Exchangeable Sodium Percentage (ESP) is another index that characterizes soil sodicity. Actually excess sodium causes poor water movement and poor aeration. By definition, sodic soil has an ESP greater than 15 (US Salinity Lab Staff, 1954). ESP is the sodium adsorbed on soil particles as a percentage of the Cation Exchange Capacity (CEC). It is calculated as:

$$ESP = \frac{[Na^+]}{CEC} \times 100$$ ……………………………………………………………………(3.8)

Cation Exchange Capacity (CEC) is often calculated as the sum of the major exchangeable cations (Ca+2,Mg+2,Na+1,K+1), including hydrogen. Both cations and CEC are expressed as meq/100g. ESP can also be calculated as:

$$ESP = \frac{[Na^+]}{[Ca^{2+} + Mg^{2+} + Na^+ + K^+]} \times 100$$ ……………………...………………………..(3.9)

ESP is used to characterize the sodicity of soils only whereas SAR is applicable to both soil and soil solution or irrigation water. Table(3.10) summarizes soil salinity regarding PH, ESP and SAR.

Table 3.11: Soil salinity and sodic soil classification reference.

Soil Type	ECe	PH	ESP	SAR
Saline	> 4dS/m	< 8.5	< 15%	< 12
Sodic	< 4dS/m	> 8.5	> 15%	> 12
Saline-Sodic	> 4dS/m	> 8.5	> 15%	> 12

d-Leaching fraction or leaching requirement:

Salts concentration in the root zone area has direct negative impact on crop production yield. In addition to continuous salts buildup in the root zone area in this manner, several salt removing processes were applied to prevent this hazardous effect. Leaching is the most suitable technique to remove this salinity buildup. Leaching is most often accomplished by pooling fresh water on the soil surface and allowing it to infiltrate by a leaching process. Leaching fraction or leaching requirement is calculated based on ECiw of applied irrigation water, or infiltration water into soil layers and EC of leaching water

LF=ECw/ECsw……………………………………………………………………(3.10)

Where ECw is applied water for irrigation (Leaching water) and ECsw is soil water (infiltrate water) and the leaching requirement is:

LR=ECw/(5ECsw-ECw); ECsw could be calculated as average soil electrical conductivity.

According to the above methodology calculation of SAR, ESP and based on laboratory measurement of CSA soil, the following results were observed:

- ESP has a total of more than 15% in all several areas of sampling sites while.
- SAR is less than 12; but in some sites, it has high ratio than 1. This indicates the ability of soil to change sodic in case of continuity using high saline water and in context of high Exchangeable Sodium percentage.
- CSA soil is alkali and has larger than 8.5 PH values.
- Chloride concentration varies from low concentration in some irrigated areas to high concentration in non-irrigated lands.
- Sodium absorption ratio in irrigated area particularly is larger than 1.5 with moderate sodic ratio, while in some non-irrigated areas, especially in the eastern part of Auja Lands, they have about 2 SAR.
- Soil electrical conductivity is about 0.15 as an average value, but in the eastern part of Auja lands it reaches 5 dS/m which makes it highly concentrated.

Based on Table (3.11) and according to ECe values in table (3.12), soil in the area is classified as low to moderate hazardous soil.

Table 3.12: Soil Hazard Classification

ECe	HAZARD
<1.5	Low
1.6-3.9	Moderate
4.0-5.0	High
>5.0	very high

Regarding ESP values, Auja soil could be classified as saline soil and moderate sodic.

Table (3.13) explains SAR, ESP, and ECe results for crop root zone at 70 cm of soil depth.(See results in Appendix 9.3).

Table 3.13 part 1: Sample results of Soil SAR, ESP, and ECe of (50-70 cm) crop root zone.

Sample Code	SAR (meq/L)	ECe (ms/cm)	Cl (mg/L)	PH	ESP%
S1(50-70)	0.57	0.11	17.73	8.92	22.08
s3(50-70)	2.45	0.27	49.63	9.02	58.17
s4(50-70)	1.16	3.85	1098.95	8.23	20.03
s5(50-70)	3.22	0.37	70.90	9.30	63.58
s6(50-70)	1.05	0.19	28.36	8.84	31.43

Table 3.13 part 2: Sample results of Soil SAR, ESP, and ECe of (50-70 cm) crop root zone.

s7(50-70)	0.69	0.16	21.27	8.83	23.28
s9(50-70)	1.98	0.36	70.90	8.91	46.52
s10(50-70)	0.44	0.22	35.45	8.59	14.97
s11(50-70)	0.75	0.19	17.73	8.92	22.91
S12(50-70)	1.25	1.12	354.50	8.53	26.29
s13(50-70)	0.87	0.12	21.27	8.83	33.14
s14(50-70)	2.27	0.72	212.70	9.04	55.19
s15(50-70)	0.63	0.29	70.90	8.72	17.76
s16(50-70)	0.64	5.36	1878.85	8.29	7.16
s17(50-70)	0.69	0.17	35.45	9.09	19.51
s18(50-70)	1.39	3.06	1063.50	8.44	27.42
s19(50-70)	1.54	2.27	779.90	3.62	31.76

3.4.2.4 CSA Zoning based on soil salinity results and leaching requirements

According to results of hydrochemistry analysis in these arable area, three area zones were identified:

1- Area Zone 1: It is the eastern part of the arable area in the CSA, non-irrigated area and has extended marsh lands in the north eastern part of the area. Its area is 4,000 donums.

2- Area Zone 2: This area includes irrigated area now and is surrounded by non-irrigated area. It is located in the middle of Auja Village close to the buildup area to the east. It has 3158 dunom irrigated area and 3,375 donums non-irrigated area.

3- Area Zone 3: This area extends towards west of Auja Village and is completely virgin land. Like area zone 1, it is not irrigated yet and its area is 4,865 donums.

Figure (3.11) shows these the three zones in the CSA.

Geographic Information System (GIS) and 3-Dimention analysis of different soil layers

In the three area zones, The following results were reached:

1- Area zone 1: ECe ranged from 0.1 dS/m to 1 dS/m at a depth of up to 70 cm. SAR value is about 1while ESP is between 9 and 26. At a 120 cm depth, salinity in some areas has different values. ECe ranges between 12 and 27, AR value is around 12 on average and ESP is from 21 to 62. This layer is from 70 to 120 cm and is classified as Sodic-Saline layer and highly hazardous.

2- Area zone 2: ECe is about 0.5 at all depths in the irrigated part of this area zone especially in the middle part and reaches 120 cm. SAR is 0.9 and ESP is around 9. In the south eastern part of this non-irrigated area zone forming the lower gradient. Extended slopes of the irrigated area, SAR reaches 13 and sometimes 23 and ESP scores 37 at 70 cm to 120 cm. This area is also sodic saline with high hazard at (70 cm-120 cm).

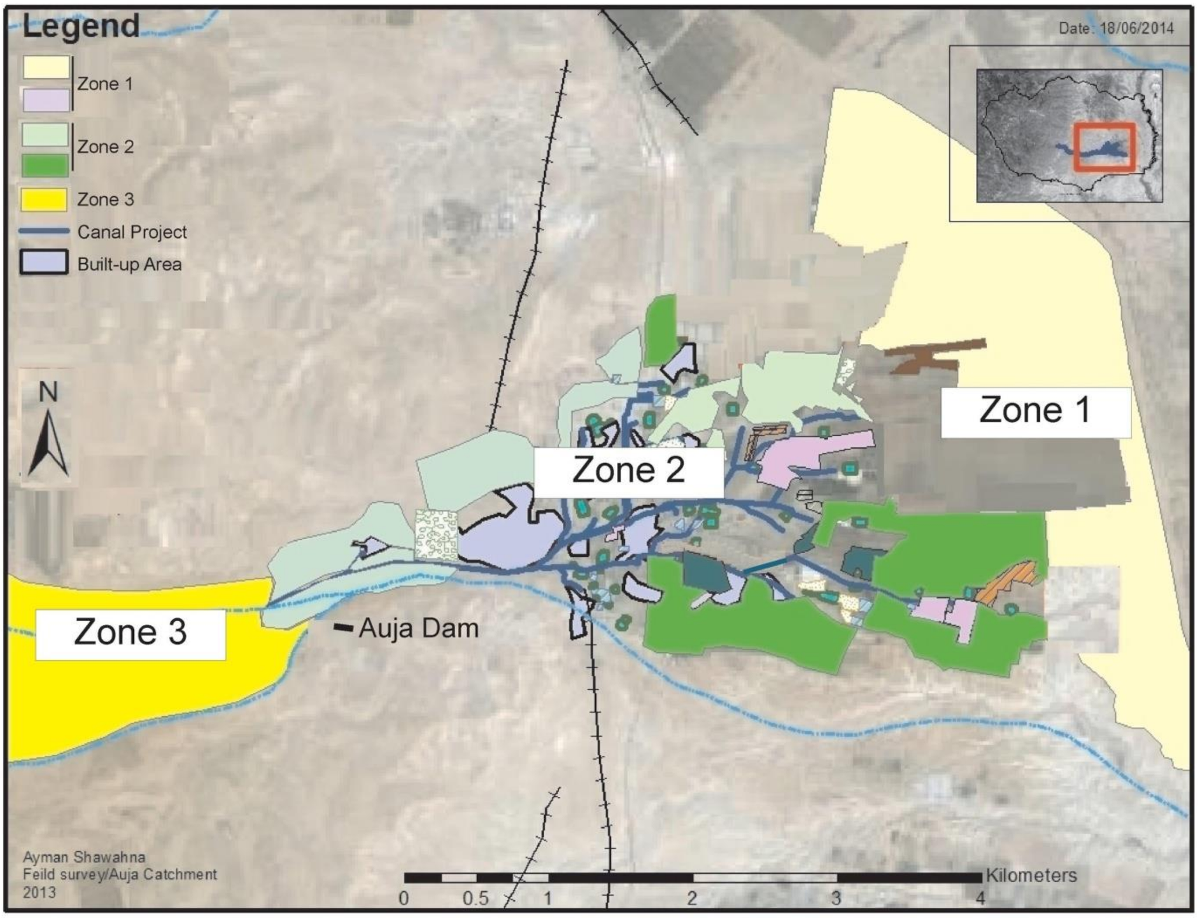
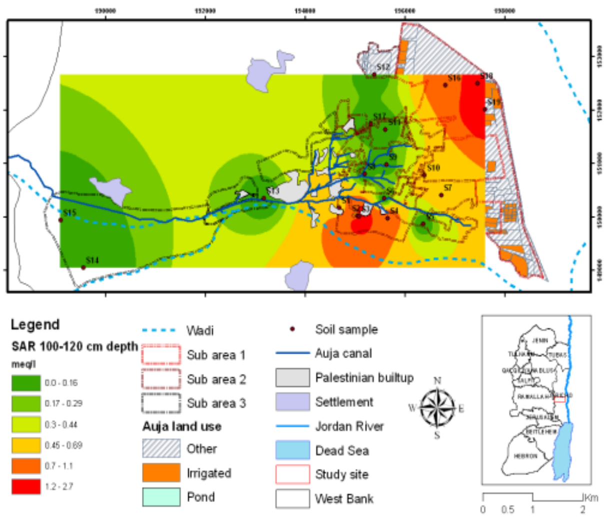


Figure 3.11: Classification of zones in the CSA based on soil Salinity consideration

3- Area Zone 3: It has 0.6 dS/m ECe at a depth of 70 cm. SAR is about 0.9 and ESP is between 14 and 21. At a depth of 70 cm to 120 cm, ECe is 0.5, SAR is about 18, and ESP is from 30 to 37. At a depth of 70 cm to 120 cm it is Sodic –saline. (**F**igure (3.12), a,b,c) and ((3.13) a,b,c), represents 3-D GIS analysis of ECe, SAR and ESP at a depth of 70 cm to 120 cm. All results are in appendix (10.4).



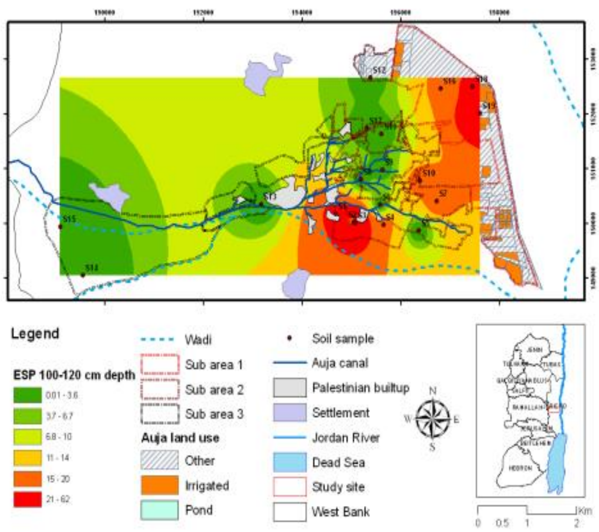


Figure 3.13, a: SAR at 70cm Depth

Figure 3.13, b: ESP at 70cm Depth

Further calculation based on salinity classification of soil was conducted. Leaching requirements (LR) based on this salinity classification and water quality supplies in the CSA were taken into consideration. Calculation in table (3.13) relates to the following:

Water supplies are divided into four main groups.

- Group A -Spring group of 0.65 dm/shallow wells contains wells of numbers 19-14/001, 19-15/005, 19-15/007, and 19-15/012 with1.5 dm/m EC.

- Group B-contains wells 19-15/011 and 19-15/023: This group has 2dm/m EC. These wells are 19-15/008, and 19-15/010. These wells' EC is 3 dm/m or larger.

LR of Spring group for Zone 1 ranges from 0.17 in 70 cm thick, and decreases to 0.01 at a depth of 70 cm to 120 cm in zone 2. LR is the same with 0.35. This is irrigated area. This indicates saturated soil with soluble salts. Zone 3 has better LR at 0.25 cm-70 cm thick and reaches 0.35 at 70 cm- 120 cm depth.

Leaching Requirements (LR) by using wells of group A,B and C is possible in zone 1 area into all soil depth, but for other layers caused hazardous salinity build up into soil profile, which leads to zero yield in crops productivity.

In terms of LR in the three zones, crop selections in the CSA will be divided into root zone of depth by 70 cm, and soil depth by 100-120 cm will be concerns of another crop patterns such as grapefruits and Date Palms, these two soil thickness based on LR suggest two different crop patterns of vegetables and orchards fruit trees.

These results will affect crop water requirements. Different crops patterns will be calculated with several scenarios.

Table 3,14: Leaching Requirements (LR) of different zones using different water supplies.

Zone	Layer interval and thickness	ECe	TSS(mg/L)	SAR	ESP%	LR (Spring group=0.650)	LR (Group A)	LR (Group B)	LR (Group C)
Zone 1	70cm(0-70)	0.90	567.00	1.00	9-26	0.17	0.5	0.8	2
	50cm(70-120)	3.80	7680.00	1.700	21-62	0.01	0.03	0.03	0.05
Zone 2	70cm(0-70)	0.50	320.00	0.90	9-11	0.35	**0.35**	**4**	**-6**
	50cm(70-120)	0.50	320.00	1.80	30-37	0.35	**0.35**	**1.5**	**-6**
Zone 3	70cm(0-70)	0.65	384.00	0.90	14-21	0.25	**0.25**	**1.6**	**12**
	50cm(70-120)	0.50	320.00	1.50	30-37	0.35	**0.35**	**1.5**	**-6**

3.4.2.5 Soil Moisture and Water Content in the CSA

The texture based method reported by Saxton et al. (1986) is largely based on the data set and analyses of Rawls et al. (1982) and has been successfully applied to a wide variety of analyses particularly those of agricultural hydrology and water management. SPAW Model (Saxton and Willey, 1999, 2004, 2006), Saxton K.E. and Rawls W.J. 2006 is based on calculated data relevant to soil texture composition and hydraulic properties. They were used in SPAW Model for calculating soil moisture (Sandy Loam Texture) content and soil calculated hydraulic conductivity K (20 mm/hr) as example. Computation results are in Figure (3.14). Table (3.14) gives soil moisture as 41.8% by volume while the field capacity is 17.9% by volume, while the saturated hydraulic conductivity (K) is 50.34 mm/hr.

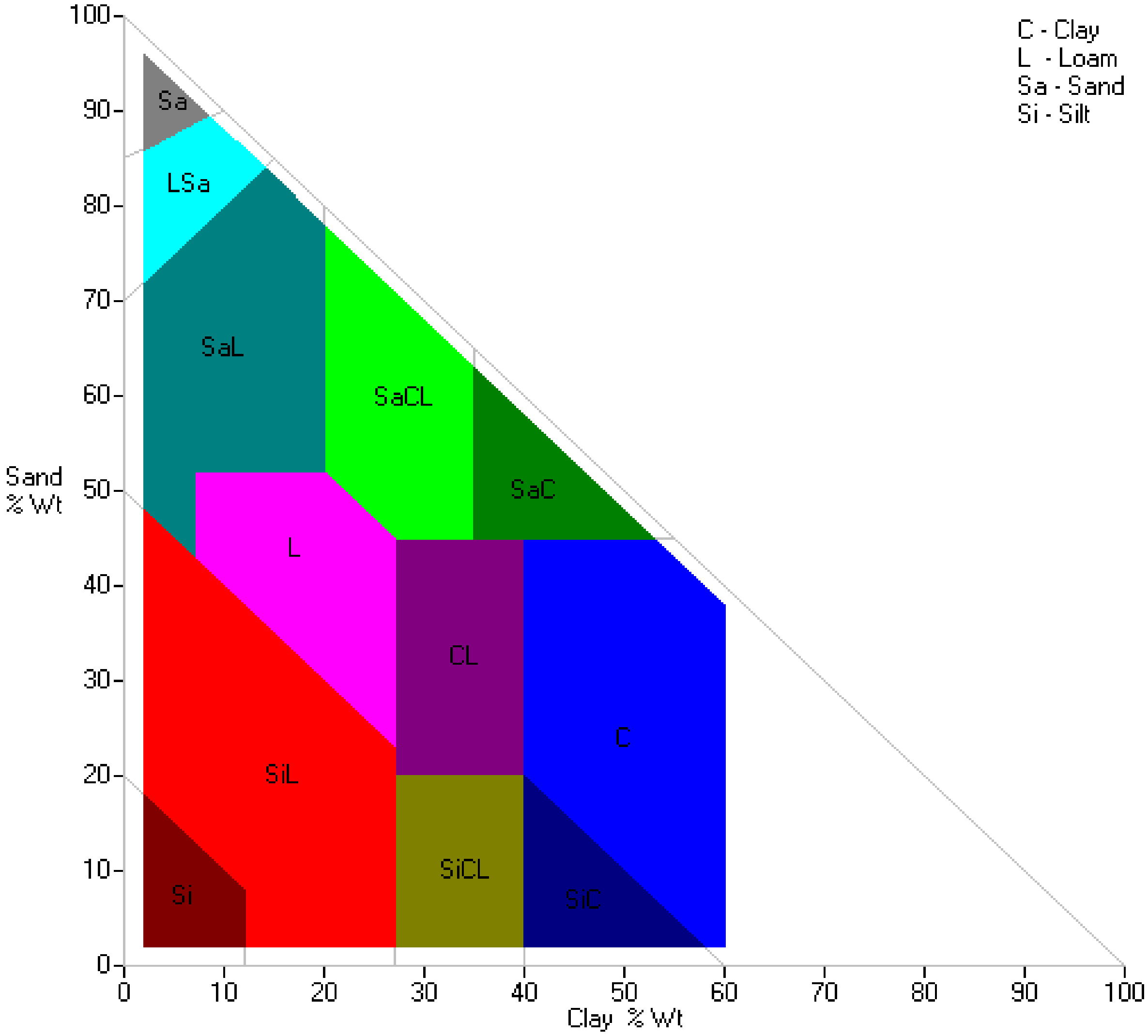


Figure 3.14: Sandy loam soil texture represented by SPAW Model.

Table 3.15: Sandy Loam sample computation of SPAW Model for Soil Water content

Sand	Clay	Silt	WP	FC	Sat	AW	Sat Cond (K)	BD	Moisture	Cond.(K)
%Wt	%Wt	%Wt	%Vol	%Vol	%Vol	cm/cm	mm/hr	g/cm^3	%Vol	mm/hr
65	10	25	8.1	17.9	45	0.1	50.34	1.46	41.8	2.01E+01

By classification of all soil texture layers into three in terms of thickness and into three area zones in the CSA (Figure 3.15a,b and c), soil texture distributes clay to Sandy clay loam in Zone 1, with soil moisture being between 45% to 48% by volume, and K from 7.5 mm/hr for sand clay loam to 50 mm/hr for Sandy Loam layer. Zone 2 is similar to Zone 1 except for the thickness layer of the second which is sandy clay loam with 7.5 mm/h and 43%volume of K and moisture content respectively. The third zone is completely sandy loam texture composition. It has 50 mm/hr K and 45% volume of soil mixture. Table (3.16) illustrates these results, Appendix (10.6).

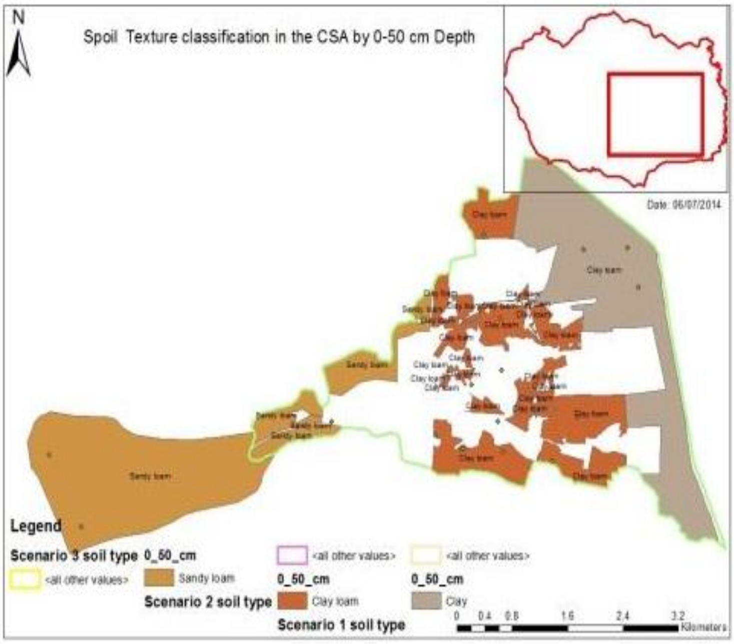


Figure 3.15a: Soil classification based on Soil Texture analysis in the CSA

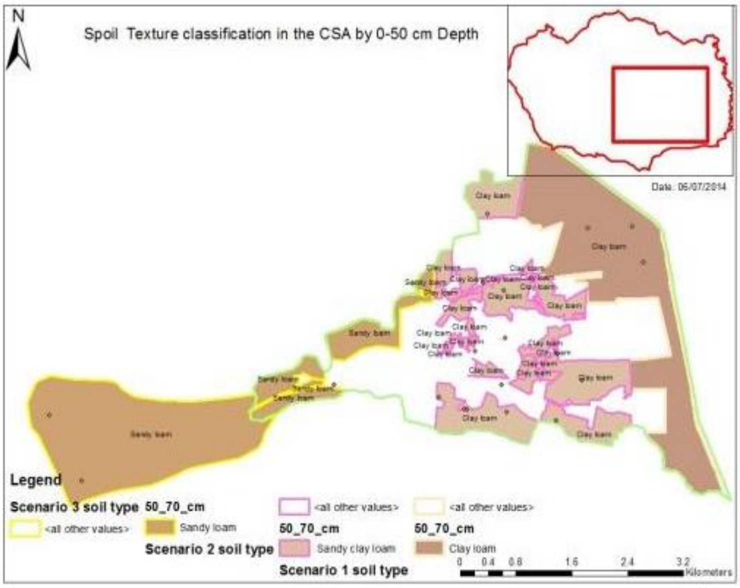


Figure 3.15b: Soil classification based on Soil Texture analysis in the CSA

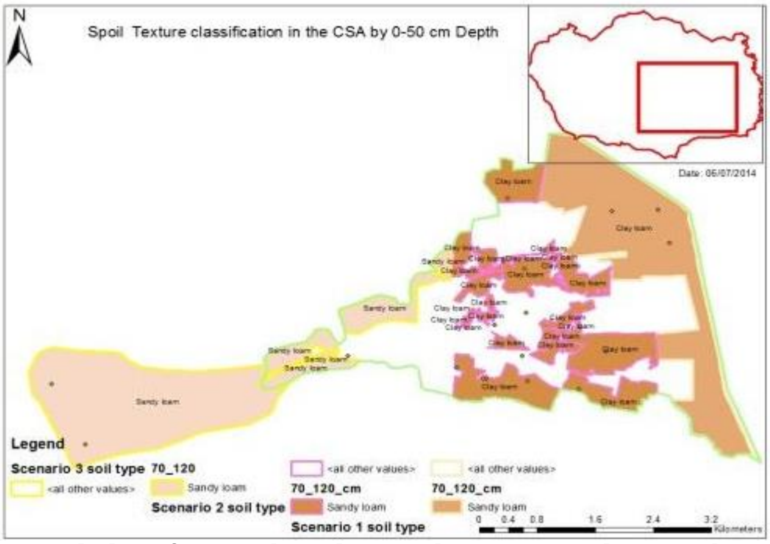


Figure 3.15c: Soil classification based on Soil Texture analysis in the CSA

Table 3.16: Calculated soil moisture percent with maximum hydraulic conductivity.

Layer Thickness	Zone 1	K(Zone1) mm/hr	Moisture% volume	Zone 2	K (Zone 2) mm/hr	Moisture% volume	Zone 3	K (Zone 3),mm/hr	Moisture% volume
50 cm(0-50cm)	clay	0.7	48.8	Clay loam	4.5	47.2	Sandy loam	50	45
20cm(50-70cm)	Clay loam	4.5	47.2	Sandy clay loam	7.8	43.2	Sandy Loam	50	45
50cm(70-120cm)	Sandy Loam	50	45	Sandy loam	50	45	Sandy Loam	50	45

3.5 Crop Water Requirement

In this section all calculation results on land crop cover survey are referenced and soil characteristics in the CSA, and hydrochemistry analysis, in addition to Field capacity and soil moisture. Crop requirement could be calculated by using CropWat software which shows the crop pattern and irrigation scheme to be adopted based on field measured and calculated data, and some FAO Crop index which is relevant to crop coefficient with different growth phases.

3.5.1 Input data for CropWat model: CropWat software version 8 (FAO) was used to calculate crop water requirement. The following is the used data:

Climatic data was collected from PMD from 1994 to 20011 in the form of monthly rainfall, maximum and minimum temperatures, humidity, wind speed and direction, evaporation and sun radiation per hour. All this data was taken at mean values along throughout the period, Evapotranspiration (ET_0) and radiation were computed by software based on climatic data. Table (3.17) shows the input and calculated data.

Table 3.17: Mean Climatic data, Jericho Station from 1994 to 2011, PMD (2012).

Month	Rain	Min Temp	Max Temp	Humidity	Wind	Evap.	Sun	Radiation	ETo
	(mm)	(°C)	(°C)	(%)	(km/day)	(mm)	(Hours)	(MJ/m²/day)	(mm/day)
January	33.40	9.10	21.90	64.00	2.00	89.60	8.00	13.30	1.38
February	31.60	5.80	23.50	63.00	2.00	2.89	9.00	16.70	1.84
March	14.60	8.50	30.50	56.00	2.00	87.90	10.00	21.00	2.85
April	0.00	11.70	36.90	45.00	2.00	3.14	10.00	23.50	3.71
May	00.00	19.60	40.80	44.00	2.00	151.7	11.00	26.20	4.79
June	0.000	20.30	43.70	46.00	2.00	4.89	12.00	28.00	5.45
July	00.00	25.60	45.70	49.00	2.00	188.4	12.00	27.70	5.88
August	00.00	25.80	43.30	45.00	2.00	6.28	11.00	25.30	5.16
September	00.00	22.80	41.50	51.00	2.00	259.6	9.00	20.40	4.07
October	00.00	17.90	38.70	49.00	1.00	8.37	9.00	17.50	2.92
November	23.80	13.50	36.70	55.00	1.00	306.3	8.00	13.70	2.04
December	16.20	9.60	27.00	64.00	1.00	10.21	7.00	11.50	1.39
Average		15.80	35.90	53.00	2.00	336.5	9.70	20.40	3.46

Crop data in this part indicated by survey is based on field data collection and observation. The crops in the irrigated area were classified into seven crop groups as previously mentioned. Crops parameters such as crop coefficient (kc), crop developing stages, maximum crops height, and crop yield response are indicated by FAO index of Irrigation and Drainage Paper Number 33.

Soil data was classified into soil texture composition in irrigated and non-irrigated lands. Calculation of soil physical and hydraulic parameters including water content, and soil depletion factor, moisture, field capacity and infiltration rate for each soil type in the CSA are discussed and shown under Section 3.4.

3.5.2 Output results and sample computation of applying climatic-crop-soil on CropWat Model

In this context, and in order to compute crop water requirement in the CSA, banana crop is taken as sample computation example. This crop is grown on a 30 dunom area (2013). Mean rainfall was 120 mm/year, while the crop evapotranspiration (ET_0) was 3.46 mm/day. There were no events in the CSA from March to October causing high water deficiency in the soil water moisture. Table (3.18) and figure (3.17) respectively show the ET0 and effective rainfall results in the CSA.

Table 3.18: ET0 and effective rainfall in the CSA

Month	**Radiation**	Rain	Eff rain	**ETo**
	MJ/m²/day	Mm	mm	mm/day
January	13.3	33.4	31.6	1.38
February	16.7	31.6	30	1.84
March	21	14.6	14.3	2.85
April	23.5	0	0	**3.71**
May	26.2	0	0	**4.79**
June	28	0	0	**5.45**
July	27.7	0	0	**5.88**
August	25.3	0	0	**5.16**
September	20.4	0	0	**4.07**
October	17.5	0	0	2.92
November	13.7	23.8	22.9	2.04
December	11.5	16.2	15.8	1.39
Average	20.4	119.6	114.6	3.46

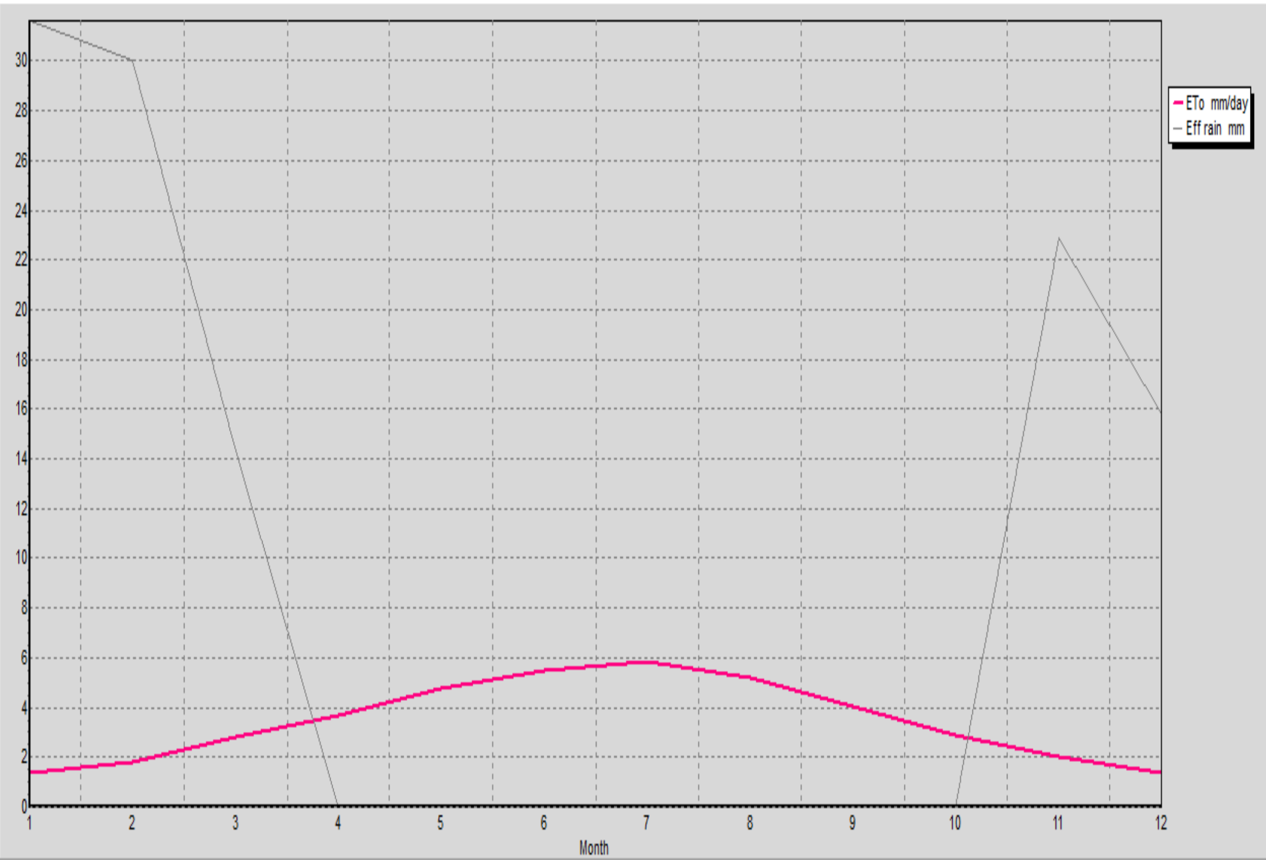


Figure 3.16: ET0 and effective rainfall in the CSA

CropWat in figure (3.17) shows the difference between RAW (Radial (Theoretical) Available Water) and TAW (Total Available Soil moisture Water). The accumulated moisture depletion every 10 days starts at 35% in the first six months. It gradually increases till it reaches 180 days of banana planting. Palm date planted in September has constant depletion percent at 55% throughout the second half of the year.

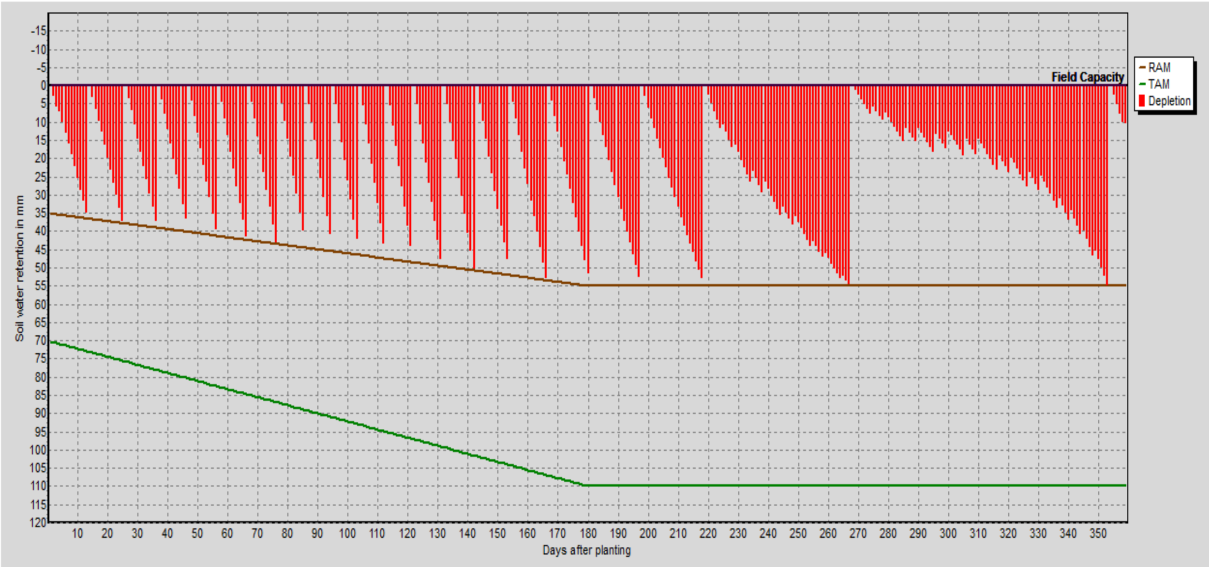


Figure 3.17: Soil Depletion of Palm Date cropping in the CSA

Irrigation requirement results and comparison between crop requirement and crop Evapotranspiration (ET) is shown in figure (3.18). It is computed by CropWat as monthly values 3 times (10 days each) each month.

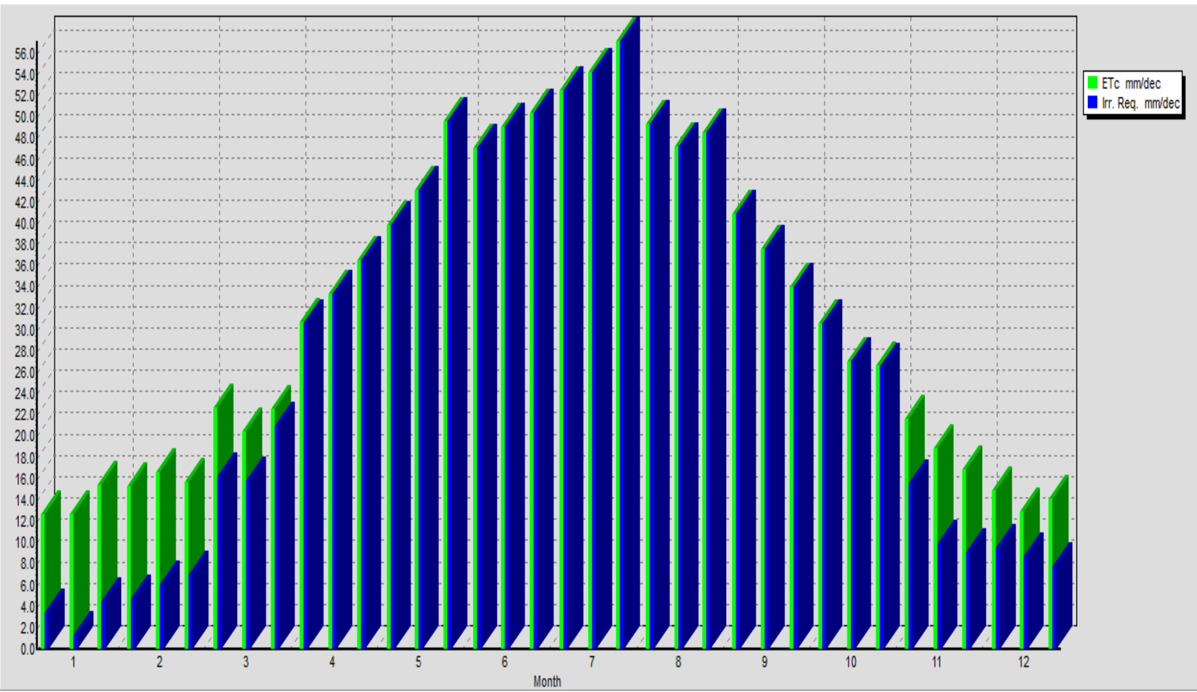


Figure 3.18: Date Palms water requirement in the CSA for one year

Results of palm date is displayed in Table (3.19). Total actual banana water requirement for one dunom per year is 1,026 CM while effective rain is 113 m^3/year. Crop Evapotranspiration during planting duration of palm date crop in the CSA was calculated at 1,139 m^3/dunom/year, more than the crop requirement. The difference is the effective rain. Therefore, the gross crop requirement is 1,139 m^3/dunom/year.

Table 3.19: Monthly Crop water requirements in different development stages of palm date

Month	Decade	Stage	Kc coeff	ETc (mm/day)	Etc. (mm/dec)	Eff rain (mm/dec)	Irr. Req. (mm/dec)
Mar	3	Init	0.9	2.82	22.6	2.3	21
Apr	1	Init	0.9	3.08	30.8	0.1	30.7
Apr	2	Init	0.9	3.34	33.4	0	33.4
Apr	3	Init	0.9	3.66	36.6	0	36.6
May	1	Init	0.9	3.99	39.9	0	39.9
May	2	Init	0.9	4.31	43.1	0	43.1
May	3	Init	0.9	4.51	49.6	0	49.6
Jun	1	Init	0.9	4.71	47.1	0	47.1
Jun	2	Init	0.9	4.91	49.1	0	49.1
Jun	3	Deve	0.9	5.04	50.4	0	50.4
Jul	1	Deve	0.9	5.25	52.5	0	52.5
Jul	2	Deve	0.91	5.43	54.3	0	54.3
Jul	3	Deve	0.91	5.2	57.2	0	57.2
Aug	1	Deve	0.91	4.93	49.3	0	49.3
Aug	2	Deve	0.92	4.73	47.3	0	47.3
Aug	3	Deve	0.92	4.41	48.5	0	48.5
Sep	1	Deve	0.92	4.09	40.9	0	40.9
Sep	2	Mid	0.93	3.76	37.6	0	37.6
Sep	3	Mid	0.93	3.41	34.1	0	34.1
Oct	1	Mid	0.93	3.06	30.6	0	30.6
Oct	2	Mid	0.93	2.7	27	0	27
Oct	3	Mid	0.93	2.43	26.7	0.1	26.6
Nov	1	Mid	0.93	2.16	21.6	6	15.6
Nov	2	Mid	0.93	1.89	18.9	9	9.9
Nov	3	Mid	0.93	1.69	16.9	7.8	9.1
Dec	1	Mid	0.93	1.49	14.9	5.4	9.6
Dec	2	Late	0.93	1.29	12.9	4.2	8.7
Dec	3	Late	0.92	1.28	14.1	6.3	7.8
Jan	1	Late	0.92	1.27	12.7	9.3	3.4
Jan	2	Late	0.92	1.27	12.7	11.3	1.3
Jan	3	Late	0.91	1.4	15.4	10.9	4.5
Feb	1	Late	0.91	1.53	15.3	10.6	4.7
Feb	2	Late	0.91	1.67	16.7	10.7	6
Feb	3	Late	0.9	1.97	15.7	8.7	7
Mar	1	Late	0.9	2.26	22.6	6.5	16.2
Mar	2	Late	0.9	2.56	20.5	3.8	15.8
					1139.6	113	1026.3

3.6 Total Crop Water Requirement and monthly Irrigation Scheme in the CSA

CropWat computed the crop water requirement including effective rain based on the planting period of different kinds of crops. Permanent crops like date palm, grapes and banana have about 96% effective rain along the year while temporary crops like vegetables, medical herbs and corn is different according to seasonal cropping time. Table (3.20)-Regular Vegetables, corn and vegetables green house

Planting stars in March and the 6-7 months cropping period is considered the driest period in the year. Effective rainfall does not exceed 4% at best, therefore, permanent groups (Date Palm and Grapes) have one season cropping period in the year, but grape farming can stop irrigation during December-February period.

Corn, medical herbs green house, regular and green house vegetables have 6 months season period with 2 seasonal cropping in a year: one in March and the other is in September, show table 3.20.

Table3.20: Monthly crop Evapotranspiration of classified crop groups, (mm/month).

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Date Palms	84.10	34.60	26.00	9.20	17.80	53.00	100.70	132.60	146.60	163.90	145.20	112.60
Grapes	61.40	8.10	0.00	0.00	0.00	3.80	39.10	102.90	135.50	150.40	131.90	100.70
Banana	91.90	43.20	32.40	15.90	26.10	77.20	75.90	73.70	81.40	91.10	100.80	100.70
Corn	0.00	0.00	0.00	0.00	0.00	14.40	128.40	167.80	184.30	197.60	166.40	13.60
Vegetables Green house	0.00	0.00	0.00	0.00	0.00	18.80	166.80	184.20	201.60	208.30	0.00	0.00
Regular vegetables	0.00	0.00	0.00	0.00	0.00	7.50	67.10	119.10	182.40	199.10	41.30	0.00
Medical herbs	84.10	34.50	26.10	9.70	13.80	21.40	55.90	73.70	82.60	142.30	146.80	112.80

There are two main scenarios in the CSA cropping system; the dominant one is the Winter Season cropping system and the second one is Summer Season. The following results were observed regarding those two scenarios:

The irrigated area for one Season is 3,190 donums and is 4,474 donums for two seasons.

Total Crop Water Requirement (CWR) in the CSA for all seasons is 3,00 Mm^3/a: 2.16 MCM/Season in winter and 2.75 Mm^3/Season in summer.

Date palms form majority in terms of water consumption (about 45% of total CWR in the CSA).

Medical herbs, which are classified as intensive agriculture of greenhouse technology, consume 19.1% of total CWR per year. As such, they are more feasible than other crops in comparison with crop water yield and crop productivity.

A big difference has been found between winter and summer CWR caused by effective rain and crop Evapotranspiration values between summer and winter. This difference appears clearly in corn and vegetables green house. It is about 7-11% of CWR between the two seasons.

Vegetables LR is 0.17 and orchard fruits is 0.35 (Table 3.14). Total CWR will be 2.00 MCM/a for temporary crops and 1.71 Mm^3/a for permanent crops, noting that CWR for temporary crops is 1.71 Mm^3 and for permanent fruit groups is 1.29 Mm^3. Table (3.21) shows these results.

Table 3.21: CWR of CSA Irrigated Area

Crop Type	Etc (m^3/do./season)	Eff. Rain (m^3/do./season)	CWR (m^3/do./Season)	Irrigated Area (do.)	CWR (m^3/Area/a)	CWR in Winter Season	CWR% in winter	CWR Summer Season	CWR% Summer Season
Palm Dates	1140	113	1026	1200	1231560	1231560	57	1231560	45
Grapes	732	52	695	20	13892	13892	1	13892	1
Banana	1037	117	917	45	41270	41270	2	41270	2
Corn (Winter Season))	353	106	246	244	60122	160160	7		
Corn (Summer Season)	866	2	864	244	210889			210889	8
Vegetables Green house (Winter Season)	282	92	190	578	109820	109820	5		
Vegetables Green house (Summer Season)	766	2	764	587	448703			448703	16
Regular Vegetables (Winter Season)	281	109	172	453	77871	77871	4		
Regular vegetables (Summer Season)	610	2	608	453	275333			275333	10
Medical herbs green house	926	115	807	650	524355	524355	24	524355	19
Total (one Season)				3190					
Total				4474	2993814	2158927	100	2746002	100

3.7 Main Results and Conclusions

Applying several calculations and computations in this chapter, interpretation of different results in previous sections relevant to soil texture, soil hydraulic properties and hydrochemistry, land use mapping, and CWR results, we concluded the following results:

- Total area of arable lands in the CSA is 15,253 donums with only 3,190 donums irrigable and 12,063 donums is not cultivated yet.

- Irrigated land is classified as low to moderate in terms of sodic-saline land and soil hydrochemistry composition. Leaching Requirement (LR) for this irrigated area is 0.35.

- Total water requirement for the irrigated area during the entire cropping season is 3 MCM/a; in winter season CWR is 2.16 MCM and in Summer season is 2.74 MCM.

- Another arable lands in the CSA cover 12,063 donums could be divided into three land zones: Zone 1, Zone 2 and Zone 3.

- Zone 1 area is Clay Loam soil with 4,000 donums; it is located in the east of the irrigated area. Its soil is low to moderate saline and sodic. Leaching Requirement in this Zone is 0.17.
- Zone 2 area is sandy clay loam with 3,375 dunom area. It surrounds the irrigated area from the south and north directions. It is classified as high salinize-sodic area, but it is not hazardous because its ECE is less than 4; it is only 0.5dm/while LR in Spring Group is 0.35.
- Zone 3 is extends towards the west direction of irrigated area. It is Sandy Loam texture in root zone with 4865 dunom area, LR is between 0.25 and 0.35,it is moderate saline-sodic soil but it is not hazardous.
- Water supply resources in the CSA are divided into four groups based on the salinity of water quality: the Spring Water Group with 0.65dm/EC of shallow wells, Group A (GA) with EC of 1.5dm/m; Group B (GB) with EC of 2dm/m, Group C (GC) with EC of >3 dm/m.

By reference to Annex 1 of Crop Salt resistivity of FAO,1985, and adapting soil salinity results and values, SAR and ESP in the CSA, and by taking into consideration water quality in the area, Agriculture Developing Scenarios in the three extension Zone areas could be categorized as follows:

- In the three Zones, there are two main Agricultural Developing Scenarios: Scenario 1 (S1) and Scenario 2 (S2). CWR for all scenarios in the three zones is 11.4 Mm^3.
- Zone 1 has one suggested scenario, i.e. Date palms planting scenario as it is applicable to different water supply qualities in the CSA. Therefore, irrigation by saline water groups (shallow aquifer wells) is good. In addition, soil salinity and crop salt resistivity meet the basic threshold with 100% yield. CWR for this scenario is 4.1 Mm^3.
- Zone 2 could be extended to 2,000 donums of medical herbs greenhouse technology. It is somehow sensitive to saline water and saline soil. The remaining area of Zone 2 could be planted by vegetable greenhouse group. Water supply is only by Spring Group; it needs 3.3 Mm^3 as CWR.
- Zone 3 has two suggested scenarios: one is grape planting scenario with 3,000 donums, and the rest is for date palms. CWR for this extension scenarios is 4 Mm^3.
- LR in Zone 1 is only 0.03, and is about 0.3 in Zones 2 and 3.

Table (3.22) shows all these concluded scenarios suggested for land availability, soil salinity classification and water supply resources quality.

Table 3.22: Different crop scenarios based on three Zones of land expansion.

Area												LR	Remarks
Area	Layer Thickness	Area	Soil	Ece (µs/m^2)	SAR	ESP%	Scena.1	Scena. 2	yield %	CRW (m^{3}/do.)	CWR/Area (m^3/Area.)		
Zon1	0-70		clay Loam	0.9	1	9.26							
	70-120	4000	Sandy Loam	3.8	1.7	21..62	Date Palm		100	1026.3	4105200	0.03	Water Supply by different water quality
Zone 2	0-70	2000	Clay Loam	0.5	0.9	9.11	Medical Green house		100	806	1612000	0.35	water supply from spring and GA
	70-120	1750	Sandy Clay Loam	0.5	1.8	30..37		Vegetables green house	100	954	1669500	0.35	
Zone 3	0-70	1865	Sandy Loam	0.65	0.9	14-21	Date Palm		100	1026.3	1914050	0.25	Spring group water supply
	70-120	3000	Sandy Loam	0.5	1.5	30-37		Grap	100	694.6	2083800	0.35	

Chapter 4

Water Budget and Water Resources System Analysis

4.1 Introduction

Water budget can be made by calculating available water and water potential on the one hand, and the current water consumption and future water demands, with a special focus on crop water requirements and climate change effects scenarios on the other. In CSA as well as LJV water quality may be classified into three main types: fresh water, brackish water and saline water and treated effluent. These three water quality kinds are distributed according to source. Auja Spring surface run off and deep aquifer wells form the fresh water resource in the CSA. Shallow aquifer wells form brackish water resource and treated effluents from Al-Bireh WWTP and Jericho Waste Water Treatment Plant (JWWTP) in Jericho City. Therefore, water resources analysis is based on available and water potential in terms of quality. Quantity is of high priority in the CSA.

In 2010, the Palestinian Water Authority (PWA) and MAO designed and approved a Water Resources Development Plan in the LJV based on JICA feasibility study done in 2007. Data is directly updated by PWA and MOA Data Bank. According to the above plan, designs are made for three terms: short, medium and long term plan. The plan focuses on developing water production from wells and springs rehabilitation, water harvesting from dams and large scale lakes, desalination technology, new resources and water import. It also includes treated effluent as a main water production source. According to this plane, expected water deficit by 2030 is about 60 MCM. Please keep in mind that Palestinians' water rights in the Jordan River Valley is a hot issue facing the increase of water production by this development plan.

This chapter will assess water budget in the CSA taking into consideration availability of water resources and water potential and analyzing actual water consumption based on current crop water consumption. Crops water requirements in the area should feed water resources analysis to fulfil future water demand in the agricultural sector. (Shawahna Field Survey in 2013).

4.2 Water Budget Assessment

This assessment divides water resources in terms of quality into fresh, brackish and treated effluent of different resources. Water availability from these resources in dry and wet years is the key step in the following analysis of these resources in actual current demands and future crop requirements. This analysis is based on the following.

4.2.1 Water Potential and Availability of Different Sources

Different water resources in the CSA are as follows:

Fresh water from (Auja Spring, Israeli deep aquifer wells, and flooding surface run of in Wadi Auja);

Brackish water of shallow aquifer wells and Lisan formation deep aquifer;

Treated waste water from Al-Bireh WWTP and Jericho WWTP.

In the context of water quality, fresh water in the area from Auja Spring and the Israeli deep aquifer wells are the main water resources for the supply of agriculture and domestic use in CSA respectively, while the brackish water from shallow aquifer have limitation in irrigation use relevant to crop types which need irrigation. On the other hand, importing water from outside CSA Catchment may be from a promised solution for water scarcity in the CSA. So, according to this situation, analysis of water resources should be as follows:

- Spring Group (Auja Spring**)** is the main fresh water resource in the CSA. It is classified as Karstic (Piston flow) Spring. It usually fluctuates regarding rain fall into dry or wet years. This spring in wet years has continuous discharge along the hydrological year, while in dry years it starts drought after mid-June causing disturbance to forming a plan and agriculture activities in the area. In this case rainfall historical data indicates the average storm runoff coefficient is 6.7%, and the average annual runoff coefficient is 3.5% of the average annual rainfall, while total flood in the Sub-Surface and Surface catchments was 10.27 Mm^3/year and 2.70 MCM/year respectively. (Abadi,2006)

−Rainfall quantity varies from year to year. In some dry years, as in1974, it was ≤300 mm and recorded about 1200 mm in some wet years like 1993. The average in 40 years is 647 mm/a. This variation directly affects the karstic aquifer, with a discharge of Auja Spring of about 2 Mm^3/a to 18 Mm^3 in wet years.

- This sharp behavior of the Spring discharge makes available water for irrigation more complex and weak management in high demand seasons, especially summer, when drought s starts.

- The rainfall, and as a result of the spring discharge, can be divided into four years' intervals in general, in which precipitation increases year by year until the fourth hydrological year after which it begins to decrease.

- It is suitable to have two scenarios for water potential and available water from the Spring discharge. One scenario the average discharge in dry years is 2 Mm^3/a and the other discharge is about 10 Mm^3/a. Figure (4.1) shows historical rainfall vulnerability.

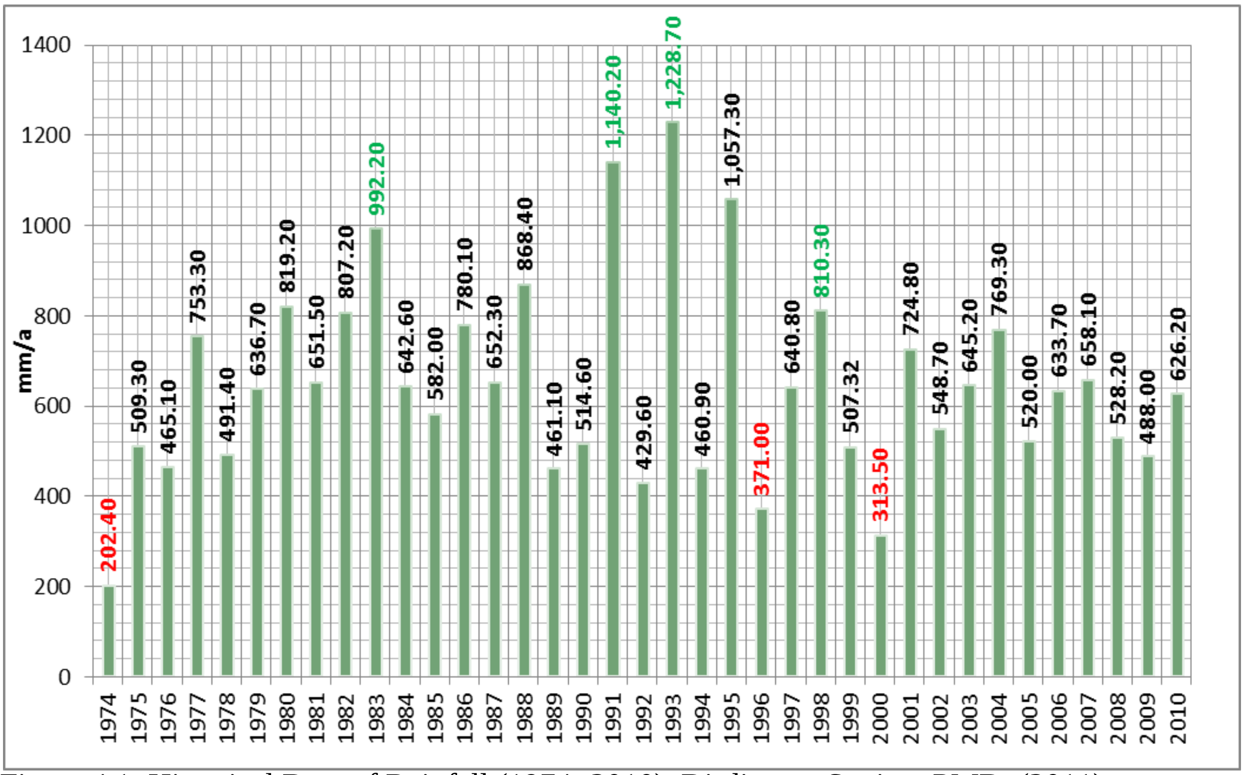


Figure 4.1: Historical Data of Rainfall (1974- 2010), Dirdipwan Station, PMD, (2011).

In 2008 JICA calculated recharge from surface water area by 9.2 Mm^3/a as indicated on the effective catchment area (Eff.C) which is 45.9% (133.9 km²) and average effective rainfall of 404.00 mm/a. In addition, Evapotranspiration in the Effective catchment area was 335.4 mm/a. Thus, in light of historical data and by the same approach the recharge from surface area = (Average Rainfall-Effective Evapotranspiration)*Eff.C/1000).

According to the calculation methodology, Wadi Auja has an average maximum rainfall of about 1,100 mm/year and the average minimum rainfall is 500 mm/a. This means that the average recharge in Eff.C is between 102 Mm^3/a in Wet years and 22 Mm^3/a in dry years.

In the last 20 years, recharge values have decreased to 23 Mm^3/a in the last 5 years and discharge amount decreased to 6 Mm^3/a. Throughout 40 years (1974-2010), average rainfall was 653 mm/year and average spring discharge was 8.61 Mm^3/a, while average recharge in the Effective Catchment (EC) was 42 Mm^3.

All results above conclude two water potential scenarios in deep mountain aquifer in every 5 years cycle, which have maximum average spring discharge of 12 Mm^3/year and minimum average spring discharge is 2.5 Mm^3/a. Figure (4.2) shows historical rain fall data and spring hydrograph along 40 years.

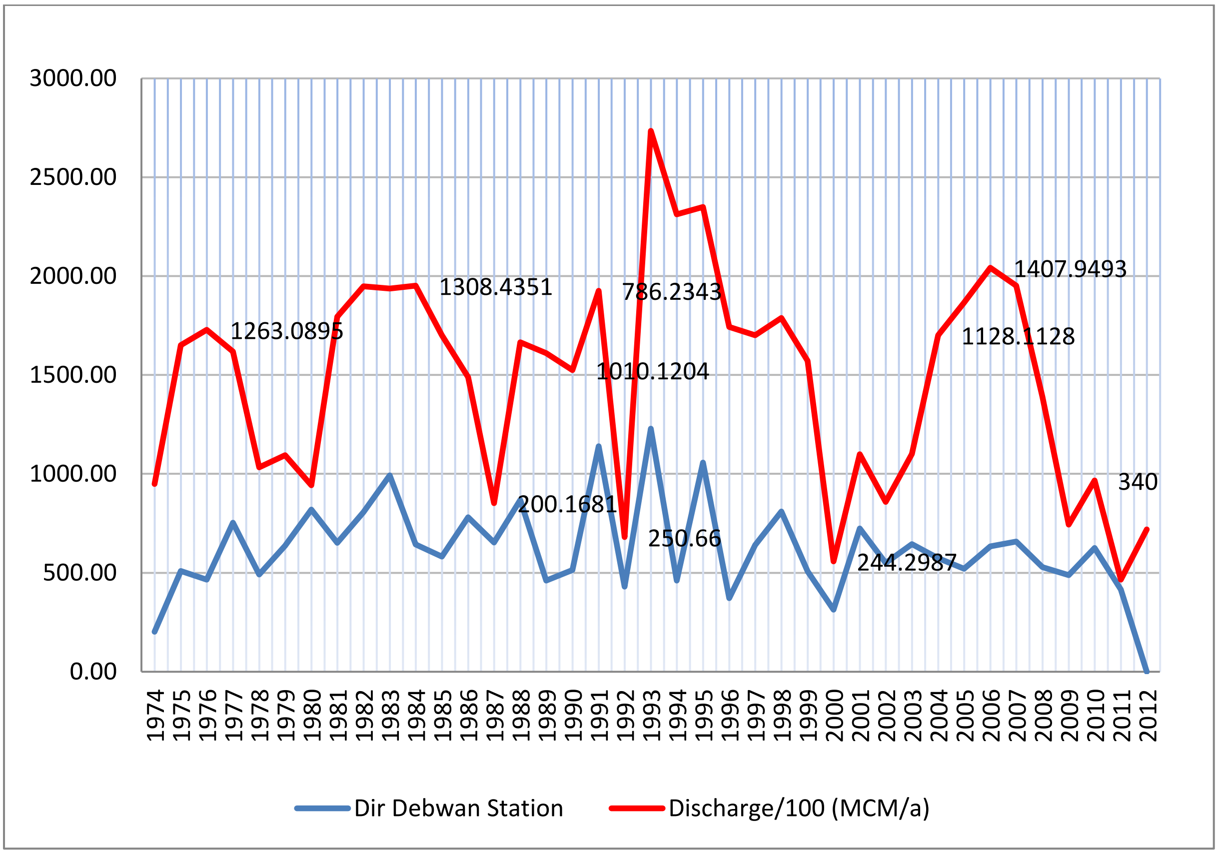


Figure 4.2:Auja Spring hydro graph in 40 years from Dir Debwan rainfall station, PWA, PMD, (2011)

Auja Spring discharge water flow is well known along Wadi Auja at about 700 m long and then it is conveyed by Auja canal which is an open cement canal of 12 Km long including all canal branches for water distribution in the irrigable lands.

Water loss during running into the Wadi has been calculated by salt dilution method. Sodium chloride was diluted in two main sites in the Wadi: the first one was 150 m away from Auja Spring and the second site was at the end of Wadi. Electrical Conductivity was measured every 5 seconds and was calipered by a curve with gradual increase of sodium chloride percent.

Figure (4.3) shows measurement sites; it is not time series measurement but only rough measurement to have a clearer picture in terms of losses and by lateral infiltration into the Wadi before conveying the Spring water by Auja canal.

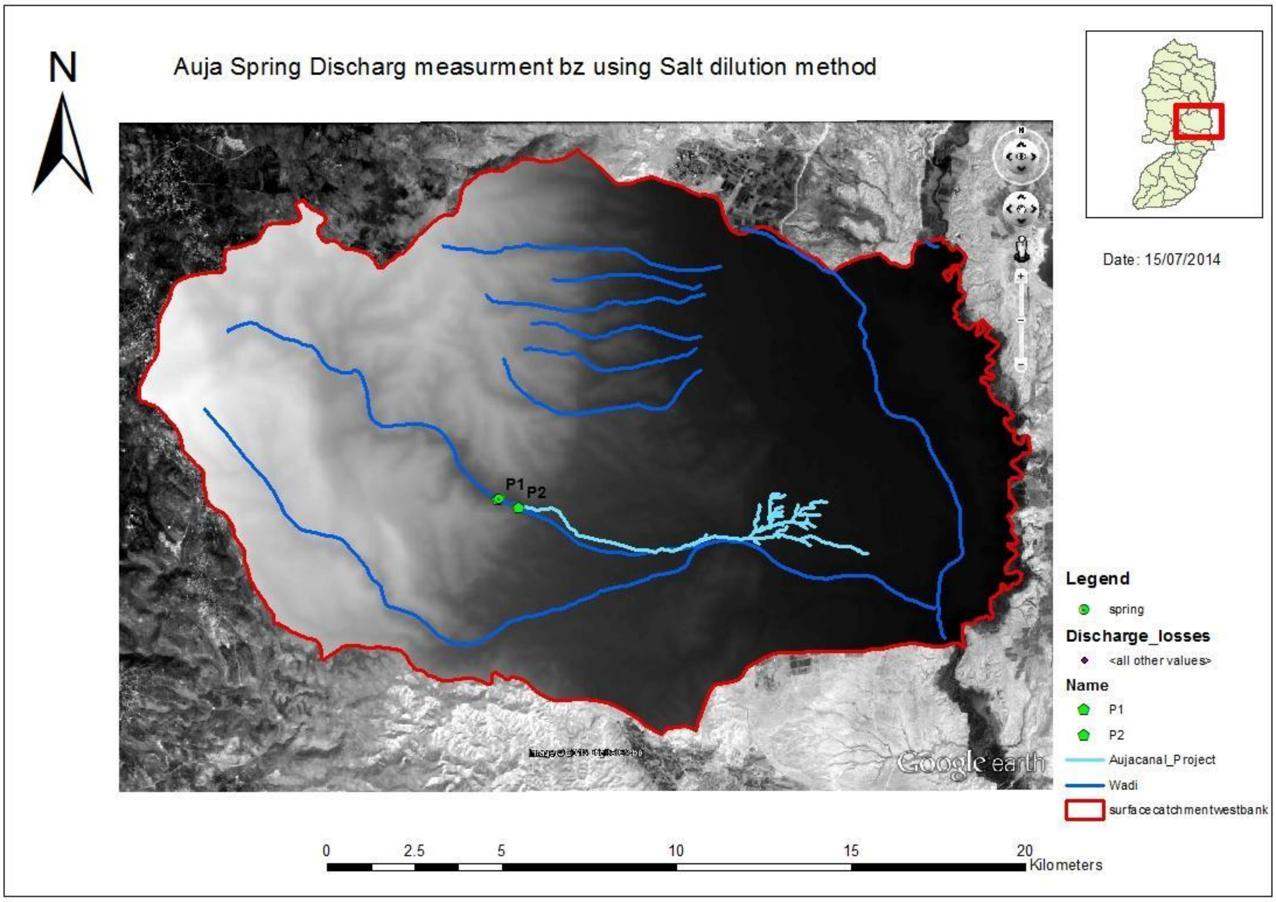


Figure 4.3: Discharge measurement site in Wadi Auja using Salt dilution methods

Calibration protocol, Figure (4.4), was used to calibrate fresh water by 600 µS/cm. By Electrical conductivity method, the salt solution has 10 gm/L of sodium chloride added gradually by 0.5 ml each time during the calibration process.

Calibration protocol	***Please enter data only in yellow fields!!!***					
Initial Volume (ml):	250		**Cal.fact:**	**0.529081**		
Vol. added salt solution (ml):	0.5		R^2	0.999977		
Conc. added salt solution (g/l):	10.00000		Res.max (%)	0.60		

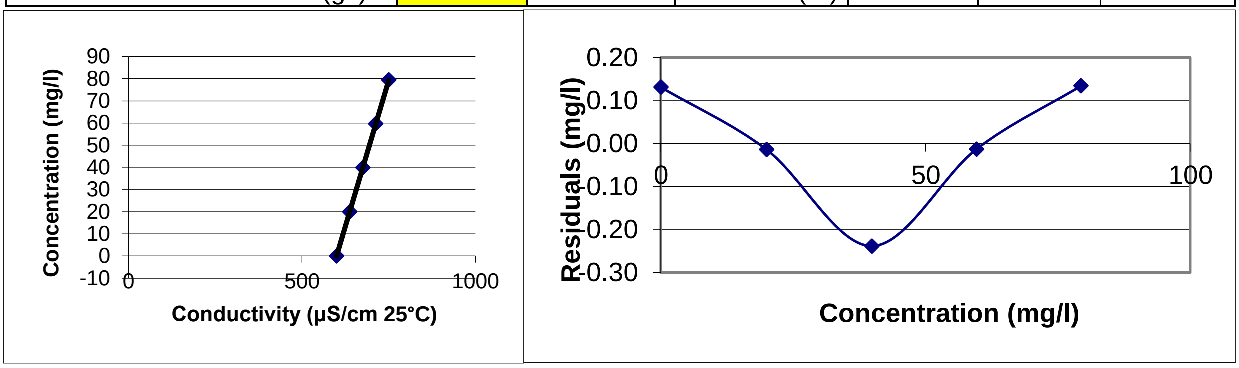


Figure 4.4: Calibration Curve of Auja Spring, Experimental Measurement of Spring discharge, June, (2013)

Calculating Spring discharge with salt sudden injection along the Wadi takes about 20 minutes in each point at the same time. Step time recording is 5 seconds and was measured in June 2013. In the start of drought season, the Spring discharge started by 357 L/s at the upper site and finished with a discharge of 195 L/s. In this case, discharge loss along Wadi Auja was 45% of total discharge. However, the real remaining discharge conveyed by the cement canal was 55% of Auja Spring discharge, see Table 4.1 illustrates the results.

Table 4.1: Integration measurement with sudden injection, Benischke, R. &T. Harum (1984)

Measuring site:	Auja Spring
River:	Auja Spring
Date:	5.06.2013
Time (Start):	10:50
Team:	Ayman Shawahna
Gage height (start, cm):	10.00
Gage height (end, cm):	25.00
Distance (m):	150.00
Tracer mass M (kg):	11
Duration (min):	21.07
Time interval *INT* (sec):	5
Calibration factor *CAL*:	0.529081
Number of measurements *n*:	422
Conductivity background C_0 (µS/cm):	600.0
Conductivity peak (µS/cm):	20000.0
Concentration peak (mg/l NaCl)	10264.2
Integral conductivity:	272600.0
Integral conductivity-background:	19400.0
Discharge *Q* (l/s):	**357.23**
Measuring site:	Auja Spring
River:	Auja Spring
Date:	5.06.2013
Time (Start):	10:30
Team:	Ayman Shawahna
Gage height (start, cm):	10.00
Gage height (end, cm):	25.00
Distance (m):	670.00
Tracer mass M (kg):	11
Duration (min):	18.72
Time interval *INT* (sec):	5
Calibration factor *CAL*:	0.529081
Number of measurements *n*:	375
Conductivity background C_0 (µS/cm):	606.0
Conductivity peak (µS/cm):	6011.0
Concentration peak (mg/l NaCl)	2859.7
Integral conductivity:	262731.0
Integral conductivity-background:	35481.0
Discharge *Q* (l/s):	**195.32**

Estimated water loss by Auja Canal is about 5% of total discharged water (Chapter 2, Section 2.5.5). Farmers received 6.5 Mm^3 in wet years and 1.3 Mm^3 in dry years.

The main concluded results of water supply analysis of Auja Spring is summed up in Table (4.3). Two main scenarios based on dry and wet years have been divided into two time intervals and by 5 years' interval of each period. It is like decreasing by 5 years based on dry climates during the 5 years interval and then 5 new years in wet conditions. The total cycle is ten years and should be considered in water management strategies in the CSA. Basically, the untapped water of spring water forms about 5% of water potential of the spring discharge. Water loss by infiltration is 45%. Table (4.2) shows Auja Spring potential and water availability scenarios in dry and wet years

Table 4.2: Auja Spring Potential, Availability and losses

	Recharge (Mm^3/a)	Spring Discharge(Potential) (Mm^3/a)	Available water from Auja Spring (Mm^3/a)	Water losses from spring (Mm^3/a)
Average Wet year	102.00	12.00	6.50	5.50
Average Dry year	22.00	2.50	1.30	1.20
Average	42.00	8.61	4.30	4.31

Auja Spring water quality has been classified as fresh water (Spring Group) which completely meets irrigation standards with all kinds of crops. There are no sensitive crops among this water quality, neither is there a big difference in salinity between water fluctuation in winter and a drought season. Salinity for example started by 652 µs/cm in February 2007 and decreased to 563 µs/cm in June 2007. This provides high tolerance for the irrigation using this water quality in the CSA. Also, Sodium concentration and salts are relatively low with no threat from soil salinity build up or crop sensitivity among this kind of water quality.

Table (4.3) shows water quality of Auja Spring

Table 4.3: Water quality of Auja Spring, Shawahna, and 2007-Al-Quds University Labs.

Date	Temp	pH	EC	Ca2+	Mg2+	Na+	K+	NH4+	Cl-	HCO3-	SO42-	NO3-	PO43-
	˚C		µS/cm	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L	mg/L
29/02/2008	20.5	7.2	652.0	88.2	41.2	55.0	3.3	0.0	42.5	497.1	30.0	21.7	0.2
20/03/2008	20.5	7.3	650.0	100.9	34.3	14.4	5.9	0.0	47.5	402.0	27.0	23.0	0.2
09/05/2008	21.2	7.5	595.0	114.5	56.3	68.5	2.5	0.0	51.9	215.5	20.0	19.7	0.1
26/06/2008	21.4	7.3	563.0	20.1	0.6	9.6	N.A	N.A	70.9	N.A	16.0	20.2	0.3

Deep Wells Group in the CSA (Israeli Wells)

According to Guttman (2007), the first well drilled in the Spring vicinity was Auja 1 (18-15/011) which was drilled in 1964 by the Jordanian authorities to a depth of 288 meters. Years later, the Israeli authorities further deepened the well to 536 meters. In 1976 Auja–Na'aran 2 well (18-15/011) was drilled to a depth of 615 meters to replace the old Auja 1 well (the Hydrological Service data). In 1978 the Auja–Na'aran 3 (18-15/012) well was drilled to a depth of 738 meters and in 1980 the Auja–Na'aran 4 (18-14/001) well was also drilled to a depth of 650 meters. Additional wells like Jericho 5 (18-14/003), Rimonim 1 (18-15/008) and Pazyel l9 (18-16/010) taking advantage of the lower Cenomanian aquifer were drilled in nearby areas (Rimmer A., 2011). Figure (4.5) shows these Israeli wells in the Auja catchment, 2011).

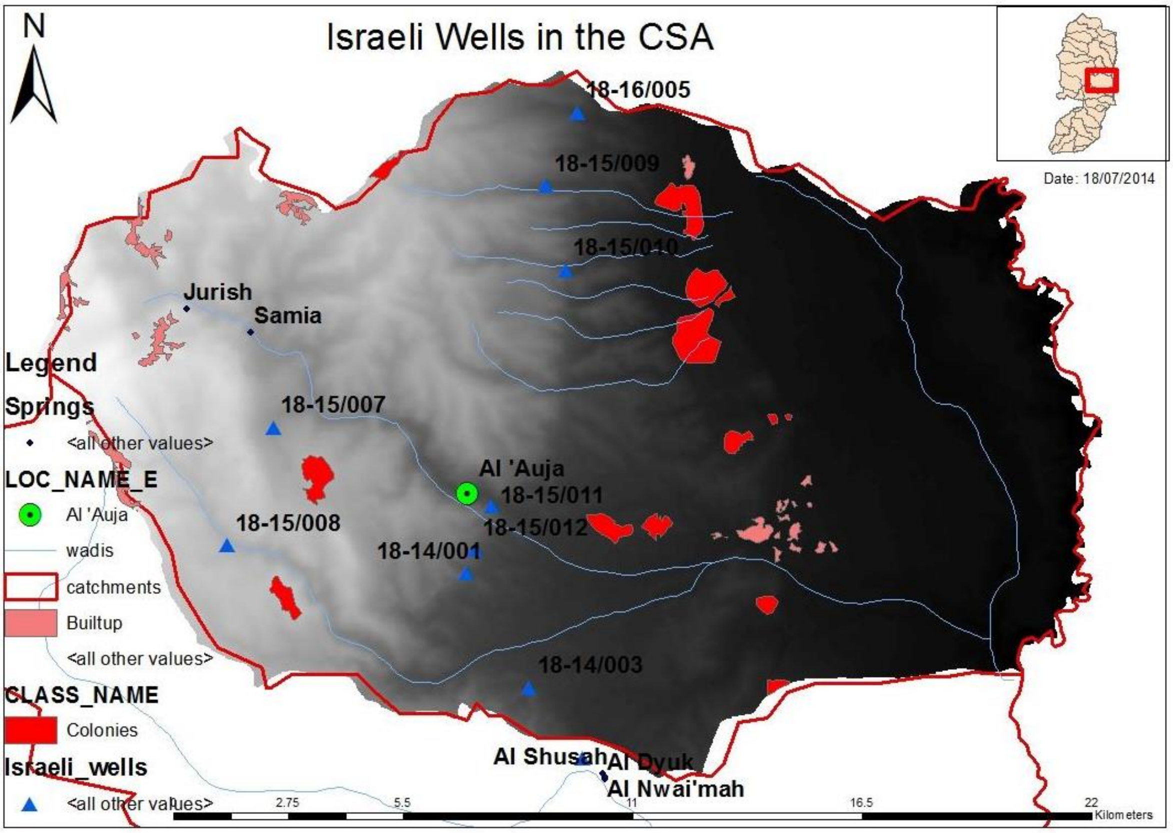


Figure 4.5: Israeli Deep Wells in the Auja Catchment

The data presented in table (4.4) shows the mean abstraction rate of nine Israeli wells in the Auja catchment (PWA, Hydrological Data 2000). There are three main well groups in the lower of the Upper aquifer in the Auja Catchment. The first is Ein Samia group, which includes the Remoneem and Kochave Hashar wells. The annual mean abstraction is about one million cubic meters. The second group is Pazayelgroup which includes Pazayel 6, 8 and 9. Abstraction rate of this group is 4 Mm^3. The third group is Auja group which comprises Na'aran 2, 3, 4 and Jericho 5 wells and has an annual abstraction rate of 5 Mm^3/a. Total annual abstraction rate mean of all Israeli wells is about 10 Mm^3. In general, abstraction of the majority of these wells is used for Israeli colonies in the catchment area. At the same time, water quality of these groups classified as fresh water with 237 mg/L supplied to Palestinians by these Israeli wells in the CSA is of total dissolved solids (TDS). Chloride concentration is about 30 mg/L except for Pazayel 6 and Jericho 5 which have more than 200 mg/L of chloride concentration, while sodium concentration is about 20 mg/L in all wells group.

Table 4.4: Israeli Wells in Auja Catchment, Pumping and Wells Depth, PWA,2000, *Guttman, J., 2007,** Rimmer A., 2011.

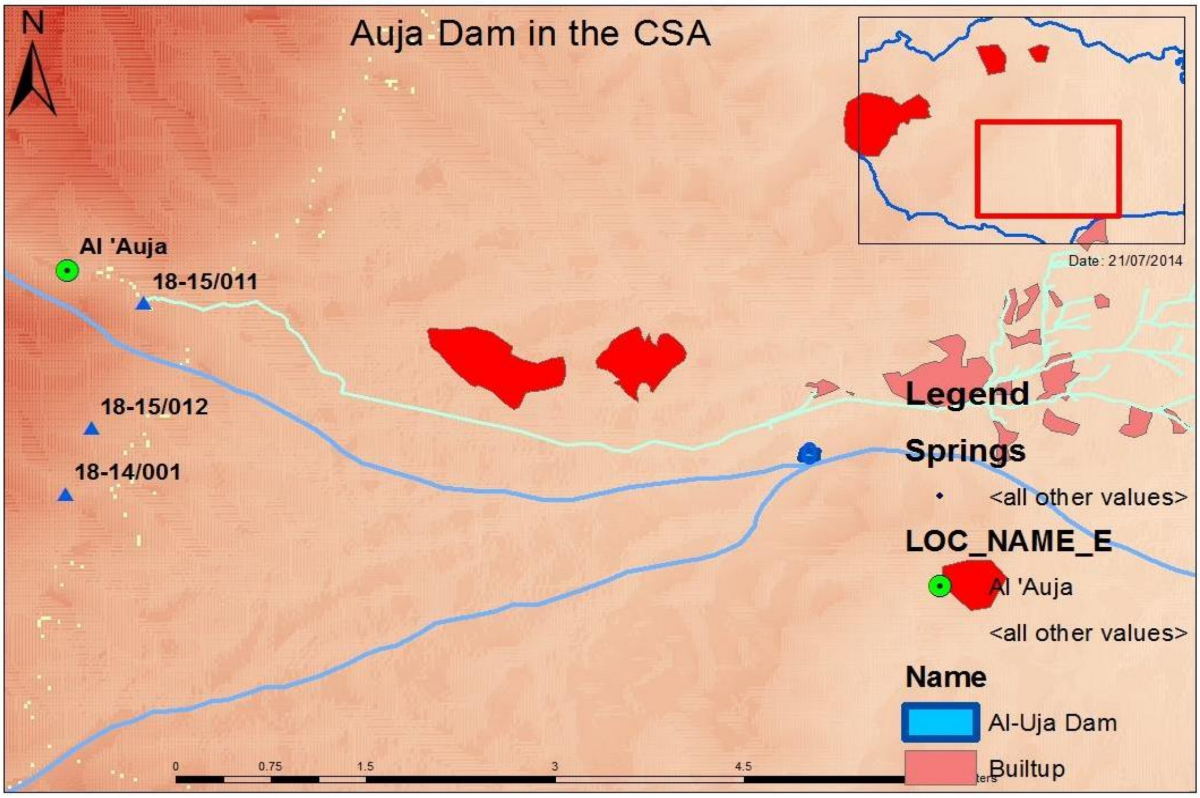
Palestinian Well ID	Israeli Well Name	Well Depth (m)	Mean Abstraction (1980-1999) (m^3/a)
18-15/007	Kochave Hashahar	758	351283
18-15/008	Mekerot(Remoneem)	**747	682636
18-16/005	Pazayel No.6	X	1617610
18-15/009	Pazayel No.8	432	923418
18-15/010	Pazayel No.9	680	1535075
18-15/011	Na’aran No.2	*615	706,317
18-15/012	Na’aran No.3	*738	961,392
18-14/001	Na’aran No.4	*650	1,476,883
18-14/003	Jericho 5	**731	1,538667
Total			**9,793,281**

Run off and Flood Flow Water in Wadi Auja

Surface run off precipitation coefficient in the Eastern Aquifer, which includes the CSA, is calculated by 3.5%. (Weinberger G., 2012) Surface run off and flood flow in Auja catchment has been discussed in Chapter 2, Section 2.2.4. This flood flow along Wadi Auja has 3 to 11 MCM between dry and wet years respectively. In this manner, for estimating actual water potential in the case of Auja catchment, infiltration and evapotranspiration should be taken into consideration as main key issue of potential estimation. Therefore, the estimated loss by infiltration and evapotranspiration actually formed 90% of total flood flow which increased actual potential to 1.2 Mm^3/a.

In Wadi Auja, the Dam Reservoir was constructed by MoA in 2012, (Italian Cooperation, OSRO/GAZ/008/ITA, and 2011-2012). This Auja Dam has 0.600 Mm^3 storage capacity. Originally, the dam was designed for collecting the base and flood flow in Wadi Auja. Auja Dam is operated to convey stored water into piping lines instead of Auja canal to the irrigable lands in the CSA. According to MOA Planning Directorate, 20011, the Dam project will involve laying 6.4 km long of closed irrigation pipeline to replace the old earth/concrete water channel. The construction, in addition to training farmers on the best irrigation management, will reduce agricultural water loss by 5% which is equivalent to 120,000 m³ of additional water. The estimated total water loss is 15% from its collection in the dam to its application to the land (360,000 m³). The 15% estimated lo3ss is from evaporation in the dam reservoir and irrigation earth pools (5%). The concrete main water canal (5%) and the secondary earth canals (5%). Therefore, the replacement of the concrete main canal with a closed water pipeline will save 5% of the total water which equals 120,000 m. By establishing the Dam project, Palestinian farmers in the CSA hope to increase irrigable lands and crop seasonal planning in the area. The Dam project aims to extend the irrigable lands by 240 donums. In addition, there is a second phase which will raise storage capacity by 1.6 m³ /a. Figure 4.6 shows the Dam site location.

Figure 4.6: Auja Dam Site in Wadi Auja



Shallow Aquifer Wells in CSA (Auja Palestinian Wells Group)

There are 12 Palestinian wells in Shallow aquifer. (Table 4.5) Only nine of them are still operating. Their current condition is as follows:

- Water quality may be divided into two quality intervals; one is from 1.5 dS/m - 2 dS/m and another interval starts from 2 dS/m to 3dS/m. Some wells reach 7.6 dS/m.

- Total potential of these wells is 1.3 Mm^3/year but the average water available (actual abstraction) is 0.8 Mm^3/a.

- Salinity of Shallow aquifer wells water increased in the last 10 years due to rising water table level from 2 to 5 meters.

- Some of these wells do not work now, wells NOS. 19-15/013 and 19-15/015 because of water table depletion and the high salinity rate.

Wells' depth ranges from 50 m to 100 m. This depth is not enough to have maximum abstraction capacity of most of these wells.

Table 4.5: Palestinian Shallow Aquifer Wells in the CSA.

Code	Depth	Work	Max. Abstraction (m^3/month)	Abstraction capacity (m^3/hr)	EC (dS/m)	Avg. Abstraction (m^3 /a)
19-14/001	59	Yes	74000	80	2.15	140274.90
19-15/005	108	Yes	65000	50	1.46	65348.33
19-15/007	105	Yes	164000	100	1.54	128814.80
19-15/008	102	Yes	122000	90	2.45	48000.00
19-15/010	102	Yes	88000	50	2.82	69621.00
19-15/011	90	Yes	128000	50	1.75	271.02
19-15/012	103	Yes	133000	100	1.41	37264.39
19-15/015	65	**No**	76000	60	***7.6**	93275.00
19-15/023	50	Yes	94000	50	2.10	103220.77
19-15/019	100	Yes	130000	100	**6.58**	120000.00
19-15/028A	90	**No**	80000	65	(X)	(X)
19-15/013	100	**No**	70000	80	(X)	63025.00
Total			**1,224,000**			**799,494.21**

Over the years 2000 to 2011, the average abstraction decreased to 0.5 Mm^3, figure 4.7

This decrease affects irrigable land area in the CSA and indicates water quality deterioration of different Shallow aquifer wells. In this manner, about 50% of irrigable lands are planted usually with vegetables.

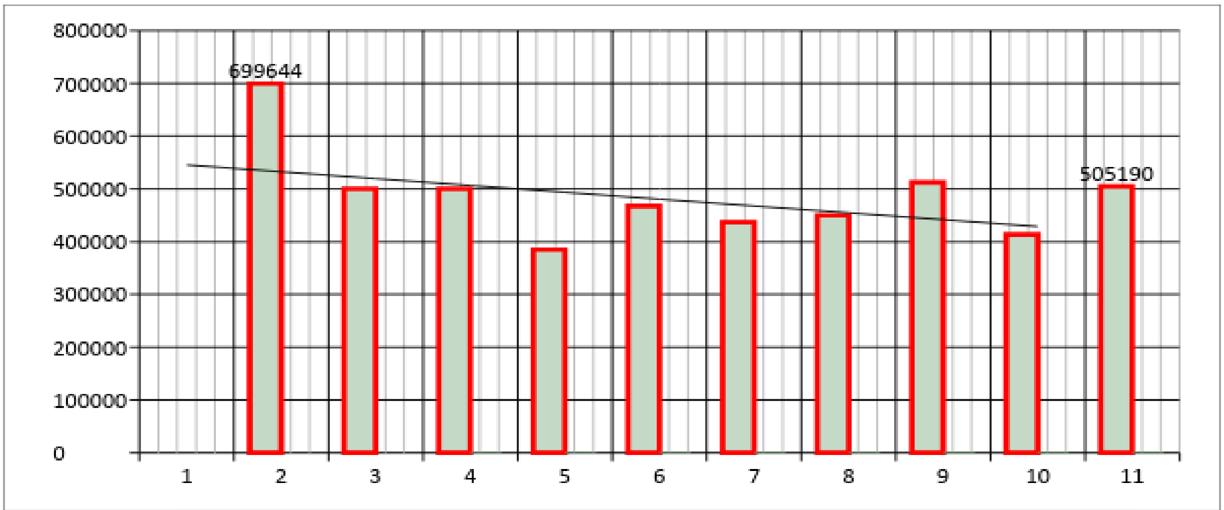


Figure 4.7: Average abstraction of shallow aquifer Auja wells during 2000-2010.

They are classified as moderate to high sensitive to brackish and saline water causing limited use of this brackish and saline water.

Saline and Brackish water from outside CSA (Dead Sea [DS] Springs Group)

The most important OPT Springs are located along the Jordan Valley area and along the shoreline of the Dead Sea (PDW, 2009). Numerous springs exist along the western shore of the DS and their annual capacity stands at 107 Mm^3. In general, discharge levels of these springs decrease as they run southward with significant variation in their salinity levels. (Elisha, R., 2006) The surface area is approximately 800 km^2 extending from the eastern slopes of Jerusalem anticlinorium through the Marsaba anticline in the west of the Jordan Valley and the Dead Sea in the east, including the Spring Complex of Ein Fashkha in the north-west of the Dead Sea (Hassan, A. J., 2009, Figure 4.8).

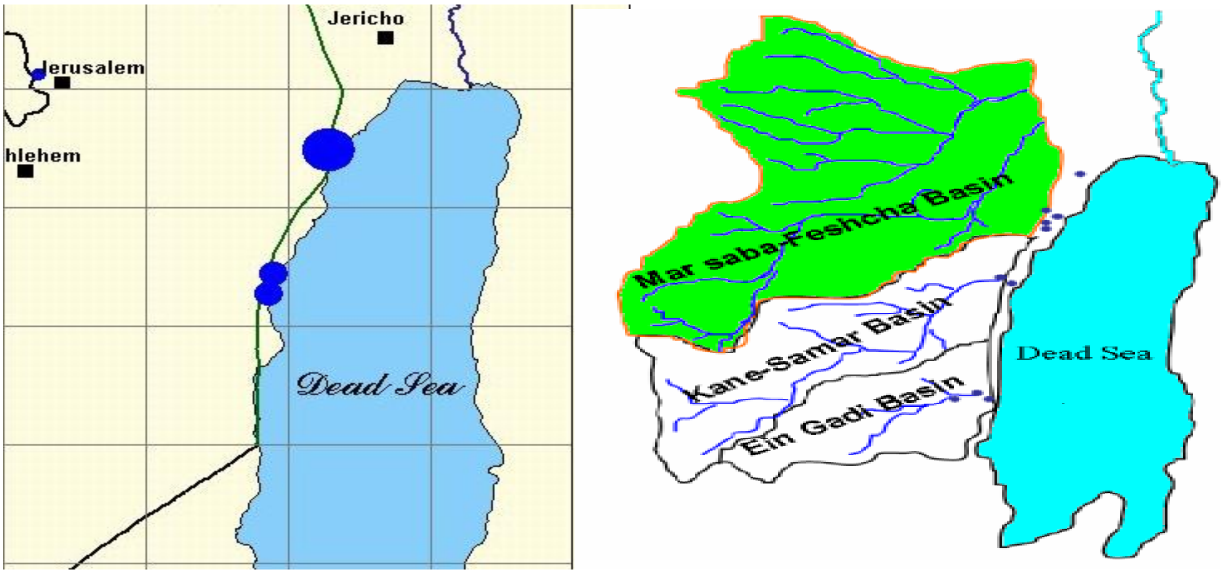


Figure 4.8: Dead Sea Springs of Occupied Palestinian Territory (oPt), PWA,(2009)

These springs are considered as a final southeastern outlet for the Eastern Basin and are located along the western shoreline of the Dead Sea within the political borders of the West Bank**.** The Spring's water flows eastward to the Dead Sea with an annual average flow of 100-110 million cubic meters of brackish water (PWA,2009**).** Actually, there are five spring groups in the Dead Sea shoreline: Fashkha, Turaba, Ghweir, Gazal and Tanur Spring. In this context, Israeli data mentioned that the flow rate of these springs is from 250 L/S (Kedem Spring) with 10.3 Mm^3/a, and about 40 Mm^3/a and 1,500 L/S of Kane and Samar Spring/Fashkha Group). In addition to sukKim Spring supplies 70 Mm^3/ year and 2500L/s. All references and surveys stated that Fashkha Spring group provides about 80 Mm^3/a average discharge. Figure (4.9) illustrates different Dead Sea spring groups according to Israeli data.

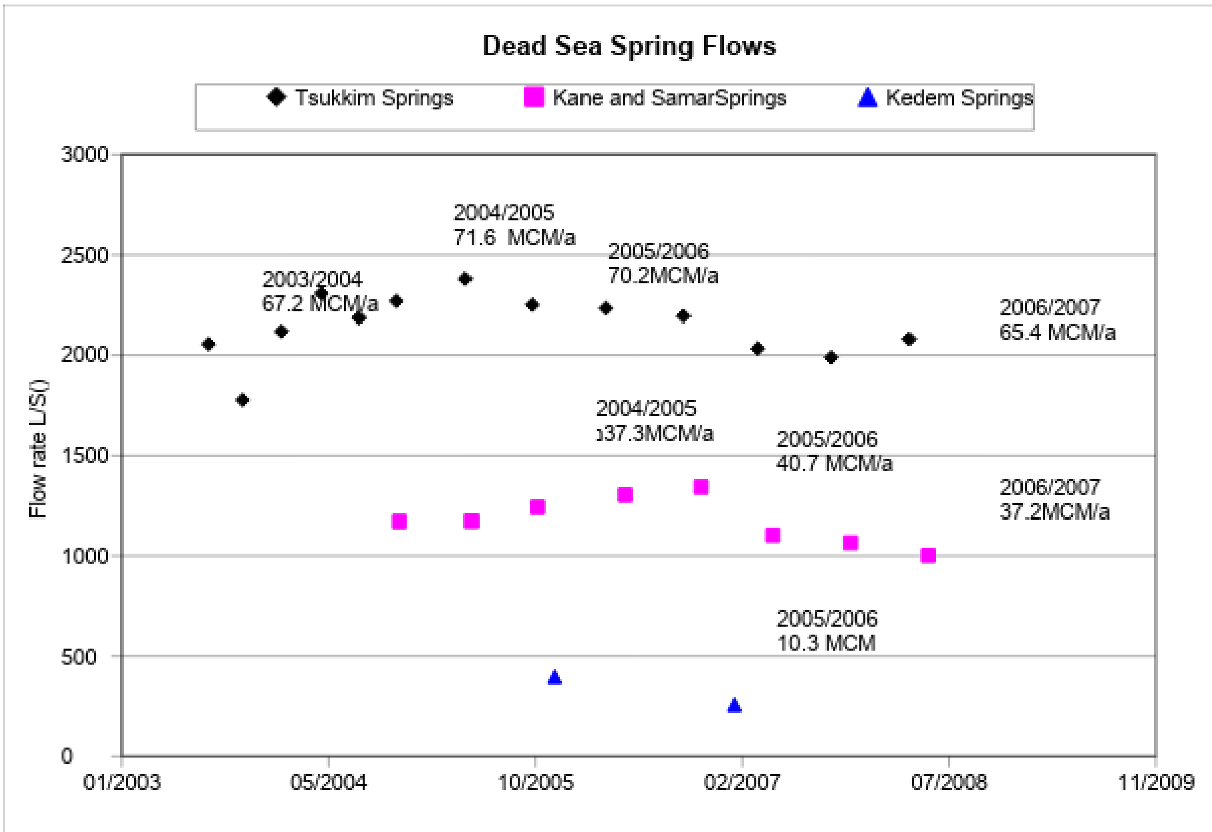


Figure 4.9: Flow rate and spring discharge of Dead sea spring groups during (2003-2009), PWA Data Base, (2011).

The quality of Fashkha springs water is classified as brackish or saline. Jawad Hassan research in 2009, Figure (4.10), analyzed ten springs and two wells in Marsaba Fashkha Spring groups and concluded the following:

The average EC ranged from 4mS/cm to 13 and in wells it was between 4-18 mS/cm.

Chloride concentration was between 1,500 to 2,000 mg/L in Springs Group and between 2,600 to 6,400 mg/L in Fashkha wells. The results classified Fashkha ground water as saline water.

The question is if this water quality could be utilized for irrigation of some salt resistance crops such as palm date trees.

Another question relates to the feasibility of this saline water in case of desalination and the importing process to the CSA in Auja catchment.

Based on the high salinity of Fashkha springs, PWA suggested in 2009 several options for utilizing this water some of which include the Reverse Osmosis (RO) desalination plant. Another suggestion called for drilling deep wells in the area at about 700 m depth for utilizing this underground water in the Dead Sea shorelines in the Palestinian area.

The last remark in this regard is that Palestinians have to make long and hard negotiations with the Israeli side to allow importing or utilizing this water.

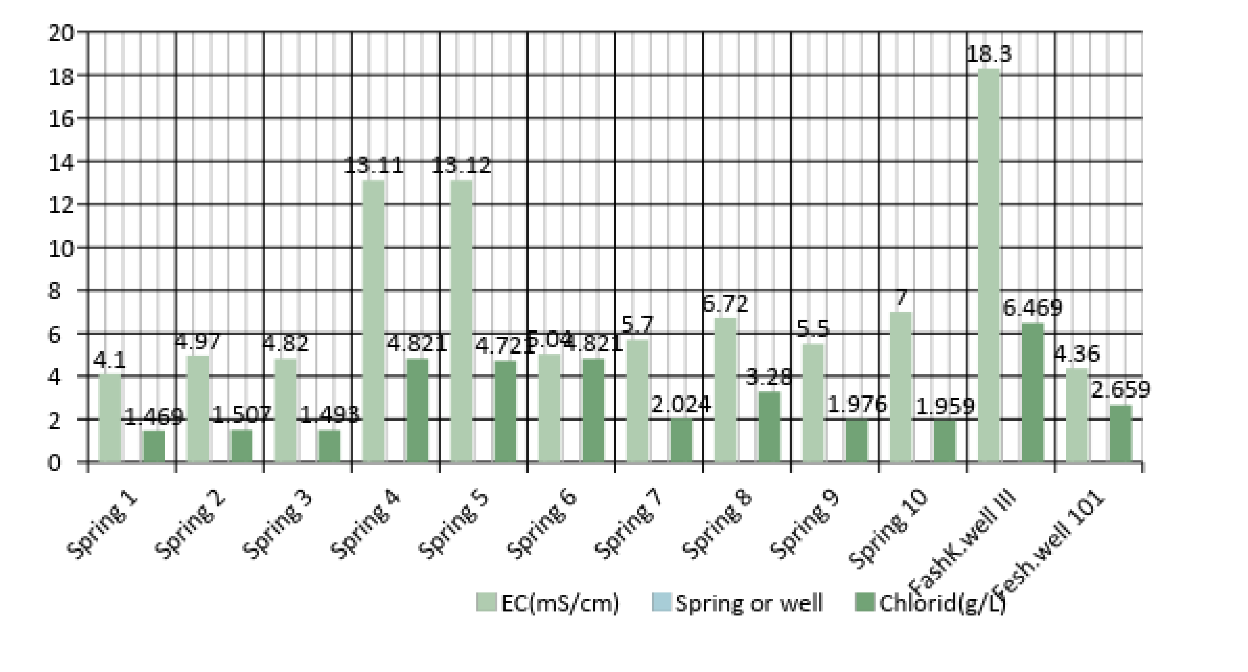


Figure 4.10: Fashkha Springs and wells Salinity in Terms of Chloride and EC.

Treated Waste Water

Treated waste water was addressed in Chapter 2, Section 2.2.4. There are two main sources of effluents which were treated outside Auja area: Al-Bireh Waste Water Treatment Plant (BWWTP) and Jericho Waste Water Treatment Plant (JWWTP).

BWWTP

Al Bireh Wastewater Treatment Plant is located at Wadi Al-Ein (East of Al-Bireh City) over 2.2 hectares including reserve area for future expansion. The plant was constructed in 2000 and cost US$ 15 million. The treatment system is extended aeration with mechanical solids handling, simultaneous aerobic sludge stabilization and sludge drying by Belt filter press. MEDAWARE, (2004). BWWTP treated waste could be described as follows:

- It confirms to Palestinian Standards (PS No.743.2003, Appendix 10.5) of treated waste water use for irrigation.

- Al-Bireh WWTP treated an average of 4,360 m^3/day with an average of 2,030 kg BOD/d in 2003. The facility is considered one of the most recent plants in the Middle East region. It has very good removal efficiency compared with the adopted effluent guidelines; 20 mg/l BOD5 and 30 mg/l TSS and Palestinian Standards as well.

- Treated effluent potential is about 1.85 Mm^3 yearly with a capability to double the water production by implementing the second stage which is proportional to the inflow quantity. In 2015, estimated treated effluent was 3 Mm^3/a , and in 2025 it will be 4.2 Mm^3.

- The average daily flow effluent is 5,000 m^3/day in dry weather and 11,500 m^3/d in wet weather. Regarding MOA's recommendation, the ideal crop selection for irrigation by this technology of treated waste water are olive trees and wheat. At the same time, it could be used for different kinds of orchards and other crops with some limitations.

Table (4.6) illustrates the daily average concentration of treated effluent over the year in each month, in addition to BWWTP high treated efficiency.

Table 4.6: Daily average of treated effluent in terms of quantity and treatment efficiency, MEDAWARE, (2004)

Raw Sewage	Unit	Jan.	Feb.	March	April	May	June	July	August	Sept.	Oct.	Nov.	Dec.	Avg.
Chemical and physical characteristics														
Q-DWF	(m^3/d)	4296	7447	6915	4682	3812	3628	3384	3552	3479	3474	3473	4186	4361
TSS	%	99	99	99	99	99	99	99	99	99	99	99	99	99
COD	%	91	-------	82	83	92	91	91	90	91	91	92	91	90
BOD	%	98	98	------	------	97	------	------	------	98	98	99	98	98
TN	%	71	69	53	54	53	53	65	------	70	59	80	82	64
PO4-P	%	56	49	43	46	54	52	43	------	42	42	52	49	48

Jericho Waste Water Treatment Plant(JWWTP):

JWWTP is located in the south east of Jericho City. It was constructed during the last two years (2012-2014) by Japanese aid by USD 32. Construction started in June 2012. The project has the following features:

- Secondary treatment effluent which produces agro-Industrial water quality; the effluent quality is similar to BWWTP effluent quality.

- Maximum capacity is 9,800 m3/day which means 3.6 MCM/day and 25.4 km trunk sewer pipes in Jericho City. The trunk sewer pipes are 29.5 KM and secondary branches of 10.5 km. There are a second and third sewer pipes network phases for future scenarios in the implementation plan as in Figure (4.11).

Figure 4.11: JWWTP site location sketch design of JWWTP including sewer pipes of future phases (JICA, PWA, Jericho Municipality (JM), 2014).

(C) Auja Waste Water

Al 'Auja lacks a public sewerage network with most of the town residents using cesspits as their main means of waste -water disposal. Nowadays, and in last June (2014), Auja Municipality council announced a construction tender for a sewerage network for Auja Village .

Based on the estimated daily per capita water consumption, the estimated amount of waste water generated per day is approximately 325 cubic meters, equal to 118 thousand cubic meters annually. At individual level, it is estimated that the per capita waste water generation is between 25 to 80 liters per day. The waste water collected by cesspits is discharged by waste water tankers directly to open areas or nearby valleys without any regard for the environment. Here it should be noted that there is no waste water treatment either at the source or at disposal sites which poses a serious threat to both environment and public health. (ARIJ, 2012) In this manner, and according to several estimations, percentage of waste water discharge from domestic use is about 80%. This means that the waste water discharged quantity of Auja Village is more than 118,000 m^3/a. According to the annual domestic consumption it will be 180,000 m^3/a.

4.2.2 Water Consumption and Water Demand by Sector and Water Source

In CSA agriculture is the main water consumption sector in the area in addition to domestic water use. This analysis analyzed consumption based on sector and water source which supplied the main sectors in the CSA.

Domestic Use in Auja Area

In CSA, there are 4,808 residents in Auja Village (PCBS, 2013). In addition, there are about 400 persons classified as Bedouins who live around Auja Spring (Ras Al-Auja and Wadi). Auja Municipality Council (AMC), 2013. Auja residents are provided their domestic needs through an Israeli water company (Mekerot), which abstracts water from deep wells aquifer in Auja area. On the other side Bedouins provide water for domestic and livestock from Al Auja Spring., However, residents' water consumption in Auja village is illustrated in Table (4.7) as follows:

- Total annual water consumption by residents is 367,398m^3 (AMC, 2013).
- Water duration consumption could be divided into two cycles, winter and summer cycle.
- In winter, from September till the end of March, the monthly consumption is about 26,000 m^3 and over the six month it is 165,942 m^3. In summer, the total consumption in six months is 210,456 m^3, a monthly average of 35,076 m^3.
- The large difference in water consumption between summer and winter indicates other uses of water consumption relative to house and garden crops, especially regular vegetables.
- Loss of provided water through networks has been estimated by 30% of total provided water. This means that only 257,178 m^3/a are received, or 140 L/d/cap.

According to World Health Organization (WHO) standards and regulations, the maximum capita water consumption for domestic use is 120 L/day. This assumption means that the real domestic water consumption in Auja Village is 219,000 m^3/a while 38,178 m^3/A were used for house gardens irrigation.

Table 4.7: Monthly Domestic Water Consumption in CSA, AMC2013

Date	Received Water (m^3/month)	Winter received with 30% losses	Summer Received with 30% losses	Total water received (m^3/a)	Maximum Total water demand (m^3/a)
Dec.2012	24673	17271.1			
Jan.2013	17914	12539.8			
Feb.2013	20554	14387.8			
Mar.2013	26325		18427.5		
Apr.2013	29431		20601.7		
Ma.2013	31916		22341.2		
Ju.2013	37673		26371.1		
Jul.2013	49193		34435.1		
Aug.2013	35918		25142.6		
Sep.2013	30446	21312.2			
Oct.2013	31414	21989.8			
Nov.2013	31941	22358.7			
Total	**367398**	**109859.4**	**147319.2**	**257178.6**	**219000**

On the other side, 400 Bedouins who live at Auja Spring area consume 15,085 m^3/a for domestic purposes and 82,855 m^3/a for livestock (GVC, FAO, 2011) from the spring's water.

Crop Water Requirement in the CSA

In general, agriculture water consumption is estimated by 70% of total water consumption all over the world and so is in oPt. In Jericho and the Jordan Valley Governorate, consumption exceeds 90% of total available water. The same case is for the CSA (Auja Catchment), the agriculture sector is considered the dominant sector in water consumption in the area. Furthermore, crop water consumption in the CSA is affected by irrigable lands area between wet and dry years which increases/decreases irrigable lands based on precipitation distribution and percent. This current situation in the CSA leads for appearing new planting crops in the area like medical herbs green house. On the other hand, other crops like banana fruit disappeared. Banana planted area in 2007 was 966 donums (PARC, 2007), but decreased to only 45 donums in 2013. This degrease points to the decision-makers as part of the problem since they are supposed to provide real solutions for Agriculture Development Strategies while taking into consideration the water availability in terms of water quality and quantity. Therefore, crop water requirement in the area was investigated to address the following concerns:

In crop water requirement, and for temporary crops (vegetables and medical herbs crops), two seasons have to be considered into annual irrigation schedule in the CSA.

Leaching requirement has been considered in crop water requirement; therefore, for palm date trees, LR is 0.03, while for other crops LR has been calculated by 0.35. Salt resistance crops were taken into account in calculating crop water requirement, based on using brackish water for these salt resistance crops while fresh water has to irrigate vegetables and medical herbs, in addition to non-salt resistance crops.

Rain-fed irrigation has been considered as part of the total gross irrigation scheme. It is not a direct part of net irrigation system; but the irrigation system could use rain values in calculating monthly irrigation based on soil-water depletion in the CSA. Rain fall average is 120 mm. Calculated effective rainfall in the Case Study Area is 95% (114 mm) of total rainfall in a year, which means about 0.5 Mm^3/a as rain value in the CSA.

Modified table (4.8) shows crop water consumption including LR according to the planted crops in the CSA. It also illustrates water quality in terms of EC for all those crops. As such, total CWR with LR for all crops and in winter and summer seasons is 3.65 Mm^3/a, while it is about 3 Mm^3/a without including LR. The crop type usually defines the LR according to salt resistivity crops. Furthermore, soil salinity and soil texture are additional crucial issues in this topic.

However, palm dates are classified as salt resistance crop. LR for palm dates is only 0.03, therefore, there is no big difference between using fresh or saline water for crop irrigation. In fresh water case it needs 1,026 m^3/a/dunom while in LF it needs 1,056 m^3/a/dunom. Inversely, other sensitive crops such as some kinds of medical herbs or even vegetables, have moderate sensitivity against irrigation with brackish water in sodic or saline soil. The LR is more than one-third of irrigation requirement (0.35) which makes CWR too high in comparison with salt resistance crops. Therefore, as main results for CWR in the CSA with 100% yield, the CWR is 3.6 Mm^3/a/all seasons, including permanent fruit trees, while in winter season the CWR including LR is (2.5 Mm^3/a). In summer with LF it is 3.3 Mm^3/a. Note the difference between CWR for two seasons and summer season is about 0.3 Mm^3 and compared with winter season it is 1.1 Mm^3.These remarks are of paramount importance as socio-economic factors as well as for crop productivity and benefits.

Table 4.8 part1 : CWR in the CSA with calculated LR.

Crop Type	Etc (m^3/do/season)	Eff. Rain (m^3/do/season)	CWR (m^3/do/Season)	Irrigated Area	CWR (m^3/Area/a	CWR with LR	Water Quality (5mS/cm)
Date Palms	1139.6	113	1026.3	1200	1231560	1268506.8	EC≥1.5mS/cm
Grape	732.3	52.3	694.6	20	13892	18754.2	EC≤1.5mS/cm
Banana	1036.7	117.2	917.1	45	41269.5	55713.825	EC≤1.5mS/cm
Corn (Winter Season)	353.2	106.2	246.4	244	60121.6	81164.16	EC≤0.5mS/cm
Corn (Summer Season)	866	2.4	864.3	244	210889.2	284700.42	EC≤0.5mS/cm
Vegetables Green house (Winter Season)	281.6	91.6	190	578	109820	148257	EC≤0.5mS/cm

Table 4.8 part2 : CWR in the CSA with calculated LR

Vegetables Green house (Summer Season)	766.1	2.4	764.4	587	448702.8	605748.78	EC≤0.5mS/cm
Regular Vegetables (Winter Season)	281.1	108.7	171.9	453	77870.7	105125.445	EC≤0.5mS/cm
Regular vegetables (Summer Season)	609.5	2.4	607.8	453	275333.4	371700.09	EC≤0.5mS/cm
Medical herbs green house	926.4	114.8	806.7	650	524355	707879.25	EC≤0.5mS/cm
Total (one Season)				**3190**			
Total				**4474**	**2993814.2**	**3647549.97**	

Livestock Water Consumption in the CSA

Based on Jericho District office data bank of MAO in 2013 and some AMC information livestock in Auja village consists of sheep, poultry and some cows. Poultry is considered the main and major part of livestock which encouraged agriculture companies' projects in the area. Sonokrot company is a live example of poultry in the area, it produces about 500,000 chickens in its poultry farms which consume about 46,000 m^3/a of fresh water.

The second main component in livestock in Auja area is sheep house farming. About 1,700 sheep consume 3,723 m^3 yearly. However, Table (4.9) shows total consumption of about 50,000 CM/a of fresh water by livestock sector in Auja village.

Table 4.9: Livestock Water Consumption in Auja village.

Animal Species	Number of Animals	Daily Consumption (m^3)	Total Consumption (m^3/a)
Sheep	1700.000	0.006	3723.000
Poultry	500,000.000	0.00025	45625.000
Cows	8.000	0.070	204.400
Total			**49552.400**

4.3 Water Budget Analysis in the CSA

Regarding section 4.2, and based on all results related to all water balance, which reflects potential and available water on the one hand and water consumption by sector or water demand on the other. Future prediction and all different scenarios should take water loss, climate change, and the effect of drought scenarios in the region into account. Furthermore, the difference between available water and minimum loss of this available water has been considered as current untapped water in water budget analysis.

In water budget context, and in terms of water quality in the CSA, three water types according to source are listed in Table (4.10): fresh (blue color), brackish (pal pink), and treated or raw waste water (grey). Analysis of water budget is as follows:

- Water potential is 19.81 Mm^3/a of fresh water, 84.2Mm^3/a of brackish water, and about 5.5 Mm^3/a of treated waste water.
- Available water quantity of fresh water is 4.6 8Mm^3/a which comes from springs and deep aquifer, while only 0.8 Mm^3 comes from shallow aquifer wells. This water is brackish to saline water.
- Total water demand of fresh water in 2013 was 3.12 Mm^3/a and was used mainly for irrigation purposes, while 1.3 Mm^3/a of brackish water is considered as crop requirement of some salt resistance crops.
- Fresh water surplus is about 5 Mm^3/a which comes from Spring discharge especially in winter. Some of this surplus comes from deep carbonate aquifer. Besides, there are 0.74 Mm^3/A of brackish water calculated as surplus quantity. In our case. surplus consideration is based on best irrigation practice in the CSA. This means using actual available fresh water for vegetables, medical herbs and some fruit trees, while palm dates should be irrigated only by brackish water.

Currently untapped water resources (CUWR) are 3.37 Mm^3/a of fresh water and 1.24 Mm^3/a of brackish and saline water while there are about 5Mm^3/a of treated effluent from BWWTP and JWWTP, in addition to 0.17 Mm^3/a of raw waste water of Auja Village.

Domestic fresh water for Auja village residents comes from deep west carbonate aquifer by MEKOROT Israeli company. This domestic demand is 0.23 Mm^3/a, while the Auja Bedouins receive about 0.02 Mm^3/a for domestic use from Auja Spring.

Growing agricultural companies' activities in the field of agricultural production of plants or animals alike is noticeable here as evidenced by increasing livestock water consumption (0.13 Mm^3/a) in the last years. Fashkha Spring Group potential falls under uncertainties in this water budget analysis because of political complexity.

Table4.10Part1: Water Budget Analysis and Current Untapped Water Resources, CUWR, (2013)

Source of Water	WP	Water Losses				Israeli Abst.	Water Availab.		Tot. WD	Sector Water Demand			Water Surpl.	CUWR
		Actual		Min. losses			Act.	Min. loss		Irrig.	Dom.	Livestock		
1.Fresh water	**(Mm^3/a)**	**%**	**(Mm^3/aa)**	**%**	**(Mm^3/a)**	**(Mm^3/a)**	**(Mm^3/a)**		**(Mm^3/a)**	**(Mm^3/a)**		**(Mm^3/a)**	**(Mm^3/a)**	**(Mm^3/a)**
1.1 Auja Spring	8.6	50.0	4.3	20.0	1.7	0.0	4.3	6.9	2.8	2.4	0.0	0.1	4.1	2.6
1.2 *Deep Carbonate wells (West)	12.0	0.0	0.0	3.0	0.3	9.7	0.3	0.4	0.3	0.0	0.2	0.0	0.1	0.0
1.3 Surface Run off	1.2	85.0	1.0	10.0	0.1	0.0	0.1	0.9	0.1	0.1	0.0	0.0	0.8	0.8
Fresh water Summary	21.8		5.3		2.1	9.7	4.7	8.2	3.1	2.6	0.3	0.1	5.1	3.4
2. Brackish Water														
2.1 Alluvial shallow wells	1.2	0.3	0.4	5.0	0.1	0.0	0.8	1.1	1.3	1.3	0.0	0.0	-0.2	0.3
2.2 *Carbon. east wells (Fashkha wells)	3.0	100.0	1.0	10.0	0.3	2.0	0.0	0.9	0.0	0.0	0.0	0.0	0.9	0.9
2.3 Fashkha Spring	80.0	60.0	48.0	20.0	16.0	NA	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

Table 4.10 Part2: Water Budget Analysis and Current Untapped Water Resources ,CUWR, (2013).

Brack. Water Summ	84.2		49.4		16.2	NA	0.8	2.0	1.3	0.8	0.0	0.0	0.7	1.2
3. Treat. Effl.														
3.1 BWW TP	1.9	30.0	0.6	10.0	0.2	0.0	0.0	1.7	0.0	0.0	0.0	0.0	0.0	1.7
3.2 JWW TP	3.7	30.0	1.1	10.0	0.4	0.0	0.0	3.3	0.0	0.0	0.0	0.0	0.0	3.3
3.3 Auja Raw waste water	0.2	30.0	0.1	10.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.2
Treat. and Raw WW sum.	5.7		1.7		2.2	0.0	0.0	5.2	0.0	0.0	0.0	0.0	0.0	5.2

* RUSTEBERG B.2014, IWRM Approach towards Strategy Development, according to Rusteberg (2018)

Considering that most of the available water is used for agricultural irrigation, this analysis depends on water quality for 100% yield of water crop consumption. This leads to have a normal crop productivity without any negative impact of crop productivity on any selected crops in several agriculture developing scenarios in the CSA.

4.4 Water Resources System Analysis (WRSA)

In the CSA, water resources are classified into fresh, brackish and treated effluent quality. According to water source, they are located in deep and shallow aquifer. In addition, flood surface run off in Wadi Auja and of course treated effluent represent good choice for providing irrigation water in the near future.

In the case of Auja catchment, as in the Lower Jordan Valley (LJV), especially Jericho District, the infrastructure for utilizing and using water in the current situation is poor and causes high loss values of real available water in the area. This is also the current case in CSA (Auja catchment).

Figure (4.12) shows Auja Canal which is the only main tool for conveying Auja Spring discharge from Wadi to the irrigable lands along about 12 Km² including several branches are distributed to and connecting 54 artificial ponds in the area with 800,000 m^3 size. This system in water conveying and distributing caused loses about 40% of total fluctuated water, . Therefore, total water loss in Wadi and along the Auja canal is about 50% of total Spring discharge. Due to this huge loss, Palestinians constructed a dam reservoir in Wadi Auja with 0.6 Mm^3 storage capacity in the first phase to reach a final 1.2 Mm^3 capacity. This dam collects flood water and surface runoff which is transferred by pipeline system to irrigable lands instead of Auja canal.

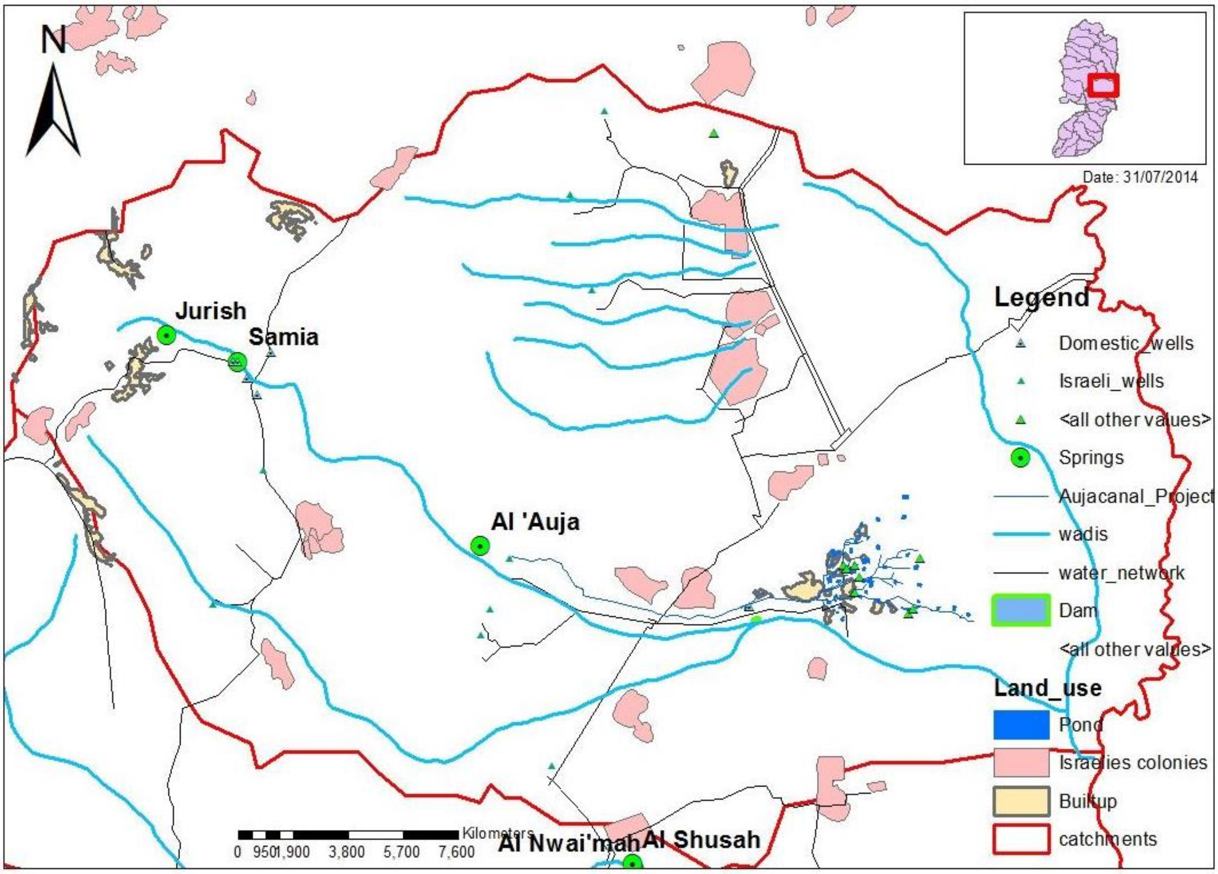


Figure 4.12: Water Sources Infrastructure in the CSA

The Israeli Company (MEKOROT) constructed the network for supplying domestic water. It provides twelve Israeli settlements in the area and Auja village with water while Auja Bedouins provide themselves with domestic water directly from Auja Spring. Resident citizens in Auja village consumed 0.23 Mm^3/a in 2013 and Bedouins consumed 0.02 in Ras Al Auja Area. Projected value of this domestic consumption regarding 3% of population growth (PCSB,2011) is calculated as 0.37 Mm^3/a within next fifteen years.

However, and based on Water Budget Assessment (WBA) results, Figure 4.13 shows Water Resources System Analysis (WRSA). This analysis depends on sources, potentials, infrastructure and water demand. WRSA could be summarized as follows:

- Water sources include the Lower part of Wadi-Auja and water import from external sources.
- In Wadi Auja-Lower, there is water potential of 11.8 Mm^3/a as fresh water from deep west aquifer, Auja Spring and surface runoff, while 2.2Mm^3/a comes from carbonate aquifer in the east and alluvial aquifer. This quantity of water potential is classified as brackish and saline water.
- Water importing is suggested to be from BWWTP (1.85Mm^3/a), JWWTP (3.7Mm^3/a), and Fashkha springs group. Fashkha Spring group is particularly saline water; it has 7 Mm^3/a (Rusteburg, B.2014), while treated effluent quality from treatment plants (Al-Bireh and Jericho) met Palestinian irrigation standards and regulations.
- Infrastructure is poor in the CSA which calls for practical and innovative solutions. Desalination (DS), pipelines networking (PL),and some mixed process between treated effluents and desalinized brackish water may be one of those solutions. In addition, managing aquifer recharge (MAR) and Water Management Recovery (WMR) are basic and innovative steps in this vision.

Auja Dam in Wadi-Auja is an artificial reservoir and is a good example for MAR process. In the last three years, the dam was not used for harvesting because of course it needs three to five years before starting water storing (PWA and MOA, 2011). Besides, the last dry year supported this late harvesting and saturation. Storing artificial recharge (AR) by surface runoff floods in winter into boreholes may be a good idea.

Many infrastructure works (dotted lines) have to constructed in the CSA. PWA and MOA are planning to convey Auja Spring water by pipelines instead of open cement canal (Auja canal). In case of water import from treatment Plants or Fashkha saline water and continuous network pipelines should be installed for this purpose as well in addition to desalination units for saline water with decentralizing system for the Well Group (WG) in the area.

Mixing process of treated effluent with brackish water is one option for getting acceptable water quality.

Predicting domestic water demand within the coming fifteen years is 0.37, while livestock demand is between 0.13 Mm^3/a, (current situation) and 0.2 Mm^3/a based on population growth and their needs.

The current irrigation demand is now 3.5 Mm^3/a and predicted irrigation demand until 2030 is 14 Mm^3/a. This is basically calculated according to an assumption of extending irrigated land by about 16,000 donums including leaching requirement for different kinds of soil and with different assumptions of crop selection (Chapter3.Sec.3.7).

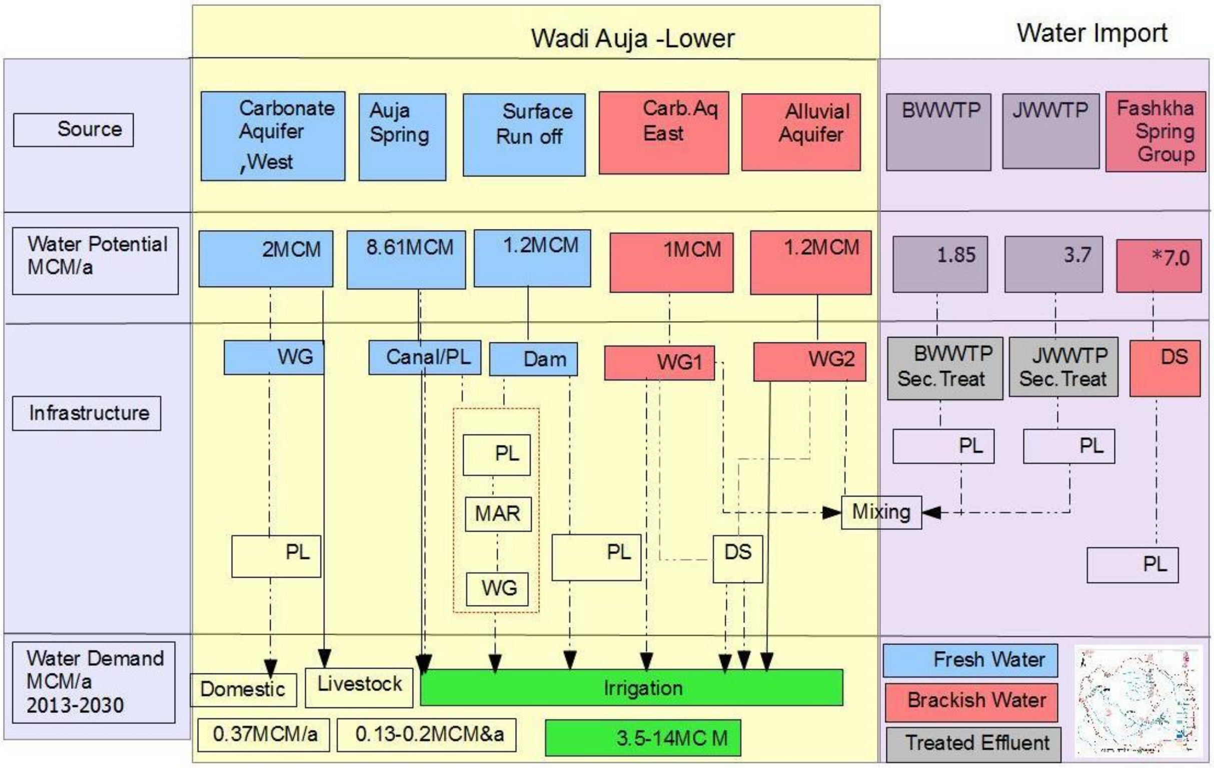


Figure 4.13: Water Resources System Analysis (WRSA) in the CSA (Rusteberg, 2014, modified)

In this WRSA, mixing treated effluent with brackish water, desalination of the saline and brackish water and MAR represent promising solutions for water production in the CSA. As for the political issue presented by the Israeli control on all resources, including water and land, it creates real obstacles and more complexity in the way of some of those solutions especially in water importing or new boreholes drilling in the area. Furthermore, Palestinian water rights in the Jordan River are 220 Mm^3/a (Johnston Plan, 1955) but unfortunately nothing was provided since Israeli occupation of 1967. This issue however has been considered as a fundamental issue for Palestinians in peace negotiations.

4.5 Discussion and Main conclusions

Water budget evaluation and water Resource System Analysis provided various opportunities for improved water resource management and development. For many decades, policy makers and water managers have been adopting the so-called “hydraulic –mission", adding new supplies in response to increasing demands (Hoff H., 2009). Therefore and regarding the large gap between limited supplies and increasing demands, the evaluation focused on all water quality grades based on Integrating Water Resources Management (IWRM) concept, and also, activating the Current Untapped Water Resources(CUWR) and in particular providing unmet water quantity for irrigation. At the same time, crop selection and salt crop resistance have to be taken into consideration for water demand prediction in the years to come.

In the CSA, water budget has evaluated water resources and water quality. CSA is divided into west and east according to sources location. In the west, there is Auja Spring with average discharge of 8.7 Mm^3/a from a carbonate deep aquifer with potential of 12 Mm^3/a which is under Israeli control and the Auja Dam with 1.2 Mm^3/a potential. All these water resources are classified as fresh water used for irrigation together with domestic water supplied by deep Carbonate well group. Loss of Auja Spring discharge is 45% of total discharge and about 20% of conveyed water (is lost) by the conveying system using Auja open canal during conveying and distribution into artificial ponds for water collection.

Brackish water in the CSA area is distributed between shallow alluvial aquifer (Palestinians agriculture wells) and deep Carbonate east well group. Palestinian alluvial well group has 1.2 Mm^3/a potential and Israelis have 3 Mm^3/a. Water quality is classified as brackish to saline in these well groups.

Treated effluents from BWWTP and JWWTP in addition to raw waste water from Auja village make about 5.7 Mm^3/a. Water potential from treatment plants is about 0.2 Mm^3/a as raw waste water. Absence of network pipelines of these treatment plants forms a main infrastructure obstacle for these treated effluents for irrigation in the CSA.

So, and by (WRSA), the infra-structure of water importing, desalination plants, and MAR are currently considered poor in the area, or more clearly, there is no real infrastructure for importing or desalinating water. This renders the solution more complex and difficult. On the other hand, incomplete access by Palestinian to their lands adds more obstacles for water production from new resources.

However, and in light of climate change scenarios, precipitation decrease by 31% until the year2050 (GLOWA Model, 2009) should reflect a great deep gap between water future demand (14Mm^3/a) and current available water quantity (5.5Mm^3/a). Loss should be minimized and untapped water should be activated.

Consequently, results of this Water Budget analysis and WRSA could be summed up as follows:

- The gap between current available water and future water demands will increase if CUWR in the CSA is not activated. CUWR is about 10Mm^3/which gives hope for substituting the water scarcity in the area.
- Construction of infra-structure is a high priority for developing water resources in the CSA; this includes pipeline projects, desalination and decentralizing of desalination process. It also

includes mixing treated effluents and brackish water as a partial step for water production solutions in the CSA.

- Scenarios of using brackish water and fresh water for irrigation should be evaluated for saving more water for the CSA development.

- Water Management strategies should consider Auja Dam on the one hand and using available brackish water for salt-resisting crops on the other.

- Increasing desalination plants in the area can contribute large water supplies to the irrigation system.

Chapter 5

Water Management Strategies and Management of Aquifer Recharge

5.1 Introduction

In the World Summit on Sustainable Development (WSSD) held in Johannesburg in 2002, delegates concluded that integrated water resources management (IWRM) and water efficiency planning should be an essential element in all national or regional development strategies by 2005. This target was added to the list of Millennium Development Goals (MDGs**)** of the (World Water Forum Theme). IWRM is one main tool to achieve MDGs goals which are relevant to poverty and hunger eradication, environmental sustainability and global partnership, in addition to health issue. Women empowerment and IWRM concept are the principles of water-use efficiency. IWRM concept is considered a crucial key principle for achieving integrity and sustainability in water use efficiency on global and local levels. According to IWRM concept, equity and balanced competition uses should be achieved, parallel with the application of all appropriate environmentally sound technologies. Economic efficiency is based on the principles of sound economy, equity and environment. The United Nation Environment Program(UNEP, 2009) has established IWRM component on three pillars which enable the environment, management instruments and institutional framework. This would lead to water balance for livelihood and water as resource. (Figure 5.1).

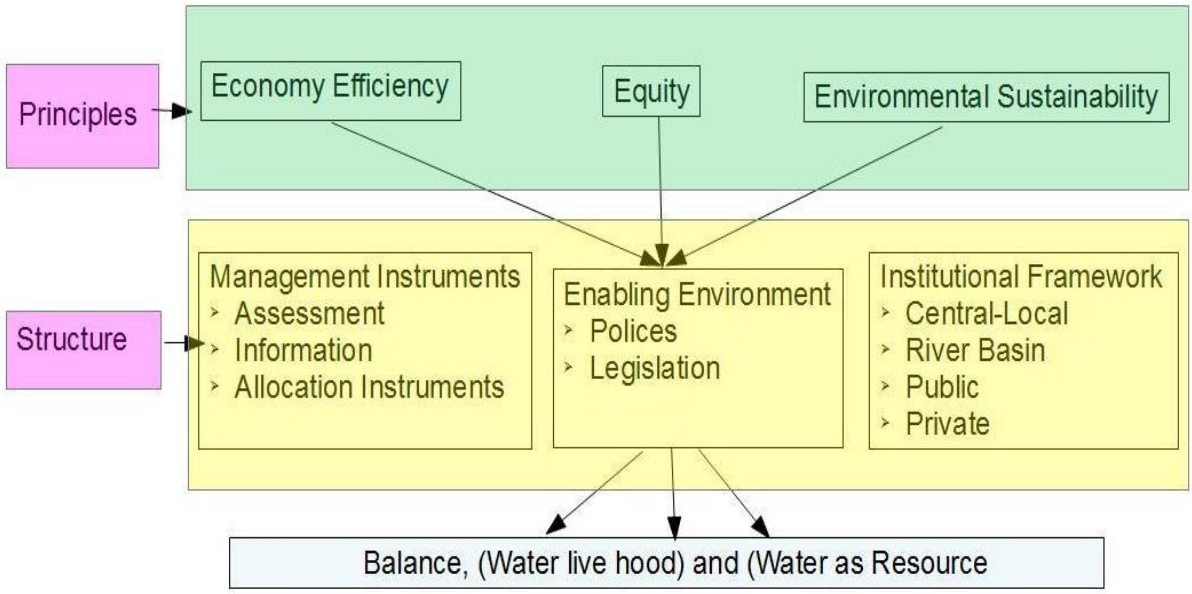


Figure 5.1: The three IWRM Pillars, Management Instruments, Enabling Environment and Institutional Framework ,UNEP, (2009).

In light of this global concept of IWRM, water management strategies should be built up under the consideration of maximizing water use efficiency regarding sustained development to reach balance between water livelihood and water as resource.

In this chapter, water management development strategies in the CSA will be based on several options regarding water importing, additional water production. In addition to water management and agriculture development in Auja case as well as LJV, many practical and combined measures could be suggested which if jointly organized with all concerned option sets, and knowing that most of those combined measures will be focused on Managing aquifer recharge and brackish water implementing in irrigation system in the CSA. Of course, assumptions and different scenarios will be suggested according to results of water budget analysis in Chapter 4 and Crop water requirement and field survey results of the CSA in Chapter 3. Therefore, land extension of Auja area and the suggested three zones (Zone 1, Zone 2 and Zone 3) will represent agriculture strategies due to different Agriculture development scenarios. In particular, water management strategies in the area are linked dialectically with agriculture development strategies (ADS) considering the agriculture sector as the dominant water consumption sector in the CSA and in the LJV.

For ADS and concerning the interaction with water management strategies, and in consideration of a variety of water consumption of ground water by irrigation system, irrigated agriculture today is the largest abstractor and consumer of groundwater. Up to 40% of all cultivated land under irrigation is ‘water well equipped’ – with large groundwater-dependent agro economies in South & East Asia while in the Middle East and South Africa it is 44% of available water volume, (GWP, 2012). The main benefits which make ground water the largest consumer for agriculture irrigation is usually its closeness to the point-of-use (on farm level). Further, it could be developed quickly at low capital cost by individual private investment in addition to its availability on-demand for crop needs as in CSA. available ground water of shallow aquifer wells form about 40% of irrigation water consumption over the entire year for irrigated lands despite increasing abstracted water salinity from these shallow wells. Farmers still use these available resources by mixing sometimes with received fresh water from Al-Auja Spring especially in drought season. This brackish water is widely used in winter seasons.

The several options of water management strategies relevant to water production, importing, desalination, and agriculture development strategies could be developed. Managed Aquifer Recharge (MAR) and Brackish water used in agriculture irrigation should be focused and will be the core for this investigation in the CSA.

5.2 Measure of IWRM and Water Management Strategies

Within a practical approach towards IWRM implementation in the LJV, identifying IWRM measures has been considered a main step of that approach (B.Rusteberg, 2011). The initial eleven measures were raised to 17 in 2014. These measures classified in options for water production and import in addition to desalination and agriculture development. The measures could be developed in accordance with soil and water quality in the CSA and were discussed together with their results in Chapter 3. There was also focus on MAR and brackish water implementation in Agriculture Development scenarios concerning inaccessible and most abundant water source in the area. In this regard, seven new measures were suggested making the total twenty four measures for introducing Water Management strategies linked with several agriculture scenarios regarding the three land zone extensions in the CSA. Table (5.1) suggests measures linked with four main IWRM options in the CSA. Nevertheless, Water Management strategies (WMS) will focus on MAR and Brackish Water implementation.

Table 5.1: Presents IWRM measures as potential strategy components.

No.	Description of IWRM Measures	
M1	Implementation and renewal of water service network	Water Production
M2	Rehabilitation of Shallow Aquifer Wells	
M3	Treating Auja Village Effluent	
M4	Agriculture Ponds Rehabilitation	
M5	Retention of Flash floods	
M6	Deep Wells in the Carbonate Aquifer – Fresh Water	
M7	Deep Wells in the Carbonate Aquifer – Brackish	
M8	Shallow Wells in the Alluvium Aquifer - Brackish	
M9	Import of Treated Effluents from El Bireh WWTP	Water Import
M10	Import of Treated Effluent from Jericho WWTP	
M11	Water Import from Fashkha (Spring)	
M12	New Deep Wells in Fashkha Area	
M13	Fresh Water Import from Palestinian National Water Carrier	
M14	Export of Surplus Water	
M15	Groundwater Desalination	Desalination & Management
M16	Mixing of Brackish Water and Fresh Water Resources	
M17	Mixing of Brackish Water and Treated Effluent	
M18	Managed Aquifer Recharge (MAR) – Spring Discharge & Surface Runoff	
M19	Extension of Regular Irrigated Agriculture	Agric. Develop.
M20	Greenhouse Technology Implementation	
M21	Palm Tree Production (Salt-resistant High Revenue Crops)	
M22	Hydroponic (Planting in water of regular vegetables)	
M23	Aquaponics (fish Farms)	
M24	Soil Mixing and Neutralization	

Despite IWRM measures mentioned in the table above and considered as potentials measures, the following important remarks may be concluded:

- Water production measures are the most acceptable in terms of the social issue. But these measures require expensive construction and reconstruction costs. In the case of Auja area, private companies may play an active role in this regard. Considered governmental policies offer suggestions and visions for implementing some projects in the area to increase water production by improving and supporting water resources infrastructure in the area. All these water production measures are including in the deep and shallow aquifer and in the water springs and surface rune off.
- Importing water measures are engulfed by uncertainties due to the current politics as the majority of lands and resources are under Israeli control. Infrastructure projects involve installation of pipeline network from one area to another through long and complex steps to get the Israeli permission. Therefore, political as well as technical issues are involved.

Additional technical measures involve desalination and management issues inside the catchment area. Such measures include the mixing processes of fresh and brackish water, or treated effluent with brackish water. MAR is also an important measure which aims to keep accessible water quality into the aquifer in the CSA. MAR and water recovery need more and deeper area modeling in terms of flow and transport to have feasible and effective scenarios for water management strategies in the area. However, some models (old and recent) in Jericho area regarding MAR will be explained in detail later.

- Agriculture Development Scenarios (ADS) in the area represent the core of this study concerns. Therefore, land extension and crops selection with several technologies are basic in coming years. Eventually ADS cannot be separated from the interaction with water strategies in the CSA. Under such measures, associating high productivity and water yield with environmental consideration should be taken into account. Regarding technological measure new planting and irrigation technologies und hydroponic use were suggested. They are promising and innovative options for saving water irrigation and for solving soil salinity in the area.

5.3 Agriculture Development Strategies (ADS) and Crop Water Requirement (CWR) in the CSA.

In order to address the concerns of irrigable land expansion, soil quality, crop selection and water resource availability, several future ADS options are suggested. In this context, current irrigated land during the year in a two-season crop cycle is 3,190 donums. The other irrigable lands are 12,615 donums (Chapter 3). Accordingly, total irrigable lands are 15,805 donums. The new suggested extension areas are divided into three sub-area zones: Zone 1 with 4,000 donums area, Zone 2 with 3,750 donums area, and Zone 3 with 4,865 donums. To deal with this case, the following scenarios were suggested:

1- ADS1op1: This scenario suggests the current irrigated land and its expansion to irrigate and cultivate part or all irrigable lands (12,615 donums) with palm date trees. This scenario needs 13.34 Mm^3/a as CWR. This scenario is important as the crop is highly salinity-resistant, which means inability to use available brackish and saline water. Monthly mean of water requirement is shown in figure (5.2). The maximum water consumption mean occurs during the hot months starting in May and until the end of July after which temperatures start to decrease and weather begins to change gradually. In cold weather the mean of water

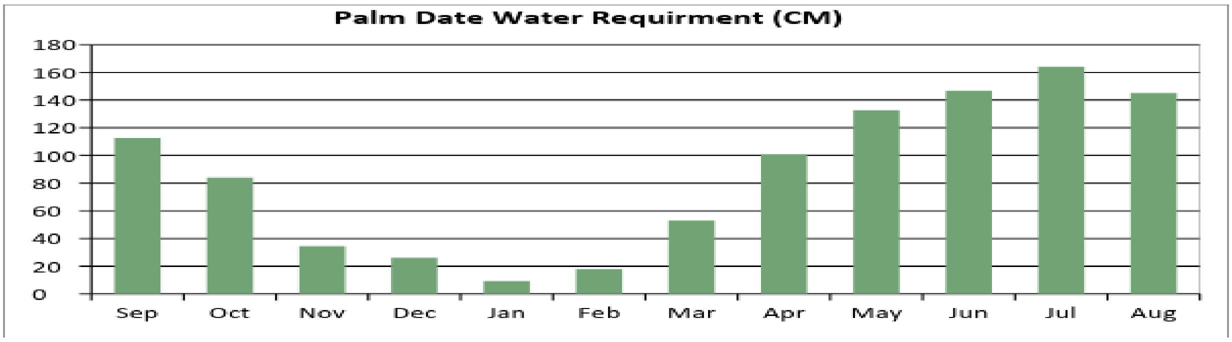


Figure 5.2: ADS1op1: (Date Palm) Monthly Crop Water Requirement Mean (CWR)

2- ADS1op2, this scenario suggests planting Zone 1 (4,000 donums) with palm date and the other two zones (8,615 donums) with grapes. Palm dates need 4.12Mm^3/a and grapes need 6.32Mm^3/a. Total water requirements, including leaching requirement for soil salinity and crop resistivity, are 12.5 Mm^3/a. Likewise ADS1 has the same CWR. However, economic and market considerations may encourage this kind of scenario. Figure 5.3 shows the CWR monthly mean monthly for grapes in addition to palm dates. Clearly, grape water consumption is less than palm date. This underlies the next scenario suggestion.

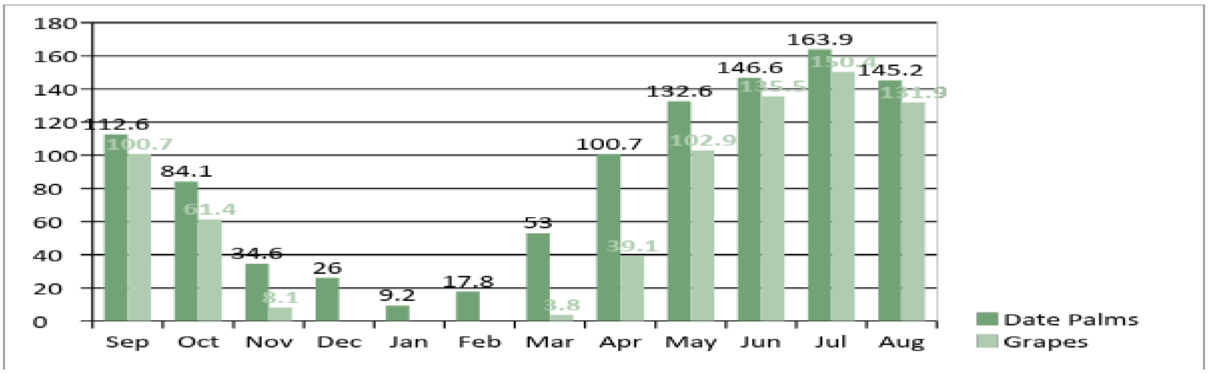


Figure 5.3: ADS1op2,Monthly Crop Water Requirement (CWR) Mean

3- ADS1op3: This scenario, Figure 5.4, suggests planting zone 1(4,000dunum) with palm date and zone 2 with green house vegetables and medical herbs. Both cover 2,000 and 1,750 donums respectively.

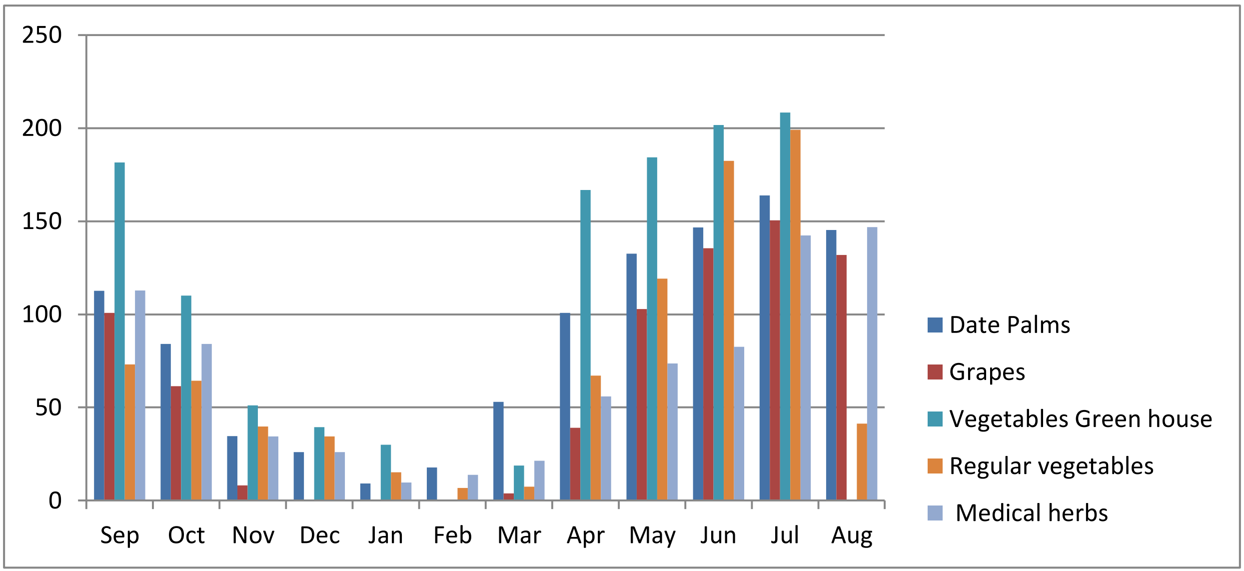


Figure 5.4: ADS1 op3, Monthly CWR Mean in the CSA

In Zone 3 about 3,000 donums should be planted with grapes and 1,865 donums with regular vegetables. According to this scenario, about 11.78 Mm^3/a are required. Note that regular vegetables have two-season crop cycle. Whether it is vegetables or grapes, fresh water will be supplied for irrigation. LR in Zone 2 and 3 is 0.3, which means an additional 2.3 Mm^3/a. In this case total CWR is 12.08 Mm^3/a.

ADS2 op1 includes 3,750 donums of banana in Zone 2 and 4,000 dunom of palm date in zone 1 in addition to 4,865 donums of grape in Zone 3. This scenario aims to revive the cultivation of bananas as banana crop is profitable and economical. In this scenario CWR includes

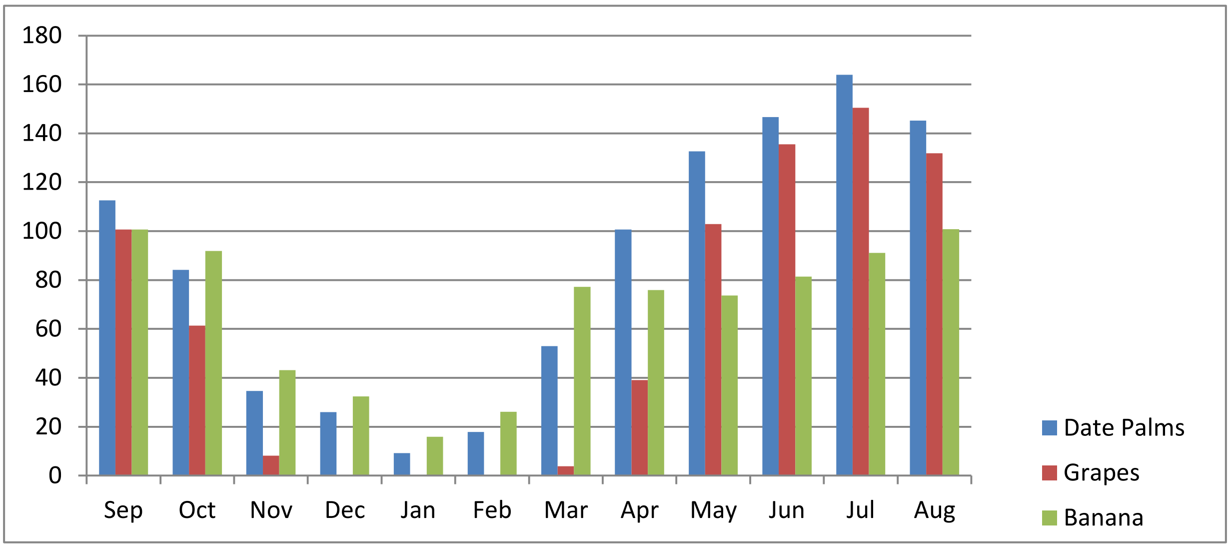


Figure 5.5: ADSII op1, Monthly CWR Mean in CSA

leaching requirement of 12.82 Mm^3/a for irrigating the total area. Figure (5-5) shows the monthly WCR mean. Grapes in this scenario are not irrigated during winter months contrary to other plants, i.e. palm dates and banana, which have continuous irrigation process throughout the year.

ADSIII op1: In this scenario, hydroponic agriculture in green house, a new agriculture approach and technology, is suggested. This kind of cultivation technique needs no soil. It is a water controlled system with special kind of composting organic fertilizers including some additives like minerals, using pipe networking system, or some closed flat plates (tanks). This system saves 50% of consumed water by intensive agriculture in green house technology. Its productivity is 4 to 10 times compared with regular vegetables cultivation. Figure (5.6) show this agriculture technique in Al-Arroub Agriculture College in 2014.

Figure 5.6: Hydroponic agriculture Al-Arroub College

with several kinds of vegetables including lettuce and tomato. In this scenario, 2,000s donums will be planted by vegetables by the hydroponic green house and 1750 also by medical herbs in Zone 2, against 4,000 donums in Zone 1 to be planted by palm date and 4865 donums in Zone3 suggested for grapes planting. In this scenario CWR is 12.04 Mm^3/a. (Figure 5.7) shows monthly CWR mean relevant to ADS5.

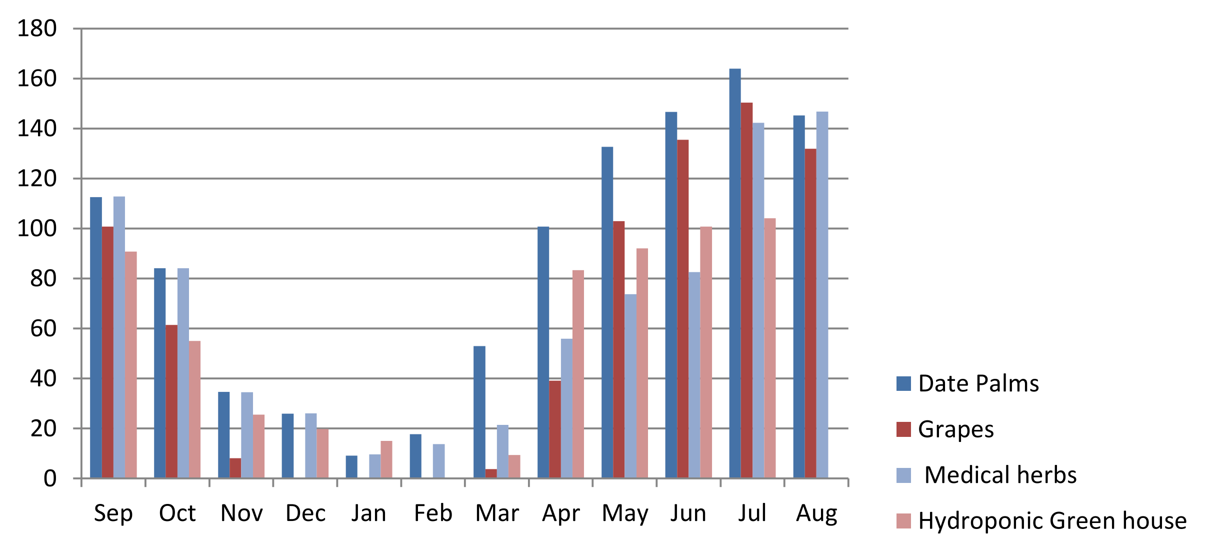


Figure 5.7: ADSIII op1, monthly CWR Mean in the CSA including hydroponic technology.

Table (5.2) illustrates all five suggested scenarios in the irrigable lands in case of irrigated lands expansion into three zones of the irrigable lands in the CSA. Results of water demand for extending irrigated lands into the five suggested scenarios range between 11.89 Mm^3/a in ADS 5 as minimum water demand and 14.02 Mm^3/a as maximum water demand in ADS 3.

Table 5.2: Suggested Agriculture Development Scenarios (ADS) probability into three zones

ADS	Zone 1			Zone 2			Zone 3			Total
	Crop	Area	CWR (Mm^3/a/area)	Crop	Area	CWR (Mm^3/a/area)	Crop	Area	CWR (Mm^3/a/area)	CWR (Mm^3/a/Area)
ADS1op 1	Palm Date	4000	4.23	Palm Date	3750	3.96	Palm Date	4865	5.14	**13.33**
ADS1op 2	Palm Date	4000	4.23	Grap	3750	3.58	Grap	4865	4.64	**12.45**
ADS1op 3	Palm Date	4000	4.23	Veg. Green House	2000	3.1	Grap	3000	2.86	**14.08**
				Medical Green house	1750	1.83	Reg.Veg	1865	2.06	
ADS2op 1	Palm Date	4000	4.23	Banana	3750	3.95	Grapes	4865	4.64	**12.82**
ADS3op 1	Palm Date	4000	4.23	Veg.Hyroponic	2000	1.19	Grapes	4865	4.64	**11.89**
				Med.Green House	1750	1.83				

The CWR requirement under the current situation, Table 3.20, in Chapter 3 is 3 Mm^3/a for irrigation of 319 donums. With several suggested scenarios, the expected CWR should be increased by 3 Mm^3/a for each scenario, bringing the total irrigated area in case of land extension to 15,805 donums. All these ADS values are not optimal values-beyond the scope of this study to optimize all these scenarios. These ADS's give preliminary indications for future water needs in case of linking them with different suggested water strategies. Figure (5.8) shows CWR of all suggested scenarios including the current situation in the CSA.

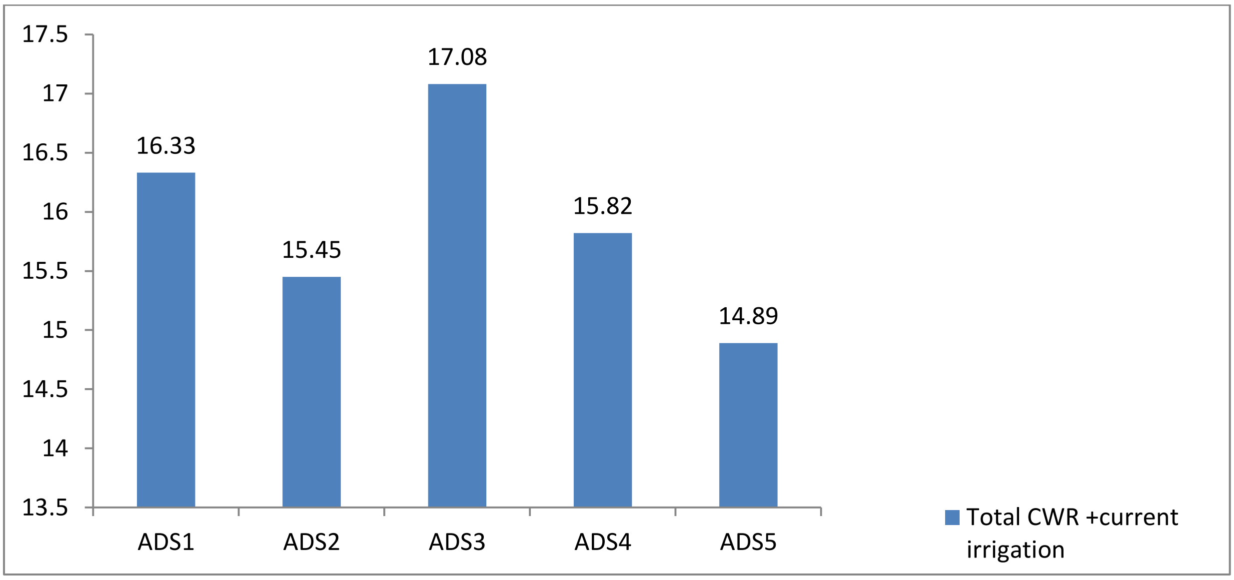


Figure 5.8: CWR of all suggested scenarios in addition to current CWR in the CSA

5.4 Water Management Strategies in the CSA

Back to water budget analysis in Chapter 4 and Water Crop Requirements in Chapter 3, several water management strategies could be suggested due to availability of water in the CSA and also with regards to water potential in light of current and future demands. The

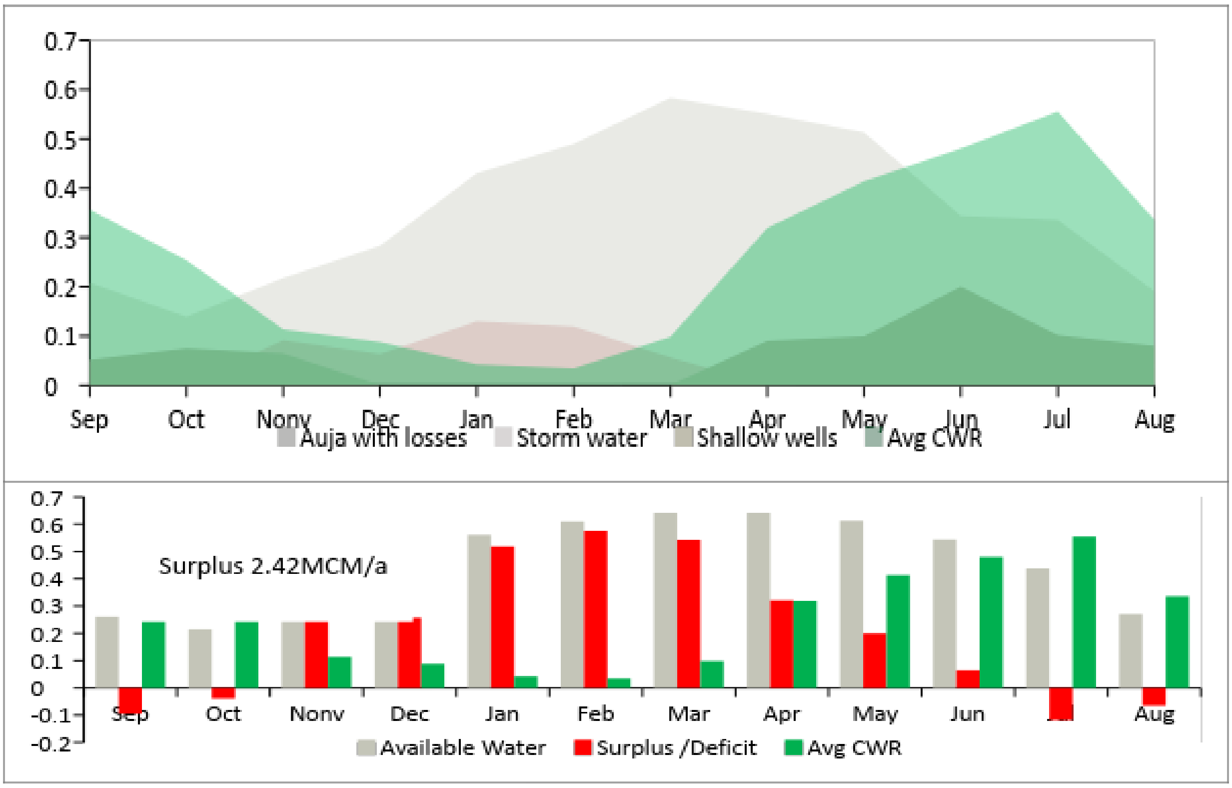


Figure 5.9: Water Budget and mean monthly CWR in 2013 in the CSA.

Current water budget; Figure 5.9, water deficit in summer months and September, even though the total surplus is 2.42 Mm^3/a, and available water is 5.5 Mm^3/a and CWR is 3.09 Mm^3. Therefore, concerning this current situation and with water surplus quantity, there is deficit in summer months of about -0.32 Mm^3/a. Deficit is usually caused by drought impact on the Spring in June which reduces received water. In addition, the water table level of shallow aquifer wells declines causing cancelation of summer season vegetables cultivation. The irrigated area also decreased from 4,000 donums to 3,150 donums. Based on current water budget, on average every 1,000 donums need about one million cubic meters for irrigation in the CSA of different kinds of crops. In this context, and concerning the suggested five ADS for the next 15 years, huge quantities of irrigation water should be provided to meet the ADS requirements. Therefore, several IWRM strategies should be planned and linked with these ADS in the CSA for the Decision Support System (DSS) in terms of sustainable development under consideration of Socio-economic and environment concerns.

In this research, IWRM strategies and water management strategies could be developed due to water resources (both available and potential). The suggested water strategies (WS) include the following:

The first water Strategy (WSI) depends on the present current situation according to irrigated agriculture and available water in the CSA. CWR is 3Mm^3/a for irrigation of 4,474 donums for two seasons of vegetables planting and mean available water with minimum loss (fresh from spring and storm water, brackish) is 8.81 Mm^3/a. 6.89Mm^3/a come from the spring as fresh water, and 1.14Mm^3/a of brackish water come from shallow well aquifer and 0.9 MCM/a come also as fresh water from storm water. The actual consumption of this available water for agricultural sector is 5.53 mcm**.** Table 5.3 modified from Table 4.12 explains available water and current untapped water in addition to water surplus in different water resources in the CSA. It also shows water resources outside CSA in case of water import as an option according to water resources analysis in section 4.4.

Table 5.3 Part 1: Available water from different resources and CUWR in the CSA.

Source of Water	**WP**	**Water Availability**		**Water Surpluses**	**CUWR**
		Actual	**Min. loss**		
1.Fresh water	**MCM/a**	**MCM/a**	**MCM7a**	**MCM/a**	**MCM/a**
1.1 Auja Spring (WSI)	**8.61**	**4.31**	**6.89**	**4.14**	**2.58**
1.2 *Deep Carbonate wells(West)	**12**	**0.25**	**0.37**	**0.12**	**0.01**
1.3 Surface Run off (WSI)	**1.2**	**0.12**	**0.9**	**0.78**	**0.78**
Fresh water Summ.	**21.81**	**4.68**	**8.16**	**5.05**	**3.37**

Table 5.3 Part 2: Available water from different resources and CUWR in the CSA.

2.Brackish Water					
2.1 Alluvial shallow wells (WSI)	**1.2**	**0.8**	**1.14**	**-0.16**	**0.34**
2.2 *Carbonate east wells (Fashkha wells)	**3**	**0**	**0.9**	**0.9**	**0.9**
2.3 Fashkha Spring	**80**	**0**	**0**	**0**	**0**
Brackish Water Summ.	**84.2**	**0.8**	**2.04**	**0.74**	**1.24**
3.Treated Effluent					
3.1BWWTP	**1.85**	**0**	**1.67**	**0**	**1.67**
3.2 JWWTP	**3.7**	**0**	**3.33**	**0**	**3.33**
Auja Raw Waste Water	**0.19**	**0**	**0.17**	**0**	**0.17**
Treated and Raw WW Sum.	**5.74**	**0**	**5.17**	**0**	**5.17**

The second suggested Water Strategy (WSII) includes available water in the CSA in addition to Managing Aquifer Recharge (MAR) and Storage and Recovery of Aquifer (SRA) in the CSA. This strategy concerns irrigated lands expansion to about 8,000 donums. This is based on ADS2 op1.

The following explanation gives answer to the question if MAR should participate in promised solution using ground water model in the CSA.

5.5 Managing Aquifer Recharge (MAR) and Ground Water Model System (GMS)-Modflow Model in the CSA

The vulnerability of surface water sources in the CSA because of their transboundary nature and climatic change raise the importance of shifting from canal irrigation system to conjunctive use of surface water and groundwater. However, groundwater development for irrigation may increase salinity of water due to leaching of dissolved solids from the salt-affected vadose (unsaturated) zone. In addition to natural effects by upcoming salts on the geologic structure, this section analyzes both MAR and discharge as one tool to maintain the groundwater quality.

MAR in the CSA was mentioned by the local model of Jericho Area, which is created by using GMS-MODFLOW model. It was calibrated and simulated on 2000 by PWA (USAID, PWA, CH2MHill, 2000) as a local model for Jericho Area. Auja area was not included in this model then and was only for Jericho, Quilt, Nui'meh and Wadi Marrar Zone. This conceptual model resulted in two model layers. The alluvial deposits, which are recent, and older deposits form the upper layer while the Lisan Formation forms the lower layer. They interact through vertical movement of ground layer.

Complexity of Geologic and hydrogeological formation of Alluvial deposit and Lisan formation, especially in overlying lances and interfingering between those two layers rendered model calibration more difficult and complex. It is difficult to correlate various gravel layers and marl layers from well to well. Therefore, in Jericho model, one cross section and six subsurface profiles were prepared with locations being dependent of availability of the lithologic logs and well data. In the Lower Jordan Valley, there are only 28 wells with lithologic logs and most of them are in Jericho area. The total depth of these wells range from71 m to 168 m and all of these wells are in alluvial deposit layer.

5.6 New GMS-Modflow Models

Developing the model included the study area. Recalibrated GMS Modflow model was developed by Florian Walter in 2013 through his Master thesis und supervision of Drop-off Martin Sautr and Dr. Eng. Bernard Roseburg. This new model was based on two layer GMS-Modflow model submitted by Dr. Mouad Abu Saada as a main task of SMART project with cooperation of the Department of Applied Geology at George-August University. In figure 5.10, the calibration curve illustrates the situation of transient flow with well number 15_15_005. It is the only well in the area which was calibrated as a basic model to give main indication of the area. The figure shows the range of calibration target is limited in range to 20 meters. It is between 300 and 320 regarding water table in shallow aquifer in the CSA.

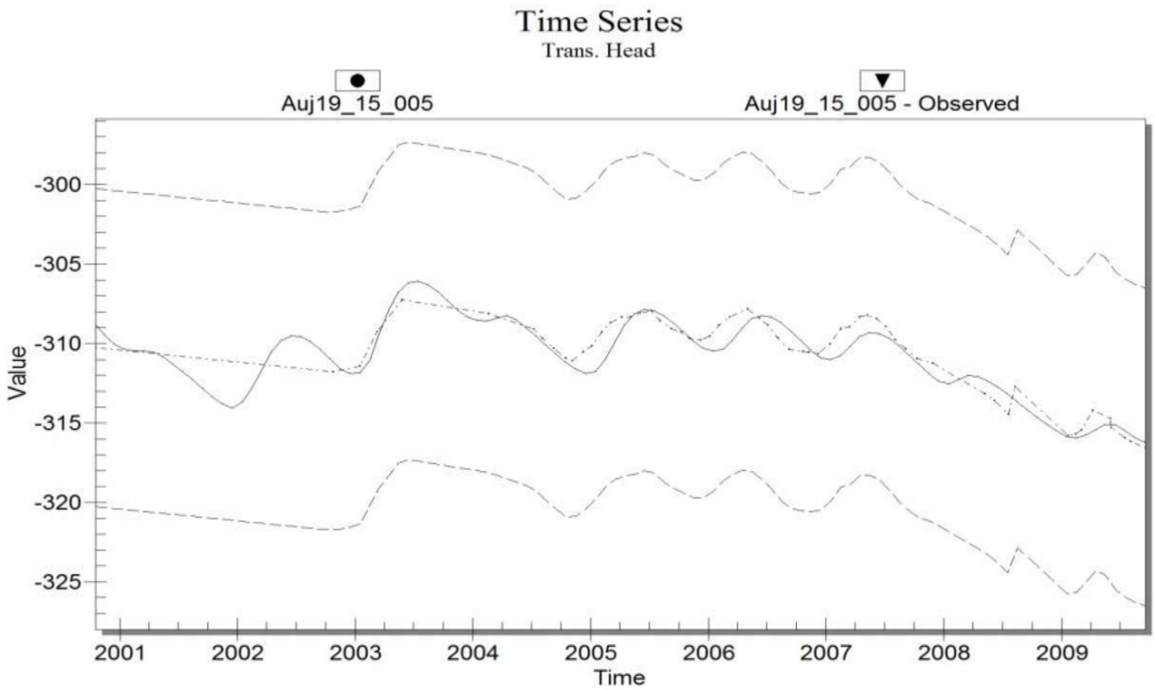


Figure5.10: Calibration Curve of well no.19_15_005, Dr. Abu Saada Basic Model, (2014).

Figure 5.11 shows flooded cells resulting from the basic two-layer model in the eastern boundaries. Results are not adequate enough to give realistic results of different development scenarios for water strategies in the CSA. Those results lead to more development of this model by Göttingen University with cooperation of Hydro-Engineering for Environmental and Informatics Consultancy, HEC, (2014).

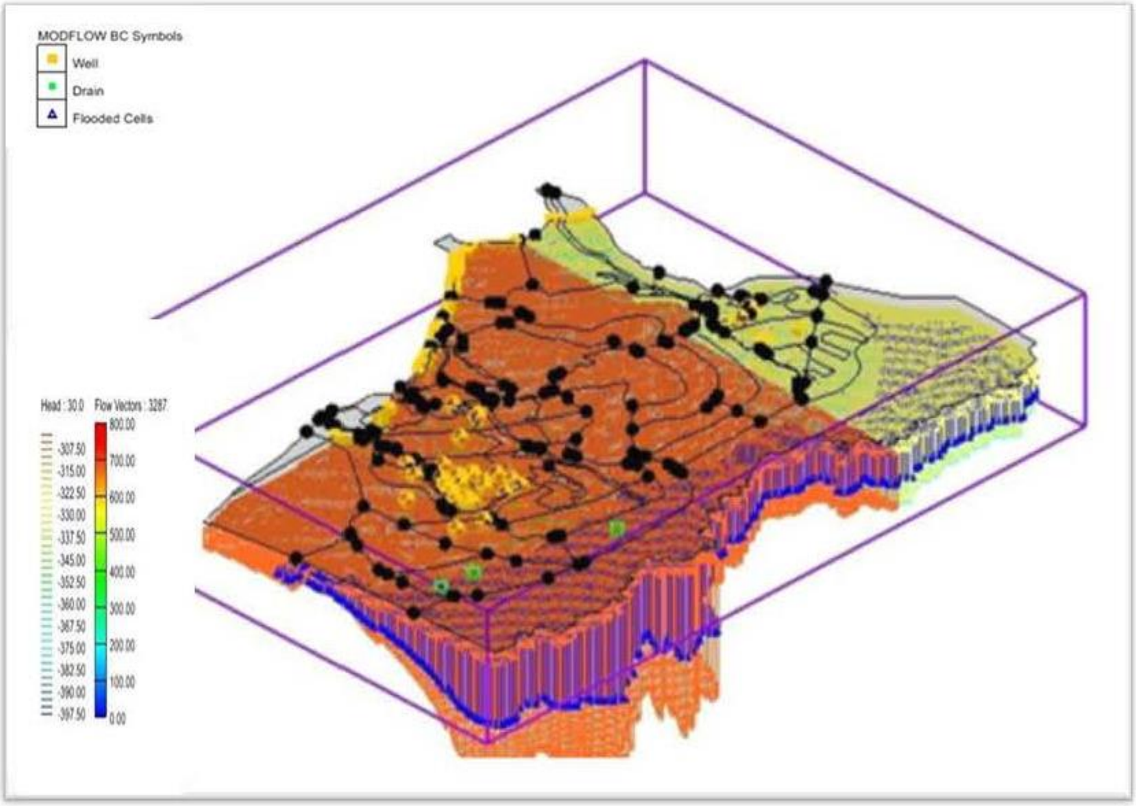


Figure 5.11: Flooded Cells of 2-layer GMS-Modflow Model of the CSA and Jericho Zone

Based on flooded cells results, 2-layer model by (Abu Saada and Göttingen university).The GMS Modflow model was developed into three layers: alluvial sediments, Lisan formation and deep carbonate aquifer layers (Walter, 2014), Figure 5.12.

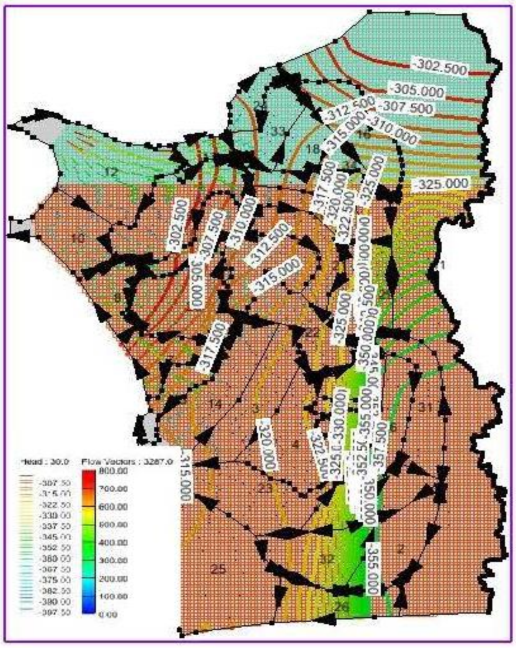


Figure 5.12: Regional Model of Jericho and Auja Area, (Walter, 2014).

Figure 5.13 (a, b , and c), shows cross sections of the model into several views which demonstrate interfingering and lances interaction of the different three layers which resulted the calibration complexity of the model in the CSA in terms of heads pressure of these layers. This explains the head pressure variation during one layer , where the head pressure in the same layer distribution resembles, sometimes distributed in a layer more likely. This explains the presence of head pressure to a lesser extent in the layer and second layer compared to the first. As a result, it has been difficult to be calibrated like an ideal model based on the data and one well in the region (19-15-05). On the other hand, the absence of information relating to deep carbonate layer (Third Layer) drove us to rethink about relying on a conceptual model consisting of two layers only.

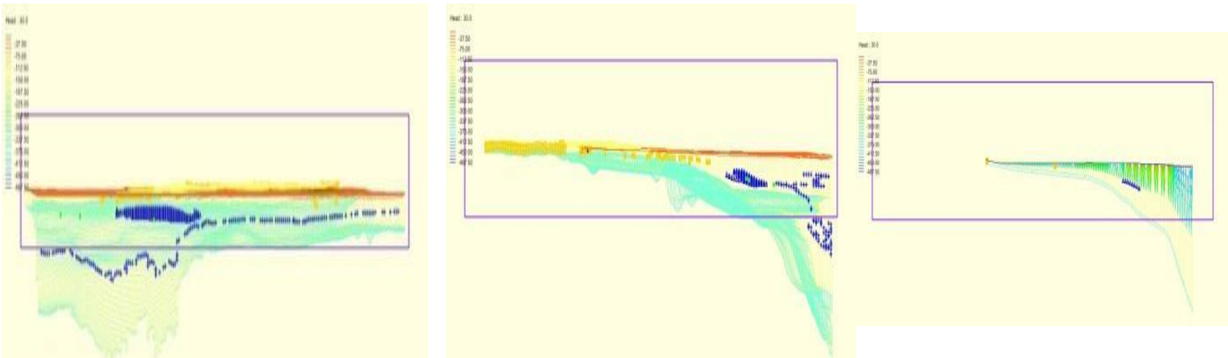


Figure 5.13 a,b,c: Three layers views, side view a, front view b, and ortho view c of regional model.

5.7 New modified and developed GMS Modflow model

A) CSA Conceptual Flow model of the 5.7.1 Geology and Lithologic construction of conceptual model

Based on recent work regarding the CSA (PWA Modflow Model 2000, Abu Sa'ada M., Florian, W. Gottingen University, SMART Project), the better understanding of the stratigraphy of the study area. One cross section and six subsurface profiles were referenced and were dependent on availability of lithologic logs of 28 wells at the Jericho area (Jericho Model PWA, CH2M Hill. 2000). In addition to that, five subsurface profiles with one cross section including 11 wells at the CSA were conducted in 2010 ,(Shawahna A., Master Thesis). The total depth of those wells range from 59 to 108 m at the Auja area and 168 m maximum depth at Jericho District. In our case, it is difficult to correlate various gravel layers and marl layers from well to well causing the formation of inter-finger and lenses formation in between these two main layers: Alluvial deposit and Lisan formation.

However, PWA, 2000 and Jericho model were used as base lithologic map to develop geologic map which is concerned with the following (Figure 5.14):

The Jordan Valley Rift Fault borders the Jericho District from the western side, and this fault may be completely applied to the CSA.

A step-fault structure can be seen on the western side of the Rift.

In the northwest and northeast direction, there are sets of faults on both sides of the Valley Rift Fault.

Auja monocline has been formed by fault displaces on the western side of Model domain.

Recent and Quaternary alluvial deposits are the youngest and shallowest materials; they unconsolidated alluvial fan deposits which are developed along the sides of the major wadis and overlie the Lisan formation in the Jordan valley. They are composed of lenticular beds of gravel and a few meters thick sand and calcium clays near the Jordan River to more than 100 meters near the foothills.

The Lisan formation covers a large part of the Jordan valley. The best exposure of Lisan formation is found along the sides of the River Jordan flood plain. Maximum exposed thickness is about 60 meters, but total thickness of the Lisan formation exceeds 1,500 meters in the western shore of Dead Sea and Ein Gedi No.2, (PWA, Jericho Model 2000).

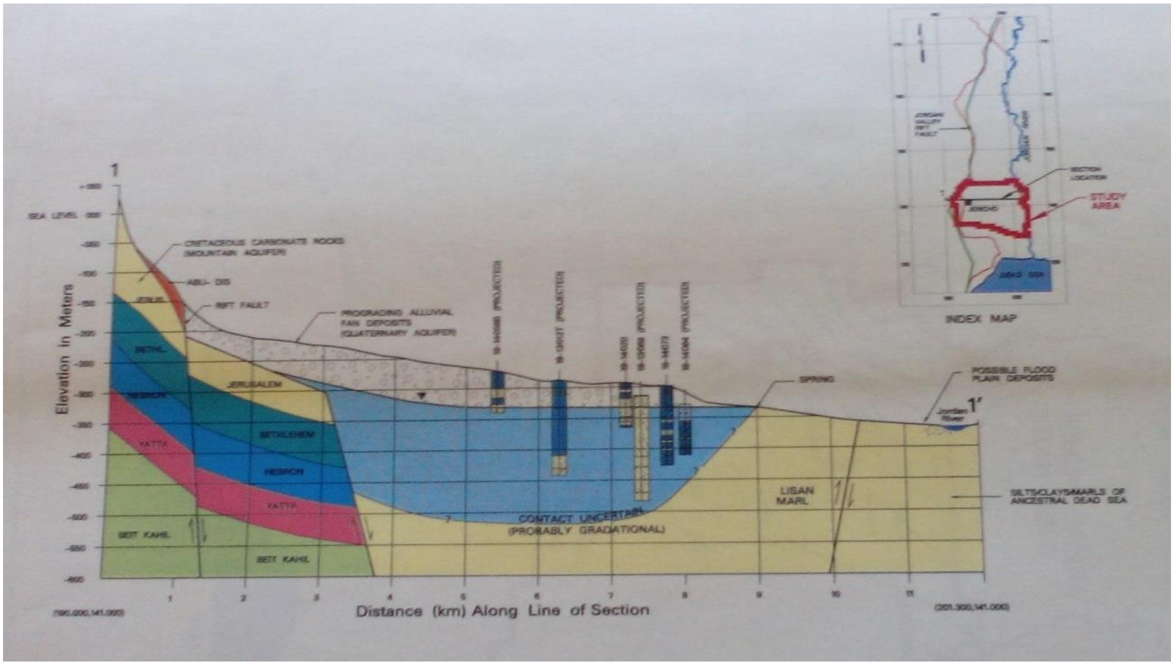


Figure 5.14: Generalized Geologic Cross Section-Jericho Model, (PWA, 2000),

5.7.2Aquifer System and Stratigraphy

Regarding stratigraphy of the CSA based on interfingering between different layers that formed the shallow aquifer in the Jericho area, two model layers appeared:

The alluvial deposit forms the upper layer and the Lisan formation which forms the lower layer.

Based on the stratigraphy classification ground water has vertical movement which is the result of interaction of these two layers. Thickness of the Alluvial deposit decreases from west to east causing the dominance of out crops of the Lisan formation;, therefore, the perching effect of low permeability Lisan formation explains the existence of Deir-Hejleh Spring near the contact zone between Lisan and Alluvial deposits; of course, this supports the idea of two aquifer systems (one Alluvial deposit with high transmissivity and the second is the Lisan formation with low transmissivity) (The Jericho model, PWA, 2001). In this manner, the sources of aquifer recharge are classified into different infiltration sources: infiltration from runoff during the winter season through wadis (Qilt, Nui'meh, Marrar and Auja) and from the return flow from base flow of springs (Dyouk, Sultan, Deir Hejleh). The lateral flow from mountains (Figure 5.15) shows the nineteenth zone which is reflected on the natural recharge system of the Jericho area.

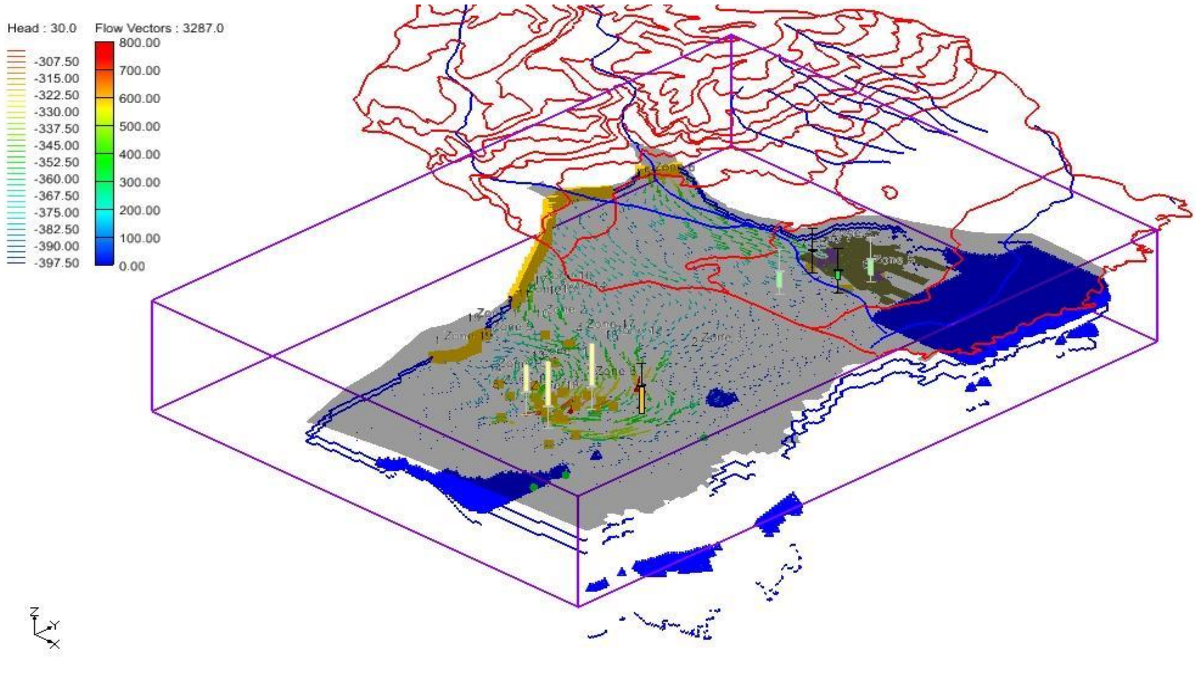


Figure 5.15: Several Natural Recharge Zones of the Shallow Aquifer in Jericho Area

Regarding PWA historical data, 5 Mm^3 were abstracted from 89 underground wells in Jericho and Nui'meh area in the CSA (Auja) Area. 11 of these wells have stopped functioning completely because of drought or high salinity of abstracted water. In the CSA (Auja), 9 wells are still operating with around 1 Mm^3 abstraction per year. In the CSA, as well as the Jericho district and the LJV area at the Palestinian side, the ground water flow direction is towards the Jordan valley in alluvial deposits. Water becomes more saline near the fans fringes while fresh water or the less saline quality occurs near the recharge area towards the wadi mouth to the western part of the catchment area of the Eastern aquifer. In this case, the main component of natural recharge comes from water infiltration from runoff during the winter season through wadi Qilt bed, wadi Nui'meh, Wadi Marrar and wadi Auja. Base flow which was considered as infiltration component by return flow from several springs (Duyuk, Nui'meh, Qilt and Auja) in the area is the second main component of Aquifer recharge source. Direct rainfall is negligible because of low precipitation and high evapotranspiration in the area, but the lateral flow from the mountain is considered. Figure 5.16 shows the main recharge zones in CSA.

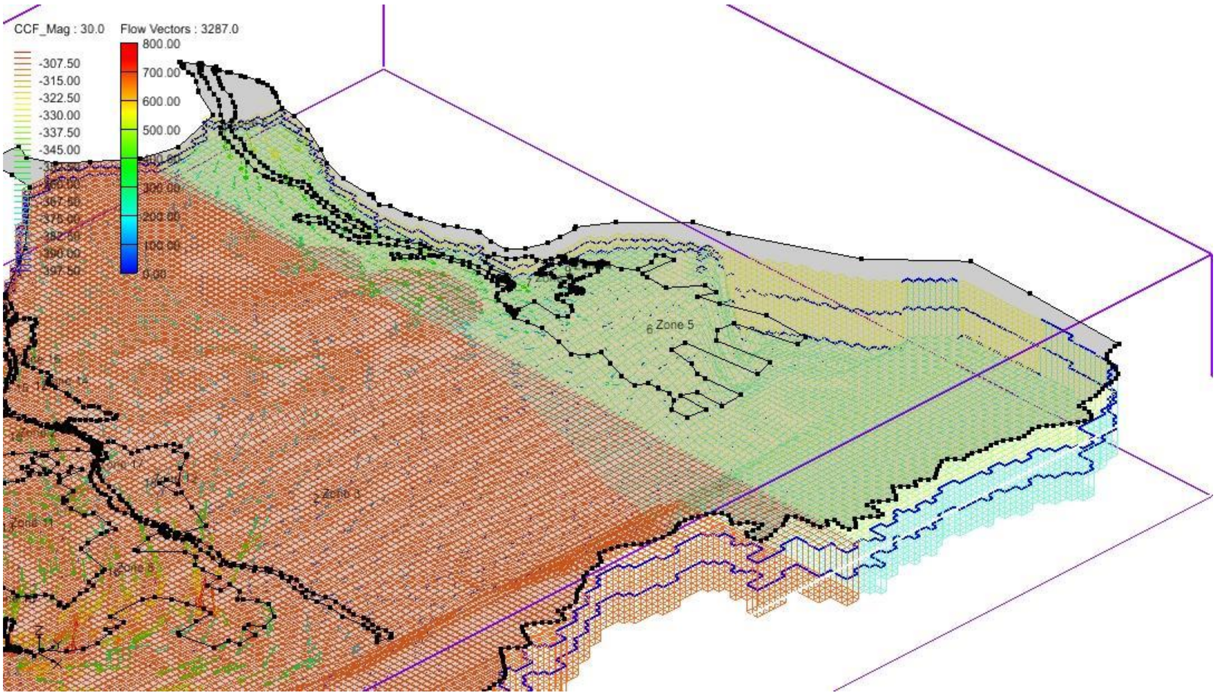


Figure 5.16: Recharge zones in the CSA including the main recharge source.

5.7.3 Aquifer Characteristics

Modeling aquifers using Ground Water System (GMS)-MODFLOW need several parameters: layer thickens, hydraulic conductivity, specific storage for confined aquifer, specific yield for unconfined aquifer. These parameters are not available as calculated values based on continuous time series regarding historic data and some new pumping test in the CSA. These data are discrete and those parameters should be estimated depending on different trends of some historic data by PWA, Table 5.4 shows the values of hydraulic parameters of model layers.

Table 5.4: Hydraulic parameters of shallow Aquifer, Alluvial deposit and Lisan formation.

Aquifer	Horizontal Hydraulic Conductivity Kx (Meters/day)	Vertical Hydraulic Conductivity Ky (meter/day)	Specific storage (L/meter)	Specific yield
Alluvial (layer 1)	1.5-2.6	0.2-0.3	2E-8 - 5E-8	0.01-0.00225
Lisan (layer 2)	0.1-0.12	0	2E-6 - 5E-6	0.003-0.0025

Thickness of the upper layer is estimated from 60 m to 170 m based on the wells' depth in the CSA and Geophysics profiles in 2010 (Shawahna, A.M.). Thickness of the lower aquifer layer regarding PWA and Roff and Raftty literature starts from few meters to more than 1,500m at the Dead Sea's western shore.

Figures below, 5.17 and 5.18, ground water elevation hydrographs of Auja wells, Jericho and LJV catchment, i.e. wells 19-15/05, 19-15/23, clearly have long term fluctuation in the aquifer recharge which usually is based on infiltrated water during the runoff.

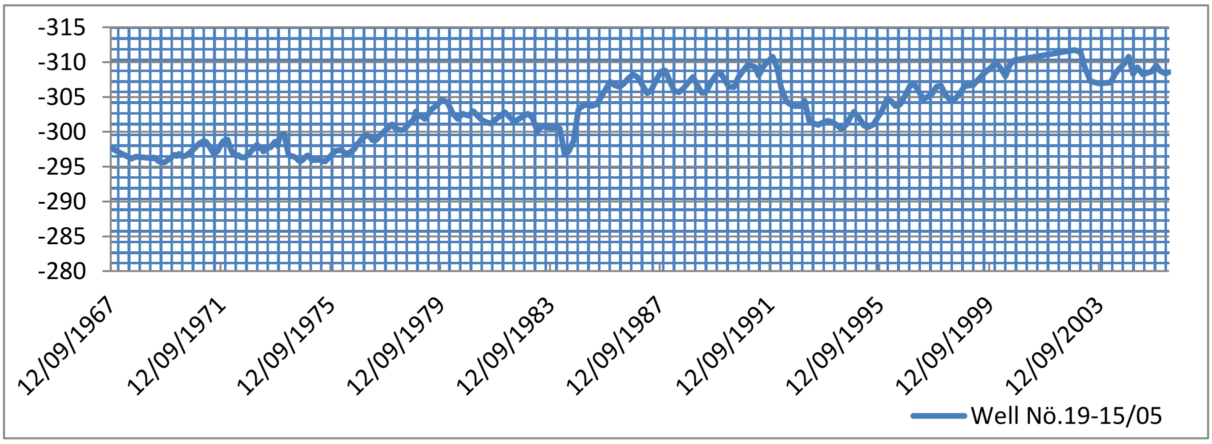


Figure 5.17: Historical data example of well No. 19-15/05, fluctuation from 1967 to 2003.

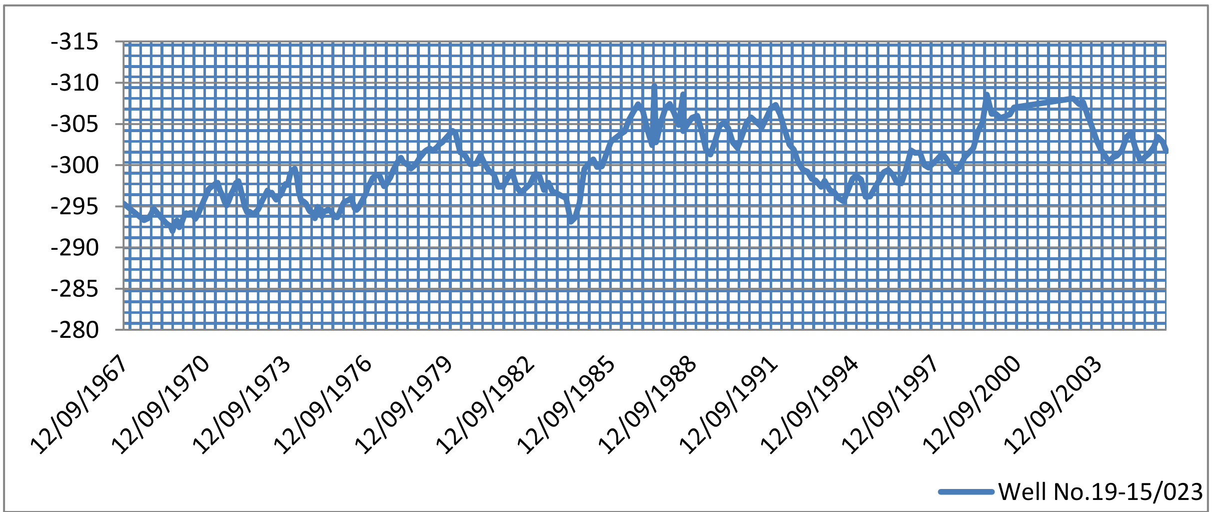


Figure 5.18: Historical data example of well No. 19-15/23, fluctuation from 1967 to 2003.

Comparing wet and dry years, seasonal fluctuation confirmed the recharge runoff infiltration. Head differences are about 4 meters in winter from 1973 (dry year) to 1974 (wet year). The comparison between summer and winter for the same year is clearer. This is explained by rainfall events, before or after and also the overexploitation between summer and winter seasons. (Figure 5.19)

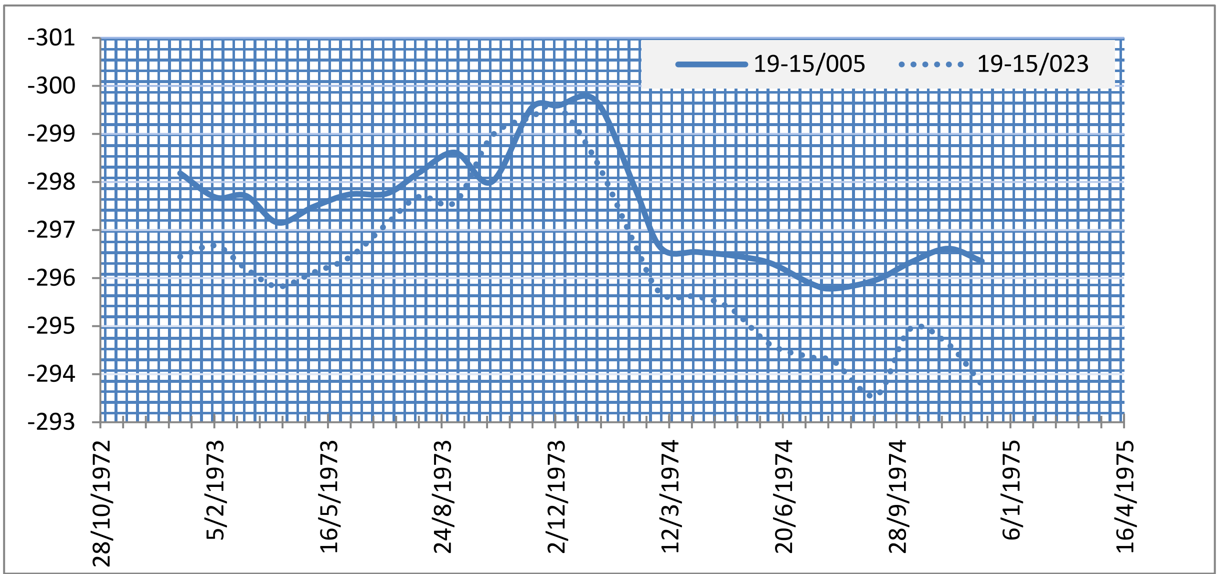


Figure 5.19: Seasonal fluctuation of some Auja wells in dry and wet years.

The model considered the average Auja wells depth in shallow aquifer 100 meters, and so it is in the west. Towards the east the average depth decreases to 35 m as in well 19-15/023. This shows the water flow direction from west to east in some places. Beside shore line of the Dead Sea, the depth of shallow aquifer does not exceed 15 m. (Figure 5.20)

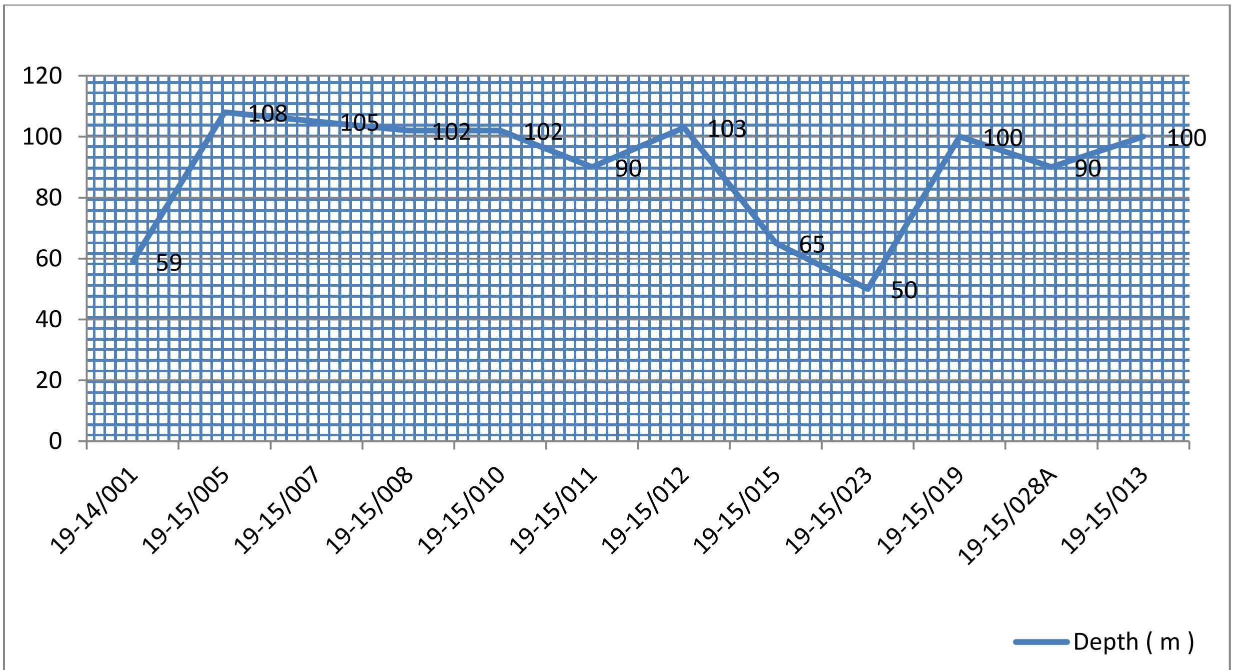


Figure 5.20: Auja Wells' Depth

Historic data of some physical properties like electrical conductivity (EC) and hydro chemical analysis like chloride Cl^{-1}, Sodium Na^{+1} and total dissolved solids (TDS) concluded increased ground water salinity in terms of chloride and EC. Well No 19-15/023, (Figure 5.21) recorded sharp increase of salinity in the last 15 years in comparison with the period 1989-2000. This sharp deterioration in CSA water quality, as well as the entire Jericho District, should usher an alarm for the aquifer sustainability and water supplies availability in terms of water quality. In addition to water scarcity in the LJV, there is also the intrusion of Lisan formation. Over exploitation and anthropogenic practice, in addition to drought in arid regions, contributed to the deterioration of water quality in shallow aquifer

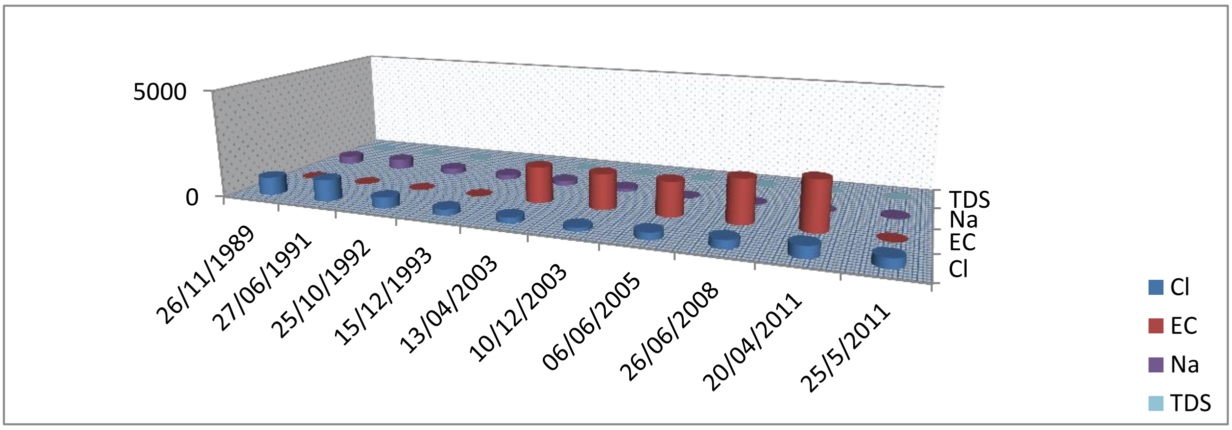


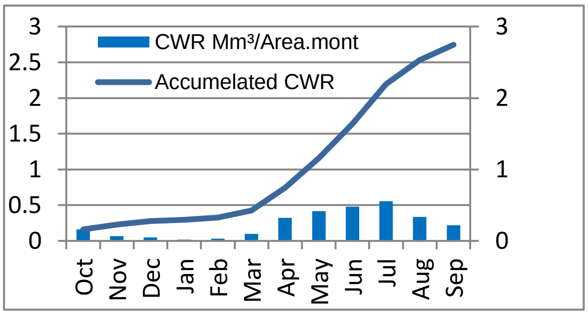
Figure5.21: Historic water quality of Well No. 19-15/023.

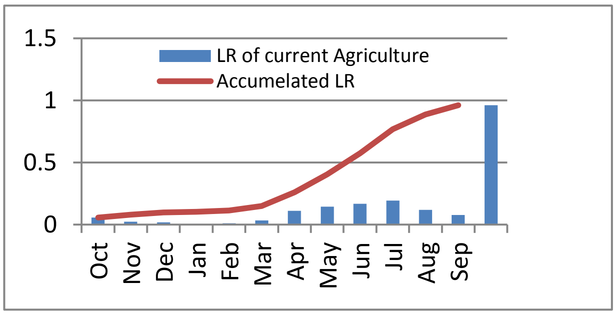
5.7.4 Ground water recharge and discharge: Water Balance (inflow/ outflow)

Inflow (Recharge): A comparative analysis of inflow (recharge) and outflow (discharge) from aquifer balance was calculated in this contest. Long term average of recharge should equal discharge unless significant change in storage occurs. Therefore, recharge source in this model is concerned with three main sources taking into consideration the negligence of a few quantities of annual average rainfall (< 140 mm) with very high evapotranspiration (2,500 mm/year). These sources are:

- Recharge from wadis run off: there are three main wadis in the Jericho model area: Auja, Nui'meh and Qilt. The run off of these wadis was estimated at 10% of the annual flood. This surface run off is affected by rainfall intensity, soil type and catchment slope. So, Auja catchment is 291.1 $km^{2.}$ Usually, Wadi Auja in a rainy year has about 3 MCM of surface water runoff. The assumed recharge from infiltrated run off to shallow aquifer equals about 10% of total run off (0.3 MCM/a).

- Return flow from applied water, irrigation system*:* Figure 5.22 (a,b) shows the monthly CWR and LR, about 35% (From Chapter 3). This helps estimating infiltration rate by 20% of applied irrigation on Current Agriculture system. Also, domestic networks leaks 30% in built up area. Leakage also occurs from conveyance by canals to several springs. Such example of Auja canal loss of about 50% of its discharge through the wadi before being conveyed by open and damaged cement canals in different places along the canal is another source. By this system about 10% of conveyed water of spring discharge infiltrates. In addition, effluents of different Auja clusters, Nui'meh and Jericho are considered actual. Thus loss of domestic water network is about 25%. This quantity is indeed distributed in buildup area where people are assumingly clustered in the CSA. About 10% of lost quantity infiltrated





(a) (b)

Figure 5.22,a: Monthly and accumulated CWR in the CSA; Figure 5.23.b shows the LR of current agriculture and accumulated LR in the CSA.

Return Flow from domestic network and waste water effluents in the CSA

In accordance with the recharge in terms of received domestic water (DW) and Waste Water Effluents (WWE), and as mentioned before in Chapter 4 (Sec.4.2.2), the total received domestic water from Auja Municipality Council is 367,398 m^3 per month. The old network leaks about 30% of this DW quantity. Estimated recharge of this leakage does not exceed 10% based on soil properties and evapotranspiration calculation (Chapter 3), so the total recharge from DW network is 112,194 m^3.However, it does not present a convenient recharge source in the buildup area. On the other hand, WWE recharge forms about 50% of WWE from permeable cesspits system that receives WWE in house hold level. The recharge quantity by WWE is estimated at146,959.2 m^3/a. However, Table 5.5 illustrates all these results.

Table 5.5 Part 1: DW recharge and WWE recharge at the CSA (2012-2013)

Date	Received Domestic Water (m^3)	Losses by network (30%), (m^3)	Recharge from DW, 10% (m^3)	Waste water effluent (80% of Domestic) (m^3)	Recharge from WWE (50%) (m^3)
Dec.2012	24673	7401.9	740.19	19738.4	9869.2
Jan.2013	17914	5374.2	537.42	14331.2	7165.6
Feb.2013	20554	6166.2	616.62	16443.2	8221.6
Mar.2013	26325	7897.5	789.75	21060	10530

Table 5.5 Part 2: DW recharge and WWE recharge at the CSA (2012-2013)

Apr.2013	29431	8829.3	882.93	23544.8	11772.4
May 2013	31916	9574.8	957.48	25532.8	12766.4
June 2013	37673	11301.9	1130.19	30138.4	15069.2
July 2013	49193	14757.9	1475.79	39354.4	19677.2
Aug. 2013	35918	10775.4	1077.54	28734.4	14367.2
Sep. 2013	30446	9133.8	913.38	24356.8	12178.4
Oct. 2013	31414	9424.2	942.42	25131.2	12565.6
Nov. 2013	31941	9582.3	958.23	25552.8	12776.4
Total	**367,398**	**110,219.4**	**11,021.94**	**293,918.4**	**146,959.2**

Lateral flow from mountains: Recorded historic data of water table of the wells in the CSA reflect recharge rate and recharge quantity in this model. They indicated monthly increase of water table throughout 38 years (1967-2005) by about 2 m increase in water table. Figure 5.23 illustrates water table variation regarding Well No. 19-15/005 friom1967 to 2005, and the same in several major wells in the CSA. This increase is very clear in wet years and after precipitation events along 4 to 5 months in every wet year. This could explain the lateral flow from mountains in the CSA.

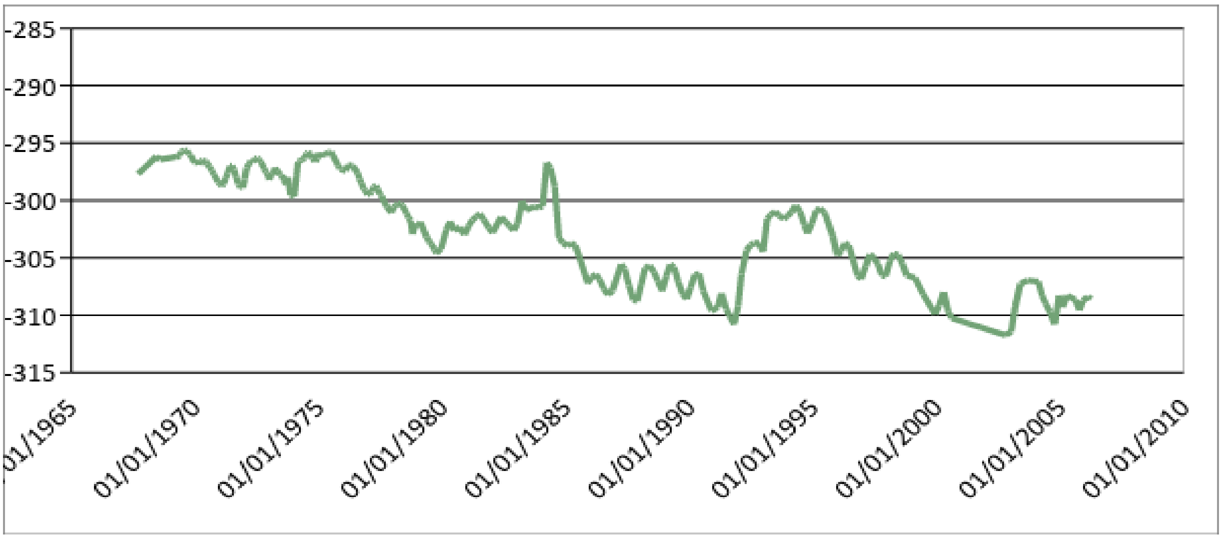


Figure 5.23: Monthly water table time series of observed Well No. 19-15/005 in the CSA.

In 2000, Millennium Engineering Group (MEG), estimated water quantity which leaves the mountain Aquifer by 19 MCM. This water recharges alluvial lenses in areas by direct contact where fractures exist. It is well known that Jericho area is close to Turonian springs which means that most of the southern part of the valley Rift Fault boundary between alluvial deposit and mountain aquifer acts as a barrier (Jericho Model, 2000). It is the southern boundary of Jericho area. But on the CSA Area in Auja area, the recharge occurs north of Wadi Nui'meh and south of Auja area. In the context of recharge estimation in the CSA, the alluvial deposit area is estimated by about 10 km^2 and the porosity is about 0.1. Therefore, and by referring to Water Table Fluctuation (WTF) methodology (Healy, R., Cook, P. 2002, using groundwater levels to estimate recharge, (Hydrogeology Journal 10, 91-109), recharge is estimated as:

$$R(t) = Sy * \Delta H / (t) \quad \cdots\cdots \quad (5.1)$$

Where;

Where R (t) = recharge rate,

Sy=specific yield (dimensionless)

ΔH=the drop of head pressure in time period

(t)=The time interval of water flocculation hydrograph

In our CSA, Sy is estimated from 0.01 to 0.0025 in alluvial deposit, ΔH is 2 m which that based on historic data and observed wells hydrograph, and the estimated recharge rate is between 0. 015 m/day and 0.02m/day in the time period. So, the recharge rate from mountain lateral flow in the CSA regarding average yearly rainfall in the upper catchment (600 mm/y) is about 0.1 Mm^3/year. In Shallow aquifer, by referring to several resources, run off, return flow, and mountain lateral flow, the estimated recharge is 0.3 Mm^3/y, 0.8 Mm^3/y and 0.1 MCM/year respectively in addition to 0.16 Mm^3/a from DW and WWE recharge. So, the total recharge in the CSA in shallow aquifer is about 1.36 MCM/ground water outflow **(**Discharge**):** In CSA, Most water discharge has two main sources: the shallow alluvial wells and deep carbonate aquifer, which is Auja Spring discharge. Details of the two main sources are as follows: Shallow wells in Jericho District are 49 wells, with only 35 working ones. Figure 5.24 Extraction from these wells has sharply decreased during the period 2001 to 2009 from about 6 Mm^3/a to 2.1 Mm^3/a in 2009.

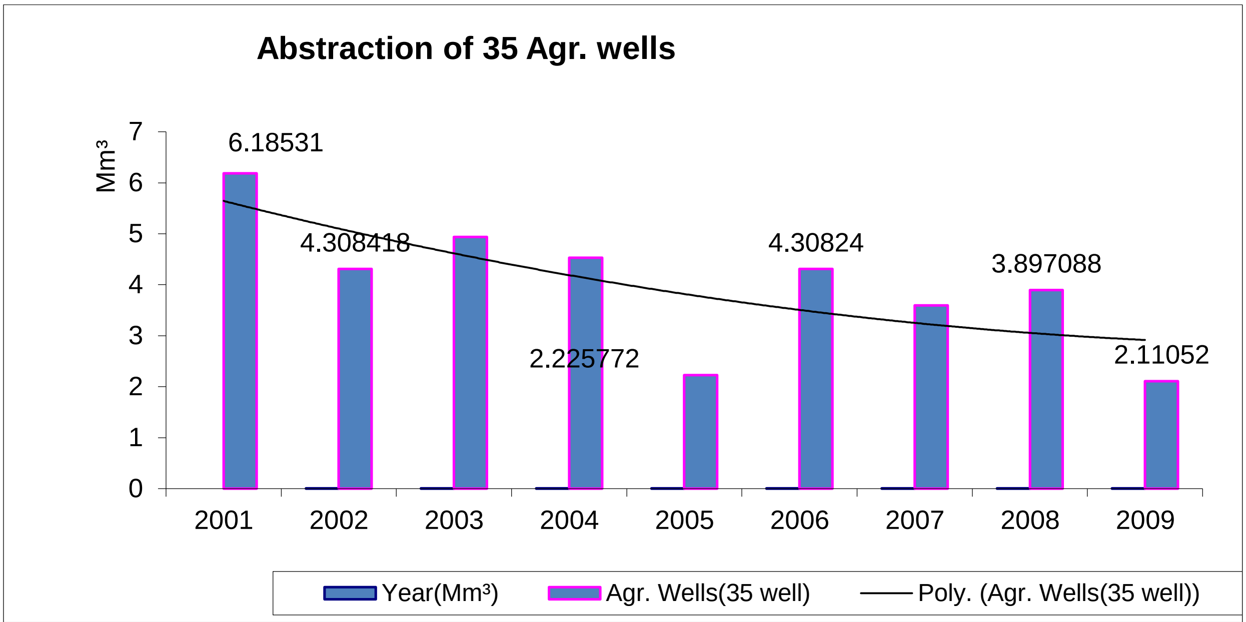


Figure 5.24: Jericho wells extraction during the period from 2001 to 2009. (PWA, 2013)

In the CSA, there are 10 working wells with a monthly extraction of about 1.02 mcm/a in wet years and 0.51 mcm/a in dry years. This model of worst case scenario of drought (Figure 5.25) displays monthly mean extraction of Auja wells in both dry and wet years.

During dry years many of those wells stop working. Therefore, the month with heavy extraction is during summer season, when evapotranspiration is very high.

Very little quantity of spring discharge will reach the irrigated area. Figure 5.25 and table 5.6 illustrate the wells monthly abstraction in the CSA.

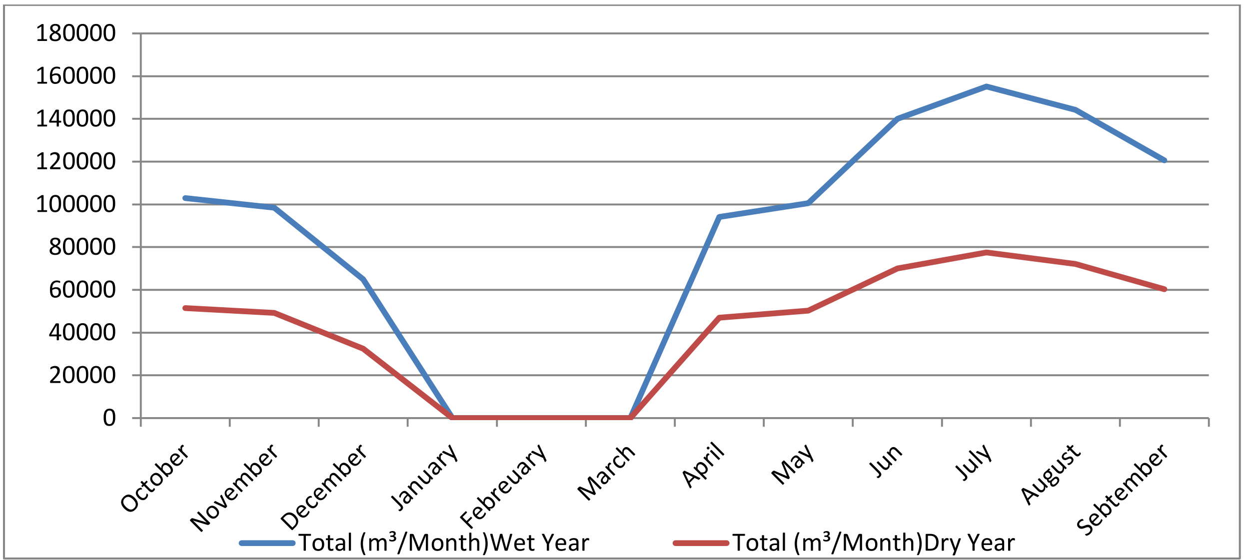


Figure 5.25: Monthly mean abstractions of Auja wells in both dry and wet years.

Table 5.6: Monthly mean abstractions of Auja wells during both wet and dry years

	Total mean Abstraction (m^3/Month) Wet Year	Total Mean abstraction (m^3/Month) Dry Year
October	103000	51500
November	98500	49250
December	65000	32500
January	0	0
February	0	0
March	0	0
April	94100	47050
May	100500	50250
June	140000	70000
July	155100	77550
August	144200	72100
September	120600	60300
Total	1021000	510500

Auja Spring discharge

In the CSA, and from mountain foot, Auja Spring (the largest spring in the LJV) is located in the karstic system aquifer and is formed from deep carbonate discharge with 8.61 Mm^3/a as mean discharge, with 50% of discharged water lost by wadi before it is conveyed by old open cement canal. The remaining quantity loses 50% because of damaged canal and its branches and by the irrigation system in the area. Only 2.15 Mm^3 are received for irrigation purposes. Figure 5.26 shows historic hydro graphic of Auja Spring discharge and rainfall from Dir Dibwan weather station.

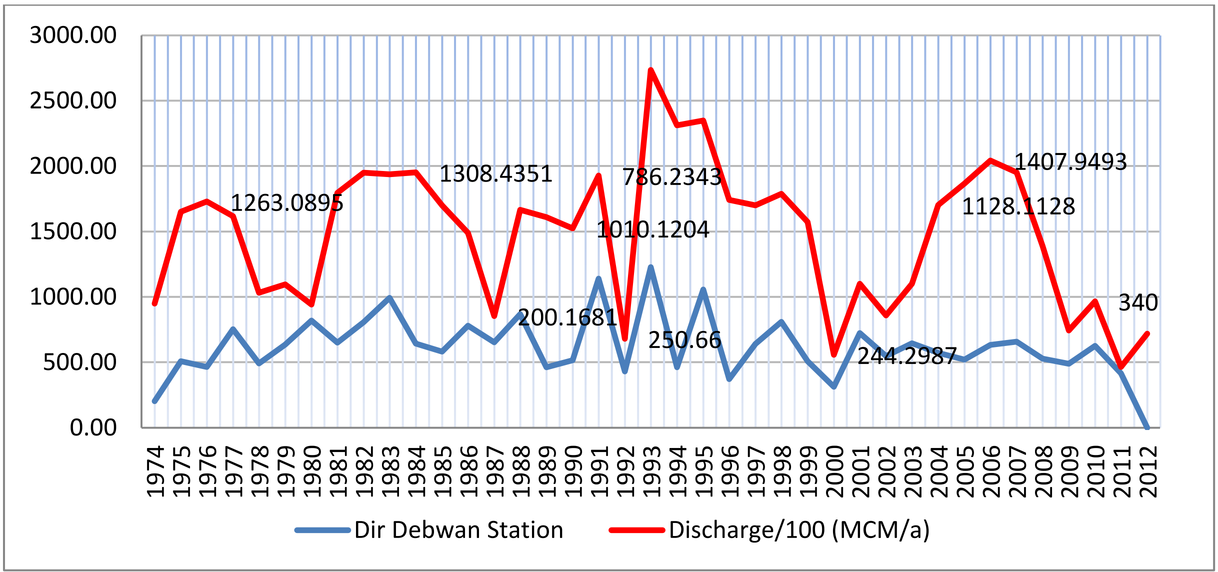


Figure 5.26: Auja Spring historic hydrograph (1974-2013) and historical rainfall records.

As shown in Table 5.7, total inflow of water into both alluvial shallow and deep aquifer is about 7.445 Mm^3/a, with only 1.46Mm^3/A of total inflow goes to the aquifer. It is assumed that 0.439 M Mm^3/a of storage inflows from subsurface of alluvial to Lisan formation. Therefore, the total abstraction from shallow aquifer based on wet years does not exceed 1.021 M Mm^3/a explainable by increased salinity of shallow aquifer in dry years in case of overexploitation coning from saline Lisan formation to alluvial deposit, in particular. Mean outflow from Auja Spring comes from deep carbonate aquifer; it is 8.12Mm^3/a as yearly mean discharge. This quantity of discharged water is distributed between irrigation (1.679 Mm^3/a), and return flow into shallow and deep aquifer. Part of this quantity also flows by Wadi Auja to the River Jordan, especially during flood days and in general during winter.

Table 5.7Part1: Inflow-outflow balance, discharge and recharge in the CSA

	Balance in Discharge and Recharge	Recharge /Discharge (Mm^3/a)	Remarks
Inflow	Wadi Auja Runoff	0.3	Shallow Aquifer
	Return flow from spring flow into irrigation canals	0.8	Shallow Aquifer
	Return flow from DW	0.11	Shallow Aquifer
	Return flow from WWE	0.15	Shallow Aquifer
	Return flow from spring losses into wadi to deep aquifer	3.83	deep aquifer and Jordan River
	Return flow from canal into deep aquifer	2.155	deep aquifer

Table 5.7Part2: Inflow-outflow balance, discharge and recharge in the CSA

	Lateral flow from Mountain Aquifer	0.1	Shallow Aquifer
	Total inflow into both deep and shallow aquifer	7.445	**Both deep and shallow aquifer**
	Total inflow into shallow aquifer	**1.46**	**Shallow aquifer**
Inflow into shallow aquifer	**Subsurface in flow from alluvial to Lisan**	**-0.439**	**Shallow Aquifer (storage in Lisan)**
Out Flow	Abstraction from wells	**1.021**	**Shallow Aquifer**
	Discharge from Auja Spring (Deep Aquifer)	8.61	Deep Aquifer
	Total out flow from both deep and shallow aquifer	9.12	**Both deep and shallow aquifer**
	Total out flow from shallow aquifer	1.021	
Differen ce of Inflow-out flow balance	Evapotranspiration and irrigation scheme from Spring Discharge	1.675	Difference of Inflow-out flow balance

5.7.5 Numerical Model

Flow model of Alluvial and Lisan formation was built using ground water Model System (GMS) MODFLOW version 7.1. This model geometry, in Figure 5.27 was designed, to calculate water flow budget in the CSA regarding the current situation of water budget.

Several scenarios were suggested based on IWRM in the CSA.

Predicting water budget for next decades took into consideration the climate change impact in

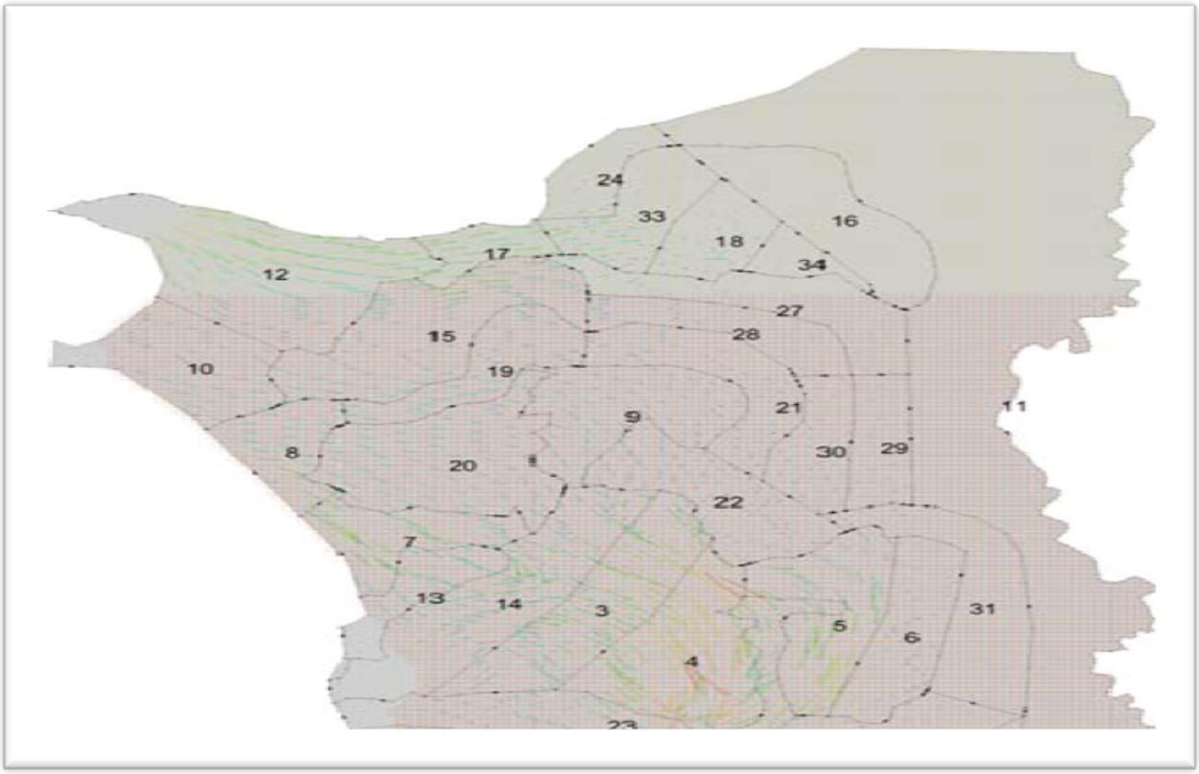


Figure 5.27 Basic Geometry of GMS model

the arid and semi-arid zone, with decreasing water budget by 10% and 20% during the coming decades up to 2050.

GMS Modflow code is referenced by 3-dimensional cell-centered finite difference. Saturated flow model was developed by the United States Geological Survey (McDonald and Harbaugh, 1988). It was performed by a State study and transition flow with wide input options relative to boundaries and layers built up stresses, files of Modflow generated by GMS before launching the MODFLOW model; and vice versa, output results post-processing to GMS.

This numerical model concerns the following parameters:

Domain and Boundaries; Recharge Zones in terms of sources; Interactions and characteristics of layers; and observation wells are as following:

1- Model Domain and Boundaries

Model area included approximately 70 km^2 which includes alluvial deposit area. The domain was defined by the Jordan River on the East and Rift Fault on the west, south and north respectively. Figure 5.28, Wadi Fasayel and Wadi Marrar.

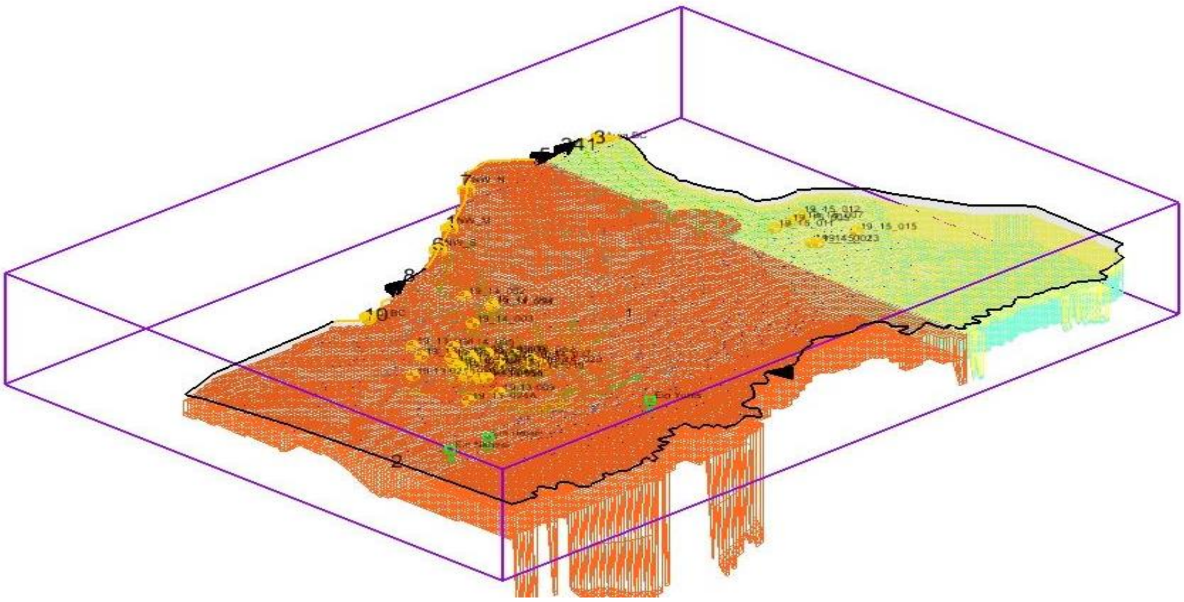


Figure 5.28: Domain and Boundary of Jericho-Auja Model based on geometry design

South and north boundaries are modeled with no flow but they are connected with impermeable Lisan formation. The eastern boundary (The Jordan River) was modeled as head boundary of the Jordan River while the western boundary was modeled with a defined flow in which this western boundary formed the contact between mountain aquifer and the alluvial. Water flow (Quaternary) in the CSA is from west to east (Figure 5.29) shows the mean flow rate (about 7,000 CM/d) during the period 2000-2010. This flow rate was estimated based on lateral flow and subsurface flow in addition to spring discharge infiltration through Wadi Auja.

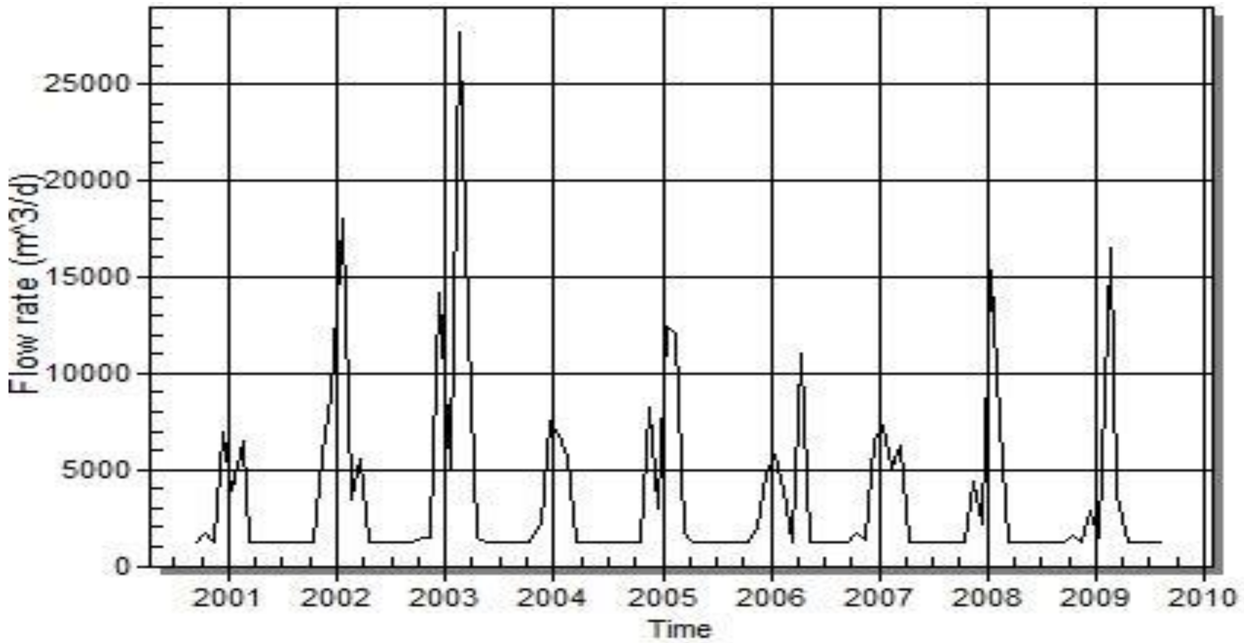


Figure 5.29: Flow rate of Western Boundary of Jericho-Auja model during the years 2000-2010

In the context of Points boundaries, there are 37 wells in Jericho and Auja area. They are in transient flow according to PWA Records, but, unfortunately, not all of these wells have continuity by time series because of drought during operation seasons and discontinuity during monthly reading. This caused many of these wells to be in a steady state flow in Jericho-Auja area. Total abstraction of those wells in case of discontinuity was divided into monthly discharges according to available records. Table 5.8 views a sample of Jericho-Auja wells. This sample is the Auja wells.

Table 5.8: Wells of Auja area considered in the model

Name	X	Y	Z	Type	Flow Rate CM/d	From layer	To layer
19_15_023	196020	150090	0	well	<transient>	1	1
19_15_015	196150	151140	0	well	<transient>	1	1
19_15_012	194590	150940	0	well	<transient>	1	1
19_15_011	194750	150000	0	well	<transient>	1	1
19_15_007	194870	150760	0	well	<transient>	1	1
19_15_005	194750	150440	0	well	<transient>	1	1

Table 5.9 Explains Horizontal and vertical discretization of the model, the grid space is about 1,000 m in both direction X and Y. The X-origin is 186,780 m with 200 cells 15,460 meters long each into I-direction and the Y-origin is 134,080 m long of 21,000 meters. It is with 150

centroid cells into j-direction. In this design, z-origin is 1,788 m with 3,577meters length. It has two cells into k-direction. This refers to layers which are alluvial and Lisan which have no exactly defined thickness. Therefore, alluvia deposited thickness is based on wells' depth, but Lisan may be extended to more than 1,500 meters. Therefore, the vertical boundary is graded between the two layers.

Table 5.9: Grid spacing and cell center design in numerical model

Grid type:	Cell Centered	Unit
X origin:	186780	(m)
Y origin:	134080	(m)
Z origin:	-1788.615127	(m)
Length in X:	15460	(m)
Length in Y:	21000	(m)
Length in Z:	3577.2302	(m)
AHGW Rotation angle:	90	
Minimum scalar:	-359.497	
Maximum scalar:	-119.806	
Numb cells i:	200	
Numb cells j:	150	
Numb cells k:	2	
Number of nodes:	91053	
Number of cells:	60000	
No. Active cells:	35424	
No. Inactive cells:	24576	

2-Recharge Zoning and Sources

Back to recharge calculation from several sources in conceptual model, and figure 5.30

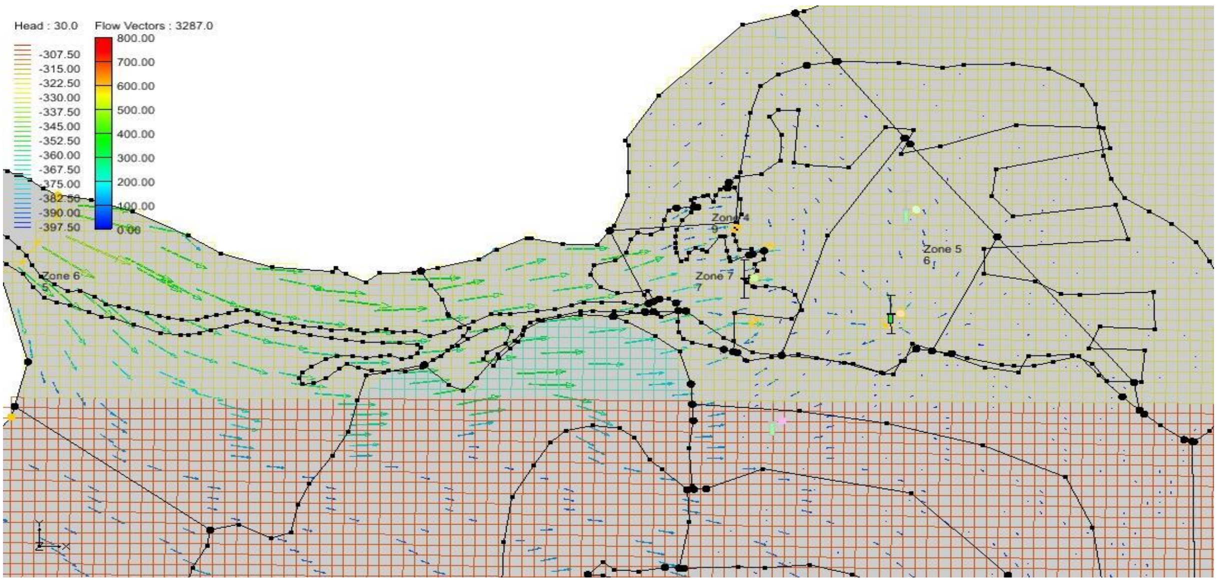


Figure 5.30: Recharge Geometry Zones in the CSA

Several resources were found: (Return flow, lateral from mountain flow and surface run off from Wadi Auja). The total inflow in shallow aquifer in the CSA is about 1.46 Mm^3/a. Geometry reflects those 4 main recharge zones into CSA: Zone 4, Zone 5, Zone 6, and Zone 7 In table 5.10, there are five recharge sources: Domestic Water Network Leakage (DWNL), Waste Water Effluent Cesspits (WWEC), Irrigation Network Leakage, Surface Runoff and Mountain lateral flow.

Table 5.10: Recharge sources in the CSA

		Recharge Sources				
Name	Recharge m/d	DWNL	WWEC	INL	Surface Run off	Mountain lateral flow
Zone 6	<transient>				X	X
Zone 5	<transient>			X		
Zone 7	<transient>	X	X			
Zone 4	<transient>	X	X	X		

3-Layer Characteristics

Regarding the nature of alluvial deposit, the upper layer is confined to semi-confined**.** It is made of lenses overlaid by reasonable thickness of alluvial marl and compact gravel site that makes the whole system act as confined aquifer (Jericho Model, PWA, 2000). On the other hand, there is not enough data on the lithology of the Lisan formation, however it has been divided here into three members bound in offshore sections by prominent gypsum layers that were traced laterally over a large distance basin wards. The Lower and Upper members in the offshore sections consist mainly of alternating laminae of aragonite and silt-sized clasts, while the Middle member contains large portions of sandy layers, (Yuval Bartov, 2002).

However, a characteristic closely related to effective porosity is the specific yield of the aquifer which is the volume of water per unit volume of aquifer that can be extracted by pumping. The amount of water stored or released per unit volume of aquifer given unit head change where S = Ss, b= the aquifer thickness (R. W. Buddemeier, J. A. Schloss, 2000). Accordingly, those Aquifer parameters were estimated by these concepts above and regarding a pumping test on Auja Well No.19-15/019 conducted by AL Quds University (Amer Marie, Kayan Manasra), in April 2012/ May 2013.

The study was concerned with two layers. Table 5.11 has clear difference in horizontal and vertical hydraulic conductivities (k); alluvial layer has horizontal k by a range of 1.5 to 2.5, while in Lisan layer horizontal k is from 0.08 to 0.12. Estimating specific storage and specific yield into two layers is not a big difference because of similarity of layer compacting and also by two-layer structure.

Table 5.11: Hydraulic properties of Alluvial and Lisan layers.

Layer 1 Alluvial with overlay and interfingering of Lisan formation					Layer 2 Lisan formation				
Name	Horizontal K (m/d)	Vertical K (m/d)	Specific storage (l/m)	Specific yield	Name	Horizontal K (m/d)	Vertical K (m/d)	Specific storage (l/m)	Specific yield
Lisan	0.08	0	5.00E-06	0.01	Lisan	0.12	0	5.00E-06	0.01
	0.08	0	5.00E-06	0.01		0.12	0	5.00E-06	0.01
	0.8	0	5.00E-06	0.01	Alluvial	1.7	0	5.00E-06	0.01
Alluvial	2.6	0	5.00E-06	0.01		1.7	0	5.00E-06	0.01
	2.6	0	5.00E-06	0.01		0.12	0	5.00E-06	0.01
	0.08	0	5.00E-06	0.01		0.12	0	5.00E-06	0.01
	0.8	0.2	0.00005	0.01		1.7	1	0.00005	0.01
	0.1	0.1	0.00005	0.01		1.2	1	0.00005	0.01
	0.08	0.02	0.00005	0.01	Alluvial	1.7	1	0.00005	0.01
	0.15	0.1	1.00E-07	0.0025		1.7	1	1.00E-07	0.0025
	0.0001	0	5.00E-09	0.00225		0.12	0	5.00E-07	0.00225
	1.5	0.3	5.00E-08	0.00225		1.7	1	5.00E-08	0.00225
	0	0	5.00E-07	0.0025		1.7	1	5.00E-07	0.0025
Alluvial	2.6	0.2	5.00E-06	0.01		1.7	1	5.00E-06	0.01
	0	0	5.00E-07	0.0025		1.7	1	5.00E-07	0.0025
	0.08	0	5.00E-09	0.002	Lisan	0.12	0	5.00E-09	0.002
Alluvial	1.5	0.3	5.00E-08	0.00225		1.7	1	5.00E-08	0.00225
	0.08	0	5.00E-09	0.002		1.7	0	5.00E-09	0.002

4-Observation Wells in the CSA

Historical records found only two main wells in the CSA- Nos.19-15/05 and 19-15/023 with historical records from 2000 to 2012. The monthly abstraction of these wells is considered as reference to calibration according to their transition head; other wells (8 wells in the CSA) are used as steady state calibration according to their mean dynamic head regarding some historic discontinuity records. There are records from 1967 but unfortunately they are not time series data. In this case, transition heads of wells 19-15/05 and well 19-15/023 were approved for this model calibration, (Figure 5.31a, b shows those two wells).

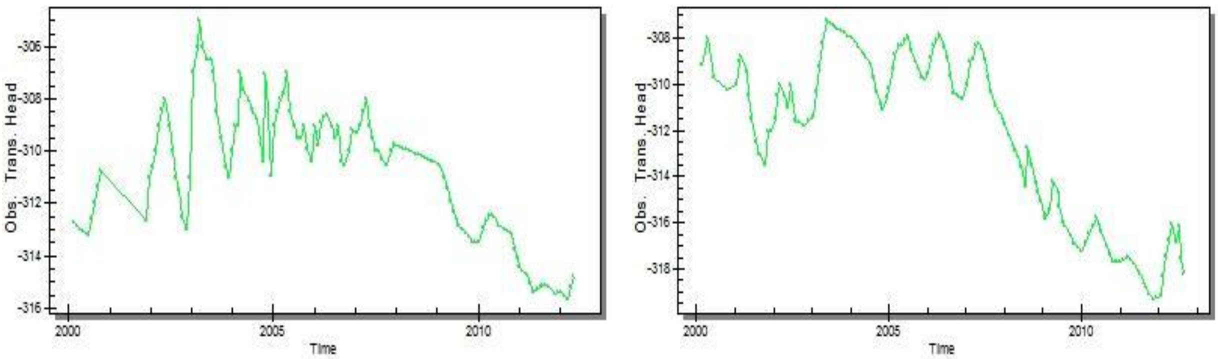


Figure 5.31: Transition head of well No.19-15/05, and well No.19-15/023 Respectively.

Observation wells are distributed in Jericho Area including the CSA into those wells. Upcoming saline water reached equilibrium very quickly when saline water was allowed to be pumped initially with overall salinity value of pumped water of 2,000 mg/L (Khaled Nassereddin, 1998). This led to stoppage of those observation wells in summer season. Pumping records caused by this saline water upcoming is much more obvious in a range of 90 m to 100 m depth, (Figure 5.32 shows those observed wells in the CSA).

Figure 5.32: Observation wells in Auja area

5.7.6 Model Calibration and Sensitivity Analysis

With regard to calibration task through this model, simulation ran many trials during several model initial parameters (Boundary Conditions), which are included in recharge rate. Hydraulic conductivity, specific storage and specific yield were adjusted by the first simulation to a range of 10 m head difference regarding historical data. But the several simulation trials with fixed parameters and changing recharge rate from return flow were produced by Auja Canal and applied irrigation. Changing high recharge sensitivity rate was remarked. However, the other parameters did not reflect high sensitivity to calibration procedure.

In figure 5.34 two wells have been calibrated regarding monthly historical data, i.e. Well No.19-15/005 and Well No.19-15/023. It was transient calibration referenced with transient observation. It was uneasy for each one's head to have it coincide with calibration curve for both wells. This explains the complexity of the hydrogeological system in the model and how much overlay and into fingering exists between the two model layers.

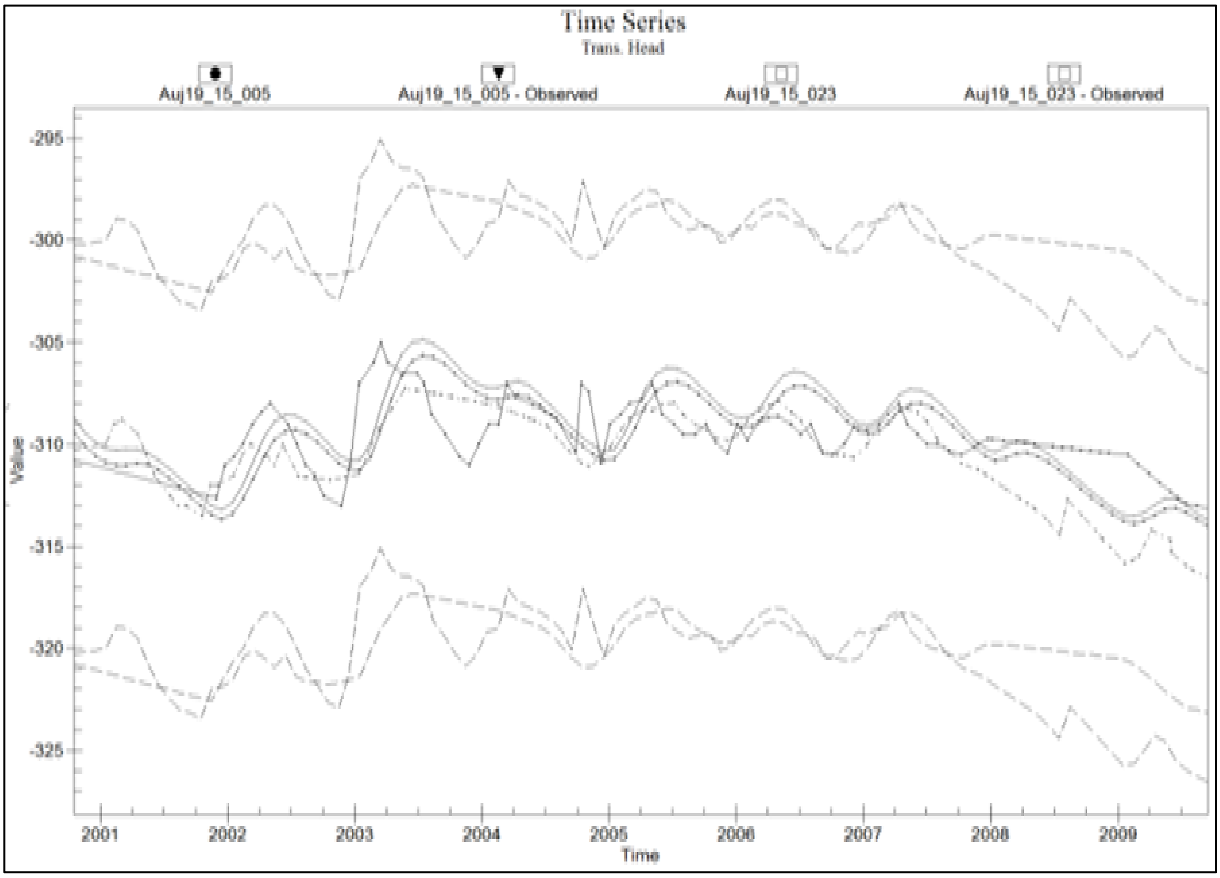


Figure 5.34: Calibration curves with calibration target of wells No. 19-15/005 and Well No.19-15/023 in the CSA**.**

Table 5.12 illustrates flow budget calibration in the CSA. In this Table, budget term and flow rate were listed into layers identified by ranges from 1 to 1 of layer 1 and range 2 to 2 of layer 2. By this computer source code identification, recharge was calculated in flow budget through those zones which are represented in layers 1 and 2. Therefore, the inflow and the out flow in budget terms are clear and good enough to satisfy the calibration target of the CSA. Further, summary of in-out flow balance is computed. This summary gives percent discrepancy between 1% to -2%. In this case, it is convenient enough to have these simulation results moved forward into several proposed scenarios. But before addressing these scenarios, it should be taken into consideration that Management of Aquifer Recharge (MAR) is one tool approach among many for handling Total Water Strategies Development scenarios, which should reflect the ability to take those water management strategies into consideration.

Table 5.12: Flow Budget Computation based on Calibrated Simulation of CSA Model.

Budget Term	Flow Rate (m^3/day)	Flow Rate (m^3/day)	Flow Rate (m^3/day)	Flow Rate (m^3/day)
	Flow Budget for Zone 1	Flow Budget for Zone 2	Flow Budget for Zone 11	Flow Budget for Zone 22
IN:				
Storage	9057.84683	1465.40743	5328.6243	3610.1673
Constant heads	0	0	0	0
Drains	0	0	0	0
Wells	9.296657085	0	3652.0654	1734.25
Recharge	2142.744739	195.8855111	424.88606	31.093066
Zone 2 to zone 1	80.25263696	0.10412679	2267.2781	0
Zone 11 to zone 1	3214.335657	0	263.23657	629.04917
Zone 22 to zone 1	0	580.1770493	5443.4477	134.64143
Total IN	**14504.47652**	**2241.574118**	**17379.538**	**6139.2009**
OUT:				
Storage	13.99855442	0.365921197	14032.061	114.93472
Constant heads	0	0	0	0
Drains	0	0	0	0
Wells	12221.61207	1269.277225	0	0
Recharge	0	0	0	0
Zone 1 to zone 2	0.10412679	80.25263696	3214.3357	0
Zone 1 to zone 11	2267.278075	263.2365707	0	580.17705
Zone 1 to zone 22	0	629.0491684	134.64143	5443.4477
Total OUT	14502.99283	2242.181523	17381.038	6138.5595
SUMMARY:				
IN - OUT	**1.483689504**	**-0.607405115**	**-1.4996428**	**0.641465618**
Percent Discrepancy	0.010229707	-0.027093587	-0.0086284	0.010449228

5.8 Water strategies based on recharge calculation and management of aquifer recharge (MAR) in CSA:

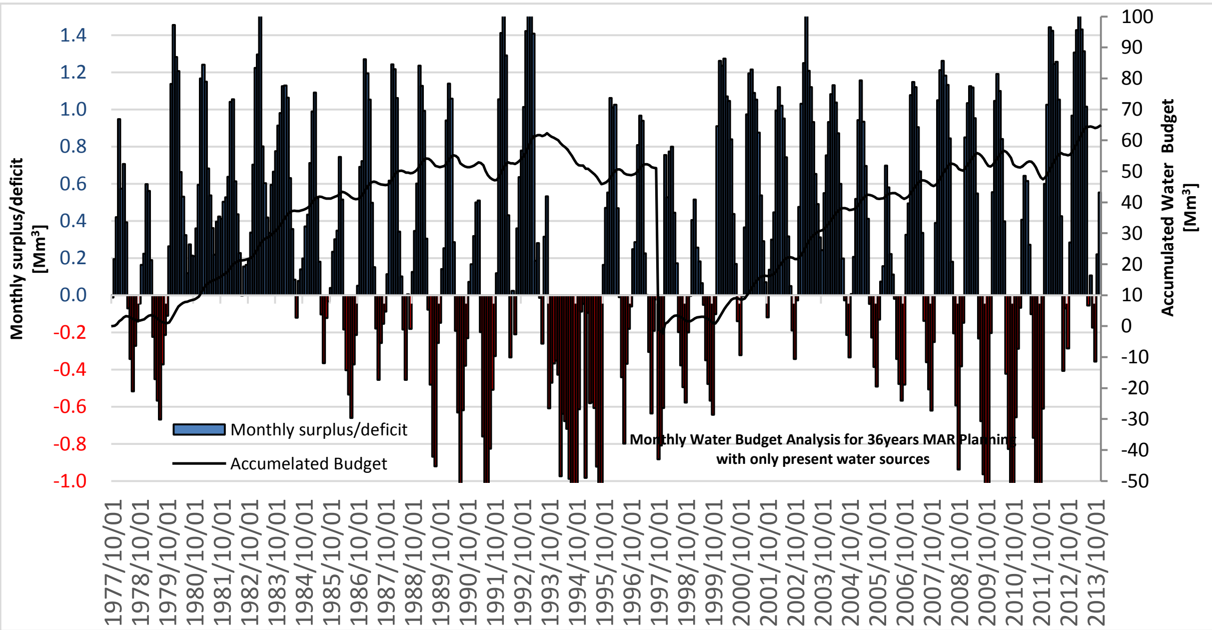
Back to Section 5.4 (Water Management Strategies in the CSA): The section suggested three main strategies: WSI, WSII and WSIII and five ADS relevant to crops and irrigated area. They were based on irrigated area in case of being under current agriculture situation as it is and the irrigated area extension. But the suggested WSs did not discuss the MAR as a management tool. Therefore, in this section all WSs should take into account MAR as an important and a core tool for this WSs management.

5.8.1 Water Strategy NO.1 (WSI)

This water strategy studied the current situation scenario with records of ordinary current recharge during long time series from 1977 to 2013. The routine recharge and routine demands took into consideration population growth. Time series were extrapolated in accordance with ordinary monthly abstraction and regular transient head of several wells in the CSA, taking into consideration the decrease of irrigated area from 15,000 donums in 1977 to about 3,000 donums in 2013, i.e. 500% decrease. In this scenario, the model explains and answers the decrease of transient head in the CSA from 3 to 4 m (Figure 5.35). This has nothing to do with (WSI) scenario considered as the resource management

Figure5.35: Simulated Transient head of the CSA by GMS-Modflow model which has nothing to do with the current status

Therefore, monthly water deficit during the period of 1977 to 2013 ranged between 1Mm^3 to 0.2 Mm^3 during summer and dry seasons. Monthly surplus exceeded 1.5 Mm^3 during wet seasons. There is a large quantity of accumulated water into the last 10 years estimated at about 45 Mm^3 (figure 5.36)Figure.



5.36: Monthly water budget analysis for 36 years.

WSI was based on the present current situation according to irrigated agriculture and available water in the CSA. CWR is 3 Mm^3/a for irrigation of 4,474 donums for two seasons of vegetables planting and the mean available water with minimum loss (fresh from spring and storm water, brackish) is 8.81 Mm^3/a. They are 6.89 Mm^3/a from the spring as fresh water, 1.14 Mm^3/a as brackish water from shallow well aquifer, and 0.9 Mm^3/a. There is also fresh water from storm water (Table 5.13), which was modified from Table 4.12, which explains available water and current untapped water in addition to water surplus regarding monthly water budget analysis (Figure 5.35) in different water resources in the CSA. It also shows water resources outside the CSA in case of importing water as one of these contemplated options of water importing according to water resources analysis in Section 4.4; but in actual use of available water, there is only 4.31 Mm^3/a in wet years from Auja Spring and 0.8 Mm^3/a from shallow aquifer, which are used for irrigation in the CSA. (Table 5.13)

Table 5.13: Available water from different resources and CUWR in the CSA.

Source of Water	**WP**	**Water Availability**		**Water Surpluses**	**CUWR**
		Actual	**Min. loss**		
1.Fresh Water	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a	Mm^3/a
1.1 Auja Spring	**8.61**	**4.31**	**6.89**	**4.14**	**2.58**
1.2 *Deep Carbonate Wells (West)	**12**	**0.25**	**0.37**	**0.12**	**0.01**
1.3 Surface Run off	**1.2**	**0.12**	**0.9**	**0.78**	**0.78**
Fresh Water Summ.	**21.81**	**4.68**	**8.16**	**5.05**	**3.37**
2.Brackish Water					
2.1 alluvial shallow wells	**1.2**	**0.8**	**1.14**	**-0.16**	**0.34**
2.2 *Carbonate east wells(Fashkha wells)	**3**	**0**	**0.9**	**0.9**	**0.9**
2.3 Fashkha Spring	**80**	**0**	**0**	**0**	**0**
Brackish Water Summ.	**84.2**	**0.8**	**2.04**	**0.74**	**1.24**
3. Treated Effluent					
3. BWWTP	**1.85**	**0**	**1.67**	**0**	**1.67**
3.2 JWWTP	**3.7**	**0**	**3.33**	**0**	**3.33**
Auja Raw Waste Water	**0.19**	**0**	**0.17**	**0**	**0.17**
Treated and Raw WW sum.	**5.74**	**0**	**5.17**	**0**	**5.17**

Regarding suggested ADS in the CSA, and based on WSI (Do nothing), the following could be concluded:

Based on Zone No.1, which is a new virgin area with 4,000 dounums, with one option into five ADS: this option suggests only date palm trees as one main useful crop. At the same time it is a salt-resistance crop which gives chance for mixing fresh with salty water during drying seasons.

According to the current situation (Zone 2), the suggested crops could be irrigated by about 4 Mm^3/a with different kinds of crops in the area.

Approximately, the same quantity of water could be used in the new virgin area of Zone 3, which is about 5,000 donums with date palms, grapes and regular vegetable crops. Table 5.14 illustrates all discussed ADSs with three probable area zones taking into consideration the current situation in Zone 2 area.

Table 5.14: ADS scenarios in light of the irrigated area extension in the CSA into three zones.

ADS	Zone 1			Zone 2			Zone 3			Total
	Crop	Area	CWR (Mm^3/a/area)	Crop	Area	CWR (Mm^3/a/area)	Crop	Area	CWR (Mm^3/a/area)	CWR (Mm^3/a/Area)
ADS1	Date Palms	4000	4.23	Date Palm	3750	3.96	Date Palm	4865	5.14	**13.33**
ADS2	Date Palms	4000	4.23	Grapes	3750	3.58	Grapes	4865	4.64	**12.45**
ADS3	Date Palms	4000	4.23	Veg. Green House	2000	3.1	Grapes	3000	2.86	**14.08**
				Medical Green house	1750	1.83	Reg.Veg	1865	2.06	
ADS4	Date Palms	4000	4.23	Banana	3750	3.95	Grapes	4865	4.64	**12.82**
ADS5	Date Palms	4000	4.23	Veg.Hydroponic	2000	1.19	Grapes	4865	4.64	**11.89**
				Med.Green House	1750	1.83				

This first water strategy (WSI), which depends on available water, soil and water salinity, and also the kinds of irrigated crops in the area, may suggest considering new water strategies that should take into consideration water quality depletion and scarcity of water quantity in the current case or in case of extending the irrigated lands. Therefore, MAR will be a main tool for this purpose suggested for the Second Water Strategy (WSII).

5.8.2 Water Strategy Management (WSII) of Aquifer Recharge (MAR)

What are MAR's objectives and benefits? They include:

- Storing water in aquifers for future use;
- Smoothing out supply/demand fluctuations;
- Being part of an integrated water management strategy;

• Stabilizing or raising groundwater levels where Auja wells are over-exploited leading to high salinity concentration;
• Applying (them) when no suitable surface storage site is available;
• Reducing loss through evaporation and runoff;
• Impeding storm runoff and soil erosion;
• Improving water quality and smooth fluctuations;
• Maintaining environmental flows in streams/rivers;
• Managing saline intrusion or land subsidence; and
• Disposing/reusing of waste/storm water.

The CSA in the shallow aquifer is alluvial sediments; therefore, alluvium can consist of fluvial, marine and lacustrine deposits ranging in thickness from a few tens of meters to kilometers like Lisan formation. Major deposits are usually found in the lower reaches of river basins forming flood plains. The topographic relief will usually be low, as will natural hydraulic gradients. The sediments will range from highly permeable coarse gravel to impermeable fine-grained silt and mud. Groundwater levels will naturally be shallow where rivers are perennial, but may be deeper in arid regions or where pumping has lowered the water table. In the former case, there is little storage space available in the aquifer and the resources in the aquifer need to be exploited, which may result in river water being induced into the aquifer.

In light of the above MAR objectives, and in order for the GMS-Mod flow model results in the CSA, based on current scenario (WSII), investigation suggests several methodologies for MAR derived from UNESCO International Hydrological Programmed HP/2005. These methodologies could be applied on the second water strategy based on managing aquifer recharge (WSII). These selected strategy methodologies are as the follows:

Spreading methods which approach CSA as follows:

- Infiltration ponds and basins which usually could be more practical in case of controlled flooding by leaky dams. This is estimated to collect about 1 Mm^3 during flooding events (6 days) in winter time (December- March) through Wadi Auja, which is closed to irrigated lands, (closed to Zones 4, 5, 6 and 7 by model Geometry). This recharging quantity is estimated at 0.5 Mm^3/a.

- Soil Aquifer Treatment (SAT) is required in the area of irrigated vegetables (2,000 dounums), which has a high SAR build up through years of cropping, by flushing soil inside green houses. Intensive agriculture indicates huge quantity of fresh water was used by farmers for about one thousand dunums providing fresh water for flushing during night (7 hours) pumping 70 m^3/hr, for one dunum of greenhouses intensive agricultures. It is 500 m^3/night/donum. Flushing process is usually launched in 5 nights for preparing the soil. Water quantity used for flushing of the entire cropping area is about 2.5Mm^3/a. Recharge is estimated at 95% of total flushing quantities (2.4 Mm^3/a); so, in this manner recharge by irrigation is estimated at 10% of water used for irrigation.

Using Auja canal surplus for wells injection is a methodology for aquifer storage and recovery (ASR). There is about 12 Km long of Auja Canal which distributes water into irrigated lands of Auja area. In winter, water needs are minimum with maximum fluctuation of Auja Spring canal and in summer period large quantities of fluctuated water are lost due to irrigation mismanagement. Surplus fluctuated water is distributed into irrigated lands. It is estimated at 50% (about 2 Mm^3 in wet years). 1Mm^3 could infiltrate by the agricultural ponds located in the irrigated area. In this case, about 95% of total quantity could recharge the shallow aquifer (Marie, A., and Manasrah, K., 2012) (Pumping, Storage and Recovery, 2012) with 0.95 Mm^3 and another 1Mm^3 could be injected directly into 10 wells in the area. Regarding the pumping test of well 19-015/019 (2012), 250 m^3/day were injected and pumped (Marie, A., Manassrah. K., 2012). This research in particular leads to good assumption to inject all ten wells with 250 m/day over all the year in wet condition. This is used by model scenario WSII.

In this strategy (WSII), water surplus in wet winter season was assumed to recharge from Auja canal into agricultural ponds and by direct injection in agricultural Auja wells. The estimated recharged quantity was 2.5 Mm^3. The Model shows the difference between current situation and MAR by injection and agriculture pond recharge by about 2 m increase in water table indicating ASR's ability during the irrigation system in the area. On the other hand, it is a good chance to improve water quality and decrease salinity in pumped water during next season (Summer Season). Figure 5.37 shows this difference with a calibrated target between -300 to -320. The simulated Head is around -312 along the historical period in 36 years comparing simulation with the current situation. It is about -314 to -315 head. This gives a clearer view for this technique of MAR in these CSA.

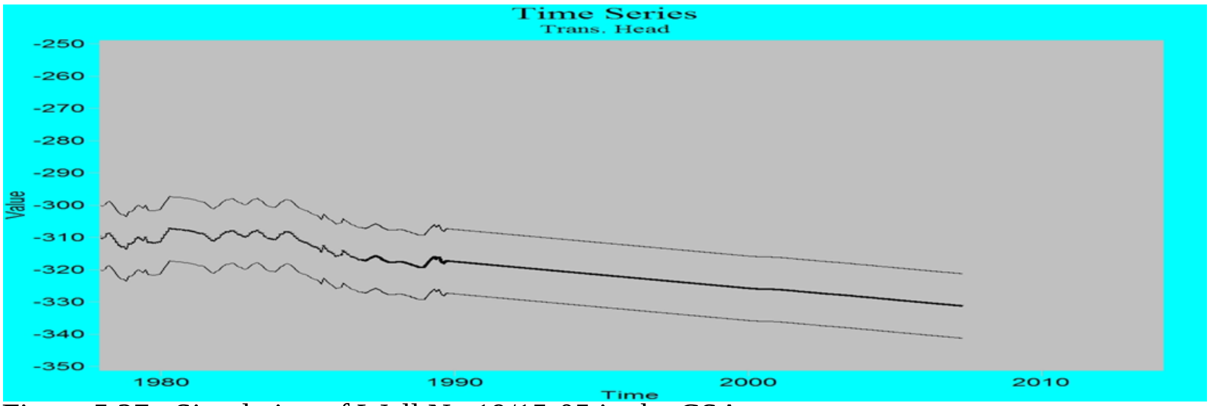


Figure 5.37: Simulation of Well No.19/15-05 in the CSA

Monthly water budget analysis explains the new situation if MAR is applied; the accumulated budget increases in winter and spring months by about 2 MCM. This increase gives new vision for irrigated land extension by new 2,000 donums on average as irrigated lands. Figure 5.38 shows this increase of monthly water budget.

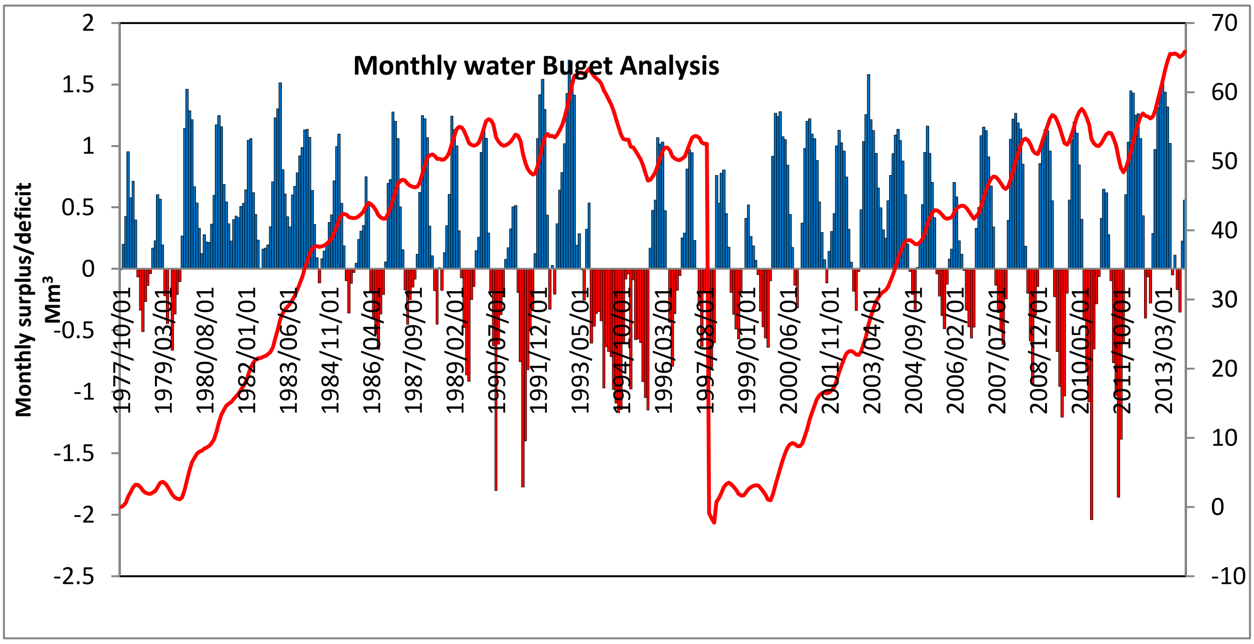


Figure 5.38: Water budget analysis applying MAR and ASR using direct injection and agricultural ponds infiltration in the CSA

Figure 5.39 explains continuity of water surplus in winter and spring periods as well as deficit during summer months (June to the end of August). This water shortage did not increase by MAR. On the contrary, it seems to decrease by about 1 Mm^3 compared with the current situation for two seasons; but deficit still happen and irrigated land expansion is unable to irrigate at least 10,000 donums. In this case, MAR could provide surplus water with additional 1,500 donums irrigated lands by ponds' infiltration and direct wells injection.

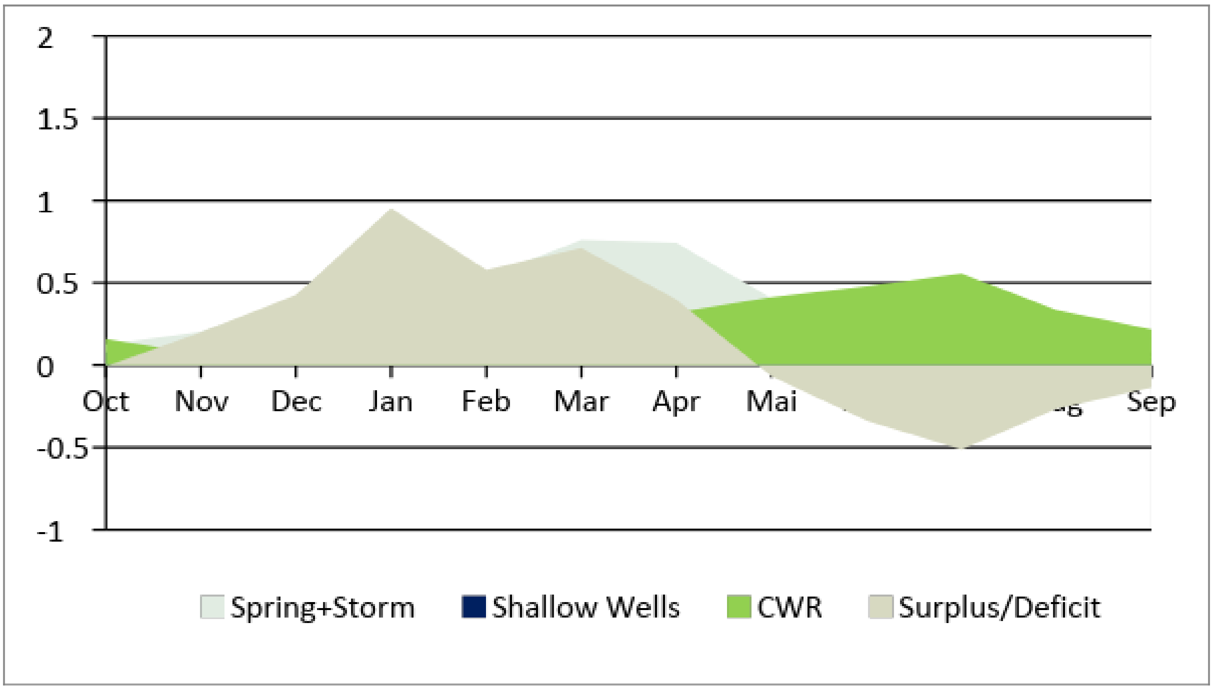


Figure 5.39: Monthly Water deficit and surplus in the current situation and MAR

Using MAR and ASR approach strategy as well as the current situation (WSII), (Table5.15) will provide 7.23 Mm^3 of water: 4.31 Mm^3 from Auja Spring, 0.12 Mm^3 from surface Run off, and 2.8 Mm^3 from shallow aquifer wells. This strategy gives a new promising solution in the area in terms of water quality and quantity.

Table 5.15, Part 1: WSII, injection and Agricultural ponds infiltration from Auja canal .

Water Source	**WP**	**Water Availability**		**Water Surplus**	**CUWR**
		Actual	**Min. loss**		
Fresh Water	(Mm^3/**a)**	(Mm^3/**a)**	(Mm^3/**a)**	(Mm^3/**a)**	(Mm^3/**a)**
1.1 Auja Spring (WSII)	8.61	4.31 (WSII)	6.89	4.14	2.58
1.2 *Deep Carbonate wells (West)	**12**	**0.25**	**0.37**	**0.12**	**0.01**
1.3 Surface Run off (WSII)	**1.2**	**0.12(WSII)**	**0.9**	**0.78**	**0.78**
Fresh Water Summary	**21.81**	**4.68 (WSII)**	**8.16**	**5.05**	**3.37**
Brackish Water					
2.1 Alluvial Shallow wells+MAR (Direct injection and Ponds infiltration ASR) (WSII)	**2.8**	**2.8 (WSII)**	**0.0**	**0.0**	**0.0**
2.2 *Carbonate East Wells (Fashkha Wells)	**3**	**0**	**0.9**	**0.9**	**0.9**

Table5.15, Part2 : WSII, injection, and Agricultural ponds infiltration from Auja canal

2.3 Fashkha Spring	**80**	**0**	**0**	**0**	**0**
Brackish Water Summ.	**84.2**	**0.8**	**2.04**	**0.74**	**1.24**
Treated Effluent					
3. BWWTP	**1.85**	**0**	**1.67**	**0**	**1.67**
3.2 JWWTP	**3.7**	**0**	**3.33**	**0**	**3.33**
Auja Waste Water	**0.19**	**0**	**0.17**	**0**	**0.17**
Treated and Raw WW sum.	**5.74**	**0**	**5.17**	**0**	**5.17**

5.8.3 Integrated Water Resources Management Strategy (IWRM), Water Strategy No. 3

This third Water Strategy is based on all probable potential water resources in the CSA and outside. In this case, treated effluent should be added to the two resources of treated effluent. The first one is BWWTP which produces 1.67 MCM/a and the second is JWWTP which adds 3.33 MCM, in addition to raw sewage water of Auja Village with 0.17 MCM/a and 2 MCM from MAR of Auja canal surplus. This water strategy should provide about 15 MCM of water for irrigation to be used for three different suggested agricultural zones (Zone 1, Zone 2 and Zone3). Table 5.16 shows the actual current potential resources with probable availability of different water resources.

Table 5.16 Part 1: WSIII: Probable availability of water potential in the CSA

Source of Water	**WP**	**Water Availability**		**Water Surpluses**	**CUWR**
		Actual	**Min. loss**		
Fresh water	**(Mm^3/a)**	**(Mm^3/a)**	**(Mm^3/a)**	**(Mm^3/a)**	**(Mm^3/a)**
1.1 Auja Spring	8.61	4.31	6.89	4.14	2.58
1.2 *Deep Carbonate wells (West)	**12**	**0.25**	**0.37**	**0.12**	**0.01**
1.3 Surface Run off	**1.2**	**0.12**	**0.9**	**0.78**	**0.78**
Fresh Water Sum.	**21.81**	**4.68**	**8.16**	**5.05**	**3.37**
Brackish Water					
2.1 Alluvial shallow wells and MAR (Direct injection and ponds infiltration ASR)	**2.8**	**2.8**	**0.0**	**0.0**	**0.0**
2.2 *Carbonate east wells (Fashkha wells)	**3**	**1**	**0.9**	**0.9**	**0.9**

Table 5.16 Part 2: WSIII: Probable availability of water potential in the CSA

2.3 Fashkha spring	**80**	**1**	**0**	**0**	**0**
Brackish Water Summ.	**84.2**	**0.8**	**2.04**	**0.74**	**1.24**
Treated Effluent					
3. BWWTP	**1.85**	**1.48**	**1.67**	**0**	**1.67**
3.2 JWWTP	**3.7**	**2.96**	**3.33**	**0**	**3.33**
Auja Raw Waste Water	**0.19**	**0.16**	**0.17**	**0**	**0.17**
Treated and Raw WW summary	**5.74**		**5.17**	**0**	**5.17**

5.9 Discussion Results and Conclusions

Three water strategies were formed and developed regarding irrigated land expansion into three ADS which are based on only one option for each ADS. These WS take the current land and expansion area to be maximized respectively with ADS. WSI is based on ADSop1 which means only 3,750 donums to be irrigated with surplus of 1MCM of available water in two seasons. WSII is based on expansion of the irrigated area to 7,750 donums. There is deficit of about 1MCM in case of ADSIIop1. The third WSIII is based on ADSIII; water surplus in this case is about 2MCM. Figure 5.40 shows the results.

WS Water quantity (MCM)		ADSIop1; Zone2 (3750 Dun.) Surplus/Deficit (current irrigated area)	ADSIIop1; Zone1+Zone 2 (7750 Dun.) Surplus/Deficit (expansion to7750)	ADSIIIop1; Zone1+Zone 2+Zone 3 (12615 Dun.) Surplus/Deficit (expansion to12615)
WSI	5.23	1	-2.96	-7.59
WSII	7.23	3	-0.96	-5.59
WSIII	14.88	16.65	6.72	2.06

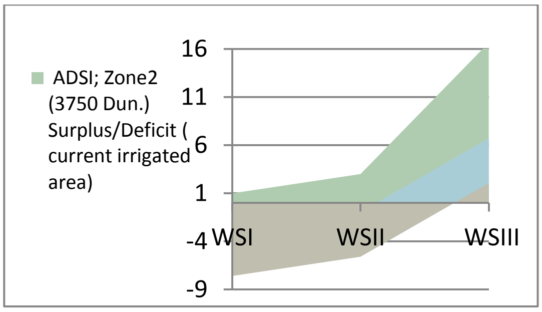


Figure 5.40 Matrixes of ADS and WSs.

By comparing these WSs with ADSs, this matrix shows the deficits/surpluses in the different WS rows and ADS columns. WSI with ADSI give 1 MCM water surplus but in case of land expansion for ADSII and ADSII, deficit will score 3 and 8 MCM respectively. In WSII, water surplus is 3 MCM; it is only 1 MCM deficit in case of ADSII. For WSIII, it could irrigate land up to about 13,000 donums expansion with surplus of 2 MCM. The following factors should be taken into consideration:

This surplus/deficit matrix has not represented the optimal solution especially when ranking with socio-economic aspects and environment issue.

ADS assumes irrigated land expansion gradually with consideration to the water quality and crop salt resistivity as it gives many options in selecting crops and land expansion areas.

Water deficit regarding CUWR forms 10% of total CWR and it starts in June and ends in October where surplus is obvious in October until the end of May. So, water deficit could be rationally applied on all suggested ADSs for all irrigated area/s.

Water quality is a key issue for irrigation in the CSA whose water availability means availability of water quality for selected crops.

In the context of water availability in terms of quality and quantity, several aspects above lead to raise the question of how can this quantity provide quality for irrigation system based on the suggested scenarios? In this manner, Management of Aquifer Recharge (MAR) is considered as a successful tool for saving water quality before thinking about saving water quantity. Likewise, brackish water and treated effluent, importing, desalinating or mixing, may be used directly for salt resistance crops like date palm trees form promise solutions for the irrigation problem in the CSA.

The following chapter (Chapter 6) will address all aspects which are relevant to the performance and impacts. Assessment of suggested water strategies should be explained and discussed in terms of water quality and ability of How cold water potential available

Chapter 6

Performance and Impact Assessment of Water Development and Management

6.1 Introduction

Governance, i.e., the institutional administrative component of water resources management in particular and natural resources management in general is an increasingly complex endeavor that forms the basis of integrated water resources management (Balázs M. Fekete and Eugene Z. Stakhiv, 2014). The search for meaningful indicators to track progress of various UN initiatives such as the Millennium Development Goals has a long history that goes back to the United Nations Conference on Environment and Development (UNCED), or Rio Conference (1992). In this context many earth summits and international meetings after Rio were held such as the World Summit on Sustainable Development (WSSD) (Johannesburg, August–September 2002), the Commission meeting on Sustainable Development (CSD), (2004 and 2005) and the Sixth World Water Forum in Marseilles (2012)…etc., all of these international meetings and conferences addressed the outcomes of sustainable Development Goals (SDGs).

Following up the outcome of the Millennium Summit 2015 and transmitting the conclusions document which is entitled (Transforming Our World: the 2030 Agenda for sustainable development) contained seventeen goals. The sixth goal was how to ensure availability and sustainable management of water and sanitation for all. Therefore, Integrated Water Resources Management (IWRM) is nowadays regarded as the vehicle that makes the “integrated view” of sustainable development operational for the management of fresh water resources, in a sense that views people interests, the society, the economy, and the environment as an interconnected whole taking care of all interests. The holistic approach adopted in IWRM implies that information is needed about the condition of the economy, society and water resources, and their mutual relationships. It also means that there must be tools for effective communication between different groups of stakeholders as it invokes the need for greater participation (Al-Zubari W. K., 2014).

In the context of sustainability, Palestinians as part of the world have moved forward towards sustainability in which they are thinking globally but are acting locally. Therefore, many of Palestinians national strategies focused on development and sustainability in terms of water resources and sustained Environment Resources. Therefore, Palestinians signed and approved the Climate Change Convention in 2016. Parallel to that they announced their strategy and action plan for sustained consumption and production. In both aspects water sector is a main component directly linked by their policies and action plans. At the same time, environment strategy in Palestine is announced as a cross-sector strategy by a Cabinet Decision in 2013. under these circumstances, water sector appears, in terms of quality and quantity, to be the most common component of sustainability polices in Palestine.

However, and regarding Palestinian current situation classified as arid and semi-arid zone, and in which Palestine is part of countries of ESCWA (Economic and Social Commission of Western Asia), it seems appropriate to simulate the ESCWA performance indicators which were prepared in May 2014. Those performance indicators for management of water resources are based on holistic framework. It is DPSIR (Driving, Pressure, State, Impact and Response), which helps Palestinians develop their IWRM concept in the CSA. In this case, performance metrics could be built up as box tool to have smart decision tool to be used by decision makers.

In this chapter, the three water strategies, and several ADSs, are analyzed and investigated. The preceding chapter (Chapter 5) categorized and addressed them using the Driver-Pressure-State-Impact-Response (DPSIR) framework to develop criteria for performance and impact assessment of these water strategies.

6.2 Methodology: What is DPSIR?

The Driver-Pressure-State-Impact-Response (DPSIR) scheme is a flexible framework that can be used to assist decision-makers in many aspects of the decision-making process. DPSIR was initially developed by the Organization for Economic Co-operation and Development (OECD, 1994) and has been used by the United Nations (UNEP 1994 and UNEP 2007) and the European Environmental Agency (Dutch National Institute for Public Health and the Environment 1995; Pierce, 1998; EEA 1999) to show the relationship between human activities and the state of the environment (EPA Archive, 2000).

According to DPSIR framework, there is a chain of causal links starting with ‘driving forces’ (economic sectors, human activities) through ‘pressures’ (emissions, waste) to ‘states’ (physical, chemical and biological) and then to ‘impacts’ on ecosystems, human health and functions, eventually leading to political ‘responses’ (prioritization, target setting, indicators).

This causal chain from driving forces to impacts and responses is a complex task and tends to be broken down into sub-tasks, e.g. by considering the pressure-state relationship.

DPSIR framework components of the investigation survey and water strategies (WS) and Agriculture Developing Strategies (ADS) was analyzed in chapters 4 and 5 and could be classified into the following categories:

- Driver (Driving force):This category could be identified by needs. One may ask about the needs which the Driving elements lead to think about developing needs and requirement. The main drivers in our CSA are:

- Population (Populate) - This driver includes more than one sub-driver like population growth rate, income/capita, and efficiency in revenue/taxation collection (Revco), gender empowerment).

-Land use and Agriculture-This includes (land cover use, irrigated lands, soil properties, irrigated lands expansions and agricultural pattern in the CSA; and

Water access to several resources in the CSA-They are coming under (Access to safe water for different uses, wastewater system coverage, storm water system coverage, water consumption, water price, Current Untapped Water Resource(CUWR).

- Pressures (Pollution Sources): This category is a result of meeting needs which is relevant to human activities led by Driving forces. Those human activities cause pressure on the environment and ecosystem in the CSA. Human activities may be divided into:

Changes in land use;

Overexploitation and excessive use of environmental resource (water table depletion and water quality deterioration); and

Resources pollution by chemicals and untreated effluents.

-State:It is a qualitative and quantitative category and should be a smart answer to the question of pressure which leads to resources. In the context of water and land it means usage. State has several variables like:

Water quality and quantity

Soil quality

-Impacts: Ecosystem and the welfare of human beings can express the reflection of changing the physical, chemical and biological environment state. It is the outcome of state changing and economy. What will happen to the Eco system balance change?

Ecological (loss of productivity and wet/irrigated lands)

Public health

-Responses: It is an action from decision and policy makers or sometimes from society, which reflects the undesired impacts. This category can affect the DPSIR-chain in the parts of Driving by partial control sometimes, as well as Pressure and State. Several items fall under this category such as:

Brackish water desalination

Storm water harvesting

Importation of water and regional water conveyance

Treated/partially treated wastewater.

Efficiency in water irrigation

Efficiency in urban water supply networks

Efficiency of water information system

Water awareness and education campaigns .

Figure 6.1 illustrates schematic diagram of DPSIR framework.

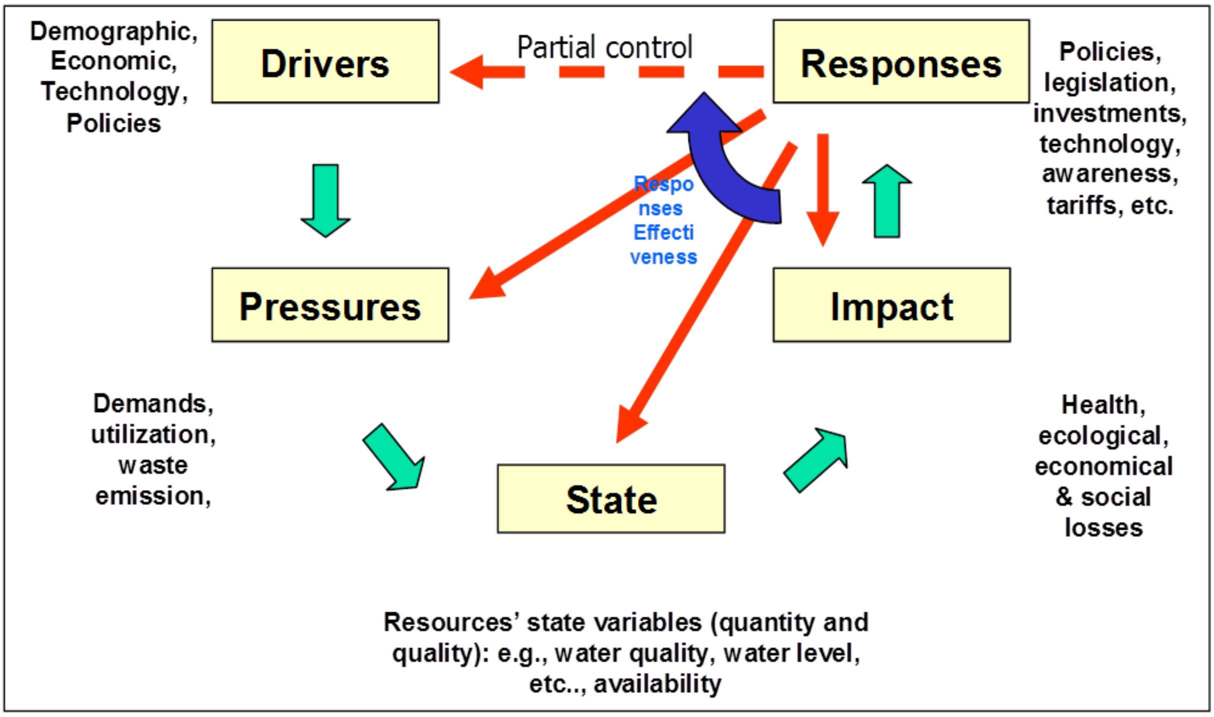


Figure 6.1: Schematic diagram of DPSIR framework, (UNEP 1994; UNEP 2007)

By applying DPSIR, several indicators should result regarding DPSIR categories, especially by compound joining of (R) category with (DPS) categories. In this manner, and based on suggested water strategies and Agricultural strategies, performance and impact assessment of those strategies may be analyzed using potential water strategies, included in:

Water production

Water importing

Water desalination and management

Agricultural development

Those water potential strategies are referenced by IWRM measures. Assessment framework should be applied to three suggested water development strategies (WSI, WSII and WSIII) with agricultural development strategies (ADSI, ADSII and ADSIII). Therefore, three scenarios could be made on comprehensive analysis:

Scenario I: Do nothing approach with WSI and ADSI.

Scenario II: This scenario covers WSII with ADSII.

Scenario III: WSIII with ADSIII.

Figure6.2 explains multidisciplinary holistic approach including Eco system and strategic impact assessment including stakeholders and expert opinion, which was formed and led to DPSIR framework WS Impact assessment

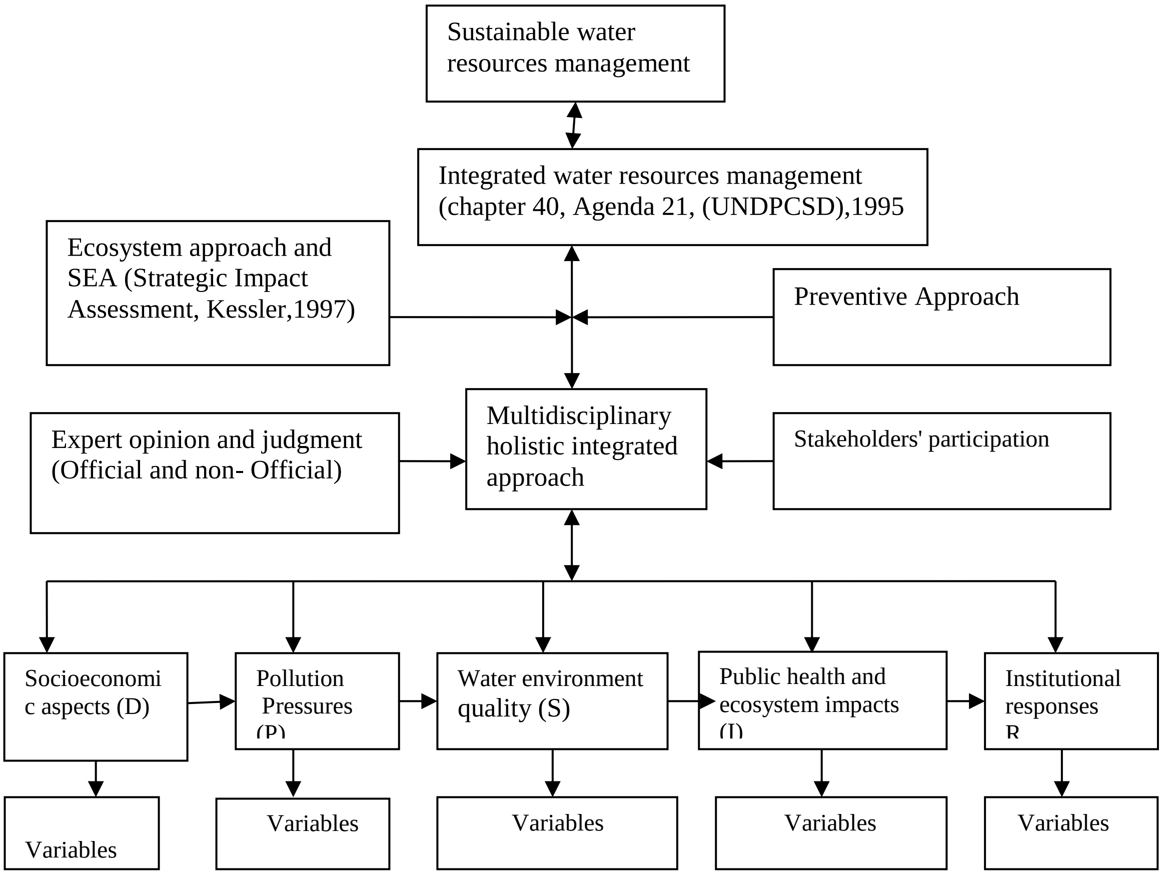


Figure 6.2: Multidisciplinary holistic approach derived from IWRM, Chapter 40, Agenda 21, UNDPCSD, 1995

In multidisciplinary holistic integrated approach, and in line with the investigation in the CSA, IWRM concept was developed into stakeholders' participation and experts' opinion and judgment, as well as strategical Environment Assessment (SEA) of Palestinian Occupied Territory (OPT). This approach which is based on characterizing the CSA (Chapter 2), Agricultural Land Use and Field Survey (Chapter 3), Water Budget Analysis (Chapter 4) and Developing of Water Strategies (Chapter 5) led to identify DPSIR Decision Variables (DV), in which those DV, through DPSIR Framework, should explain the next steps regarding performance indicators and Multi criteria Decision Analysis of the suggested three water strategies.

Through the performance assessment and impact context, three main items will be analyzed into main variables. Items would jointly be linked with the measures for each variable and weighted by performance indicator regarding the identification of the indicator itself.

Classifying the indicator type would explain the relationship between all of these variables. Table 6.1: Sample illustration of the methodology in this work. The main three items are:

Enabling Environment and Institutional Roles

Supply Availability and Management

Demand Management and Protection

Table 6.1: Sample illustrations of performance assessments ,Modified by ESCWA, (2007).

Issue	Sub-issue/ Element required to be measured	Current performance Indicator covering issue	Unit	Type of Indicator (DPSIR)
I. Enabling Environment and Institutional Roles				
Policies	National water resources policies based on IWRM	**- Existence of national water resources policies based on IWRM principles**	Y/N	R
II. Supply Availability and Management				
Availability of Water Resources	Available conventional water resources	- Total surface water (12) - Available surface water as a % of total renewable water resources (16)	Mm^3	S
III. Demand Management and Protection				
Efficiency of Water use	Efficiency of water supply systems in different sectors	Irrigation system efficiency (Agriculture)	%	S + R

6.3 DPSIR Decision Variables (DV) and Performance Assessment regarding (WSI-ADSI), (WSII-ADSII), and (WSII-ADSIII)

In this section, DV relates to enabling environmental Supply Availability and Management. Demand Management and Protection should be analyzed based on the context of the findings in the CSA boundaries together with the resulting performance indicators in the area. These findings are jointly reflected by what there is on the ground regarding community activities with water and agricultural sectors in the area. People attitudes start changing in terms of their feeling with water deficit for agricultural uses and the future of the CSA. Therefore, the main (DV) of the driving force category is as follows:

6.3.1 Category of Socio-economic and Natural Driving Force Variables

1-Population (Populate)This refers to population living within the boundaries of municipalities in 2012/2013, (Palestinian Central Bureau of Statistics, PCBS: Population of Auja is 4,548 capita). It is measured in numbers.

2-Income per Capita

Income (Average is 480 Euro/month in the CSA) refers to the average gross national income. It is measured by Euro/Year.

3-Land Use

Land use represents the ratio of urban to agricultural areas (4.3%) within the boundaries of the municipality and village council. Urban areas include public buildings, residential and housing plots, parks and gardens. They include also commercial and industrial facilities (Jericho Municipality, Auja Village Council, Ministry of Agriculture, and Palestinian Land Authority).

4-Access to Safe Water Supply

This represents the proportion of the population connected to municipal and village council water supply network. Measured by percentage (%), it is 100%.

5-Wastewater System Coverage

This item represents the proportion of population connected to the conventional wastewater conveyance system. Measured by percentage (%), it is 0.0%.

6-Storm water system coverage

This represents the proportion of urban and rural areas served by storm water systems. Storm water systems include pipelines, culverts and storage ponds. Measured by percentage (%).

7-Water Consumption per Capita

This refers to the per capita average daily municipal and village council water use within the boundaries of municipal and village councils. The main sources of the municipal and village water are the imported water from Mekerot (Israeli Water Company). It is measured by cubic meters per year (145,716 m^3/a).

8-Water Price

Water prices (0.95 Euro/ m^3) represents the billed price of water supply to users. It is defined by Euro/ m^3.

9-Efficiency in Revenue/taxation Collection

This represents the proportion of collected revenues to the billed taxation of water services(0.5). Water services include water supply and wastewater collection.

10-Agricultural Water Consumption

This refers to the amounts of water pumped by agriculture wells, springs discharge distribution and used for agricultural purposes (3.5 M m^3/a). It is measured by million cubic meters per year (M m^3/a).

11-Gender Empowerment

This refers to the proportion of female employees in water resources management departments in Auja area. It is measured in percentage (%).

12-Unaccounted-for Water (UFW)

The unaccounted-for water represents the water loss calculated as the difference between the quantity of water fed into a distribution system and the quantity of water put to legitimate use (30%), which has been metered or can be estimated. There are two types of UFW: the physical losses and the non-physical losses. Physical losses are the amount of losses which are lost without being used due to failures and deficiencies in the distribution facilities; they mainly represent the real leakage. Non-physical losses include meter under-registration and illegal connection. It is measured in percentage (%).

6.3.2 Category of Pressure Indicators: Depletion and Pollution Sources

1-Generation of Domestic Wastewater

Domestic wastewater represents the liquid waste generated by households (117,000 m^3/a in the CSA), public institutions, schools, hospitals and public places. It is approximately 80%-90% of the water used in the West Bank (UNEP Desk Study, 2003). It is measured by million cubic meters per year ($m^3{}_{/a}$).

2-Water Abstraction, Overexploitation and Water Table Depletion

Overexploitation of water through pumping from shallow wells should yield much brackish and saline water (≥3000 mg/L of colored concentration), and will give 1 m/a of water table depletion. It is measured by m/a and mg/L of chloride concentration.

3-Change in Land Use

Proportion of urban land use and other purposes like industry to agricultural area is present in this DV (0.83). It is measured as a ratio between new urbanization and agricultural lands.

4-Change in Soil Hydrochemistry

Hydrochemistry of soil is affected by irrigation with brackish water in the CSA. Sodium Absorption Ratio (S.A.R), Exchangeable Sodium Percent (ESP) % and electrical conductivity of saturated soil (ECe) are measured by (dm/m). S.A.R measures suitability of water for use in agricultural irrigation with concentrations expressed in mill equivalents per liter (meq/L).

6.3.3 Category of State Variables:

Water quality in terms of Chloride and Sodium ions is basic indicator of water salinity in the CSA.

1-Chloride (Cl)

Chloride refers to the compounds of chlorine with another element especially with Sodium and, to a lesser extent, with Calcium and Magnesium. The availability of Chloride in groundwater is attributed to return flow from irrigation and also from overexploitation and natural resource by up-coning saline layers. The WHO standard for Chloride is 250 mg/L.

2-Sodium (Na)

This refers to the Sodium salts soluble in groundwater. High levels of Sodium in groundwater are caused by the Sodium mineral deposits and seawater intrusion or up-coning. In general Sodium salts are not acutely toxic, but excessive salt intake seriously aggravates chronic congestive heart failure, hypertension and other ill effects. The effects of Sodium on infants are more serious from those on adults because of the immaturity of infant kidneys. Sodium may also affect the taste of drinking water at levels above 200 mg/L.

Available water (Water Quantity): In this regard, the main conventional available water resources are:

a-Shallow wells abstraction: This refers to monthly abstraction from the CSA shallow wells (mean monthly abstraction is 10,000 m^3/m). This DV is measured by m^3/month.

b-Spring fluctuation: This DV represents the water fluctuation from Auja Spring during the hydrological year (mean of fluctuation is 0.8 Mm^3/month) and is measured with Mm^3/month.

6.3.4 Category: Impact Variables

1-Loss of productivity

Loss in productivity means the reduction in the yield (decreasing 30%) of agriculture land measured percent, or by tons.

2-Loss of Irrigated Lands

This refers to the area of wetland already dried as a result of the drawdown of water table. It is measured by donums.

6.3.5 Category of Response Variables: Responses are the main performance indicators among IWRM plan, which are mentioned by interventions in different levels (Technologies, Laws and policies, and administrative plans of IWRM. In this manner, all of responses as joint compound measures should be considered. They include:

a- Water Production State Variables

1-Implementation and renewable of water services network: this DV proportional of water shortage quantity and total account quantity means water leakage by networks and conveying systems (35%) measured by percent.

2-Rehabilitation of shallow aquifer wells: All Auja shallow aquifer wells do not have maximum pumping capacity (1,100,000 m/hr of ten wells). The indictor unit is measured by m^3/hr.

3- Auja Village Effluent treatment: This DV is considered the effluent quantity which is disposed in the municipality borders (116,000 m^3/a). It is measured by m^3/a.

4- Agriculture Ponds Rehabilitation: Experiments approved the high infiltration quantity of agricultural ponds in the CSA (600 m^3/7 days); this means about 85 m^3/day should infiltrate and only about 0.007 m^3 evaporated. The DV in this case avoids water infiltration through irrigation ponds. The unit is measured by (m^3/a) day.

5-Retention of Flash floods: The estimated flash floods during 6 days events is about 3 M m^3. Retention percent (20%) is good. DV is measured by percent unit.

6-Deep wells in the carbonate aquifer (Fresh water): Abstraction capacity of deep carbonate new wells (120 m^3/hr) is measured with maximum abstraction capacity by m^3/hr.

7- Deep wells in the carbonate aquifer (brackish water): abstraction capacity of deep carbonate new wells (120 m^3/hr) in Fashkha area is measured with maximum abstraction capacity by m^3/hr.

8-New shallow aquifer wells in the CSA: abstraction rate of shallow wells in the CSA is about 80 m^3/hr and is measured by m^3/hr.

b- Water Import State Variables

1-Import treated effluent from Al-Bireh Waste Water Treatment Plant (Al-Bireh WWTP): This involves water quality and quantity; it is about 2.11 M m^3/a with secondary treated effluent which is in compliance with Palestinian standards (PSI 742-2003) for use in irrigation purposes. The DV is measured by M m^3/a with Biological Oxygen Demand (BOD_5).

2- Import treated effluent from Jericho Waste Water Treatment Plant. This DV is like the preceding one and is measured by (BOD_5) and the yearly maximum treatment capacity is 3.4M m^3/a.

3- Water import from Fashkha springs: brackish water potential from al-Fashkha springs is 7 Mm^3/a and is measured by Mm^3/a.

4-New Deep wells in al-Fashkha area: there is water potential at least of about 0.9 M m^3/a regarding Israeli wells and estimated surpluses in the aquifer. Measurement unit is M m^3/a.

5-Fresh Water Import from the River Jordan: Palestinians have water rights of 220 Mm^3/a according to Johnston Agreement in 1955. But in light of what was on the River Jordan, the estimated water potential is 66 Mm^3/a and Palestinian rights percent is based on Johnston Agreement 1955. This Issue is highly crucial in Palestinian-Israeli negotiations in the future (if any). This is measured by Mm^3/a.

c- Water Desalination and Management State Variable

1-Ground Water Desalination (4Mm^3/a): This DV is inter-connected between importing and management State variables. This means it includes desalination of brackish water in shallow aquifer in the CSA and the imported brackish water from outside of the CSA and is measured by M m^3/a.

2-Mixing brackish (4 Mm^3/a) and fresh water (4.31 Mm^3/a): This should include the shallow aquifer wells and fresh water from Auja Spring. Measurement Unit is Mm^3/a.

3-Mixing of treated effluent (5.17 Mm^3/a) with desalinated brackish ground water (4 Mm^3/a) and is measured by Mm^3/a.

4-Manage Aquifer Recharge (MAR) (2 Mm^3/a): It is measured by yearly storage and recovery quantity. This DV has the meaning of quantity and quality as suggested by the management system.

d- Agricultural Development Measures State Variable

1-Expansion of regular irrigable agriculture which reduced the regular irrigable lands in the CSA. In addition to considering DV as one driver in the investigation, it comes as Response DV in the CSA and is crucial in agriculture development. This DV is measured by irrigated thousands of donums in the CSA.

2-Green House technology implementation in the CSA plays a main role in developing the area; it is a united measure in thousands of Greenhouse donums.

3-Salt resistance crops productivity in the CSA: Date palms planting is one of the promising options for using brackish water (2.2 kg/m^3/donums/a). Farmers started this option in the past ten years in the CSA. This DV is measured by Kg/ m^3/Donum.

4-Hydroponic farming: This kind of technology is new in the Palestinian Territory. There are basic results for this kind of agricultural approach. Strawberries for instance produce 5 times with 50% of water consumption more than the conventional greenhouse approach (50 kg/ m^3/donums). This DV is measured by kg/m^3/donum.

5- Aquaponics farming (80 kg/ m^3/a): Some projects in oPt were implemented such as the Parayilian Project which was planned in the LJV. Some of these projects were constructed and operated in 2013. Productivity reached 30 kg/m² in 100 m^3 fish pools. This DV is measured by pools productivity per volume during one year (kg/m^3/a).

6-Soil flushing and neutralization: The practical implementation of flushing and neutralization of sodic and saline soil in treated zone (Zone 2 in the CSA) with 2,500 m^3/donum in intensive herbal planting (greenhouse herbs). This quantity of flush by fresh water needs to give 100% yield in terms of production. This DV unit is measured by the unit of water yield percent .It is the percent of real demand to consume quantity of used water for irrigation to produce 100% of crop production.

By Defining the main DV of response category in terms of technologies and management which are jointly linked with governmental and institutional response. The Several DVs included are:

National policies, strategies and legislation based on IWRM and DV indicator. In this case the DV indicator should be measured in the Palestinian case should consider water and environment legislation. The last approved Polices by Palestinians are the National Policies Agenda (NPA) which regulates the use of treated effluent (National Policy No. 27).

Last year the Government implemented many projects in the water sector including waste water treatment plants in Jericho Governorate. This project cost $ 32,000,000/56000 capita. This DV is measured in $/capita investment.

Institutional Framework: This means the number of institutions relevant to the water sector.

Capacity Building: This DV indicator is measured by the number of professionals working in the water sector and the number of trained employees in the sector.

Stakeholder's Participation and Gender main-streaming: This means translating the society role in managing the water sector. It deals with the number of societies that participate in the management of the water sector.

Awareness and Civil Society Involvement: This refers to awareness activities and water education involving Non-Governmental Organizations (NGOs) in these activities. It is measured by numbers.

In the context of IWRM by using multidisciplinary methodology based on DPSIR frame work, many DV were identified. This identification helped explain IWRM current indicators. Figure 6.3 illustrates all DVs regarding DPSIR framework.

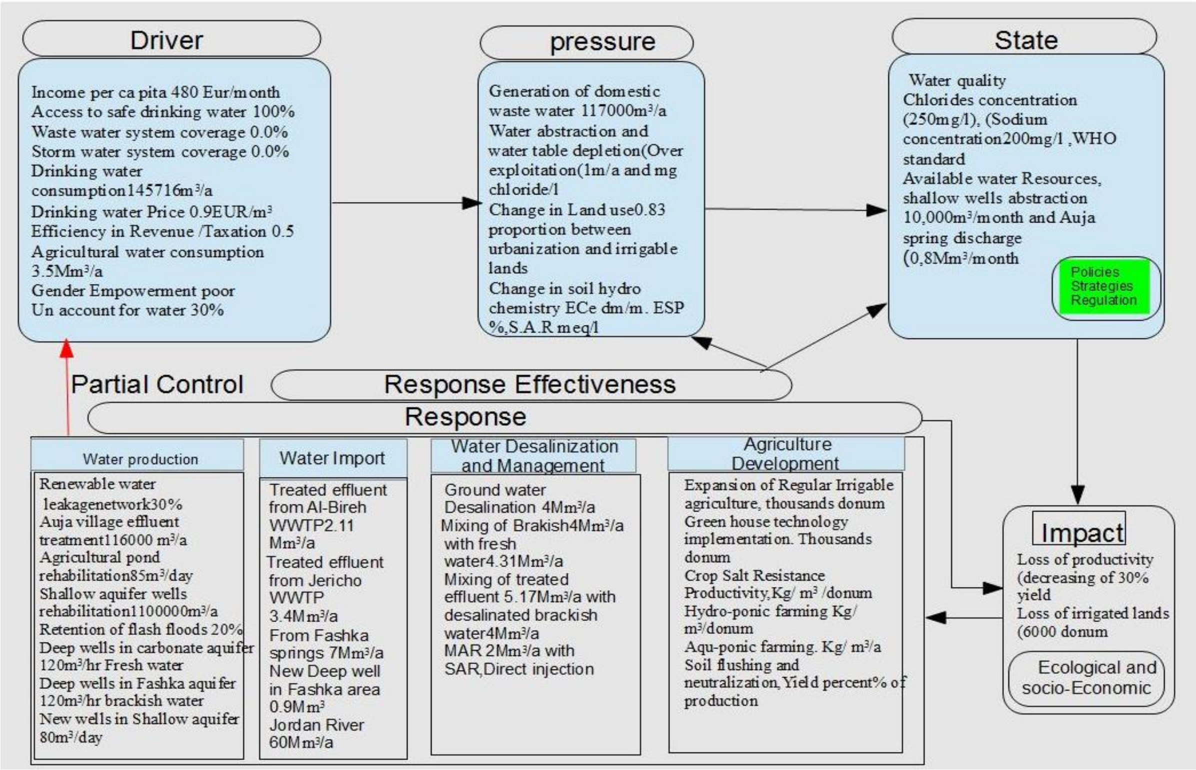


Figure 6.3: Schematic analysis of DVs in CSA regarding DPSIR framework.

6.4 IWRM Indicators for the CSA

After defining the different DVs which are jointly linked with DPSIR categories, the current indicators should be linked with all DVs in the following main issues:

I. Enabling Environment and Institutional Roles: This main issue includes policies, legislation, financing and investment in water sector, and the institutional framework in addition to capacity building and public participation. In this regard, Palestinians have good knowledge in policy planning and management. There are many strategies and policies which have been developed in the water sector. This issue was developed in 2012 when a 10-year water strategy was issued. In 2014 a reform plan for water sector was announced to be implemented in two years. The last step was the approval by Palestinian Cabinet of the National Polices Agenda (NPA) on December 2016. All these polices and strategies concluded the IWRM steps focusing on reuse of treated effluent and desalination of brackish water in addition to integrity processing in reforming water sector.

In the treatment of effluent reuse, the investment capital in the water sector was calculated by PWA for capita for one m^3 per year and was found to be $ 180/capita/m^3/year. This means one m^3 cost could be calculated regarding the year mass production and served population.

Institutional framework included PWA, Jerusalem Water Undertaking (JWU), Auja Municipal Council, EQA, and MoA. All these institutions are directly relevant to the water sector in terms of quantity and quality. Obviously, PWA is the regulating body of the water sector while JWU with local authority (Auja Municipal Council) are the institute which is responsible for distribution of drinking water. In addition, EQA is the authorized governmental institute for permitting waste water treatment plant construction and operation under the Environment Impact Assessment Terms of References (TORs) and MoA plans and implements irrigation water sector. Finally, the Higher Council for Water Resources plans by inter action and sometimes by duplicity with PWA; unfortunately, its efficiency for implementation is not enough.

In this investigation, capacity building programs still lunching for more 3 person for each 1000 capita, and stakeholders of the sector are about 52 including the persons/institute who/which has rights in spring discharge or owns ships of shallow aquifer wells in Auja Area.

II. Supply Availability and Management**:** In this regard, several issues were indicated with different measures jointly relevant to PSR decision variables. Many of those DVs represent response in the current state as current indicator before proposing a different scenario of WSs with ADSs. Actually, five main issues were explained and quantified regarding the current situation with their measure; these are aridity, availability of water resources, and water use by the sector, water dependency and water use sustainability. Explanation of these follow.

1-Arridity issue: This issue is completely state variable regarding the current status in the CSA. It represents the direct climate variable in terms of long term annual average of rainfall and difference from the mean. In this case, scarcity appears as a result of the state of current status of rainfall indicator; however, and in the CSA, and by rainfall referenced data with PMD and over 40 years, the long term annual average of rain fall is 120 mm/a, while rainfall change over the mean is 16%. This indication is important for the climate variability and the effect on yearly water budget in the semi- arid zones like the case of Auja and the LJV. The scarcity measure is 28 m^3/Cap/a.

2- Availability of Water Resources: This issue explains the relationship between state DVs and current indicator, which represents the availability of conventional water resources, both from surface and ground water. It is Do-nothing approach which means WSI with ADSI. In this case, indicators show the zero values of available surface water, the main source, i.e. the River Jordan in the LJV. Palestinians have no access to this important surface water resource. About 60 Mm^3/a remain as unutilized quantity (The natural quantity is 240 Mm^3/a). This quantity is also pumped yearly by Israel In our case the main available conventional water resource in the CSA is ground water from Auja shallow wells and Auja Spring fluctuation.

Mean available quantity is 11 Mm^3/a while real consumption does not exceed 4 Mm^3/a. The estimated recharge is usually 26% from total recharge (40 Mm^3/a) in the CSA.

On the other hand, non-conventional water production/reuse is closed to zero quantity. This forms a second Agricultural Developing strategy (WSII with ADSII). It appears as Response indicators in terms of Artificial recharge and Manage aquifer recharge. In case these strategies (WSIII with ADSII) are implemented in the CSA, three kinds of non-conventional water resources are addressed: treated effluent from Al Bireh and Jericho-WWTPs-, desalination of brackish and saline water from shallow aquifer and Alfaskha area, and water harvesting by Auja Dam, which until now and since 3 years ago (The dam was constructed and operated in 2013), pumped nothing to be used in irrigation purposes. Its storage capacity is 0.6 Mm^3/a.

The important issue in this state and response analysis is the dependency ratio, i.e. the ratio between available non-conventional water resources to renewable water resources. It is zero value. This will push the area to have a new approach in implementing IWRM in the area in future.

3-Water Use by Sector**:** This issue evaluates indicators of consuming sectors, use of sectors by source, resources dependency, water use sustainability and over-exploitation of water. All these sub-issues are classified as Pressure and Response DVs in case of IWRM plan as sustainability and overexploitation act as pressures on DVs.

In the CSA, the main consuming sector is the agriculture sector in Palestinian territories as well as in the neighboring countries. 4 Mm^3/a (1995)were consumed in the CSA for agriculture while the mean consumption for agriculture in the Palestinian Territory is 72% of total water consumption which represents 0.116 Mm^3/a. It forms 3% of total water consumption in the CSA. Water demand for the irrigable lands is only 12 Mm^3/a reflecting high deficit in the sector's demands which directly leads to the need for assistance from other sources.

In the context of sector consumption, ground water is the only source which is 100% used for agriculture where water dependency is 45% and water use sustainability is 36%. This presents a warning of ground water depletion in quantity and deterioration in quality regarding shallow aquifer status. This indicator is the one which provides a major boost for implementing the IWRM in CSA.

III. Demand Management and Protection

This section addressed seven main issues for analyzing performance indicators in light of the current status. They are: efficiency of water use, economic tools, and water cost recovery, economic returns and water resources allocations, reuse in main water consuming sectors, and resources protection.

Efficiency of water use has focused on efficiency of the supply system in irrigation which is the efficient approach by open canal and drip irrigation provided this does not exceed 42%.

Un countered flow for water is 58%, in which the percent of irrigated areas using water saving irrigation system is only 25%. In this manner, the economic tools and water cost recovery in the domestic and agriculture sectors do not exceed 40%, while gross domestic production (GDP) by agriculture in the LJV is 3% and decreases by 4% during last ten years. The agricultural labor force in the Palestinian Territory is around 100,000 persons while in the CSA they are 300 persons. The total agriculture labor force is 13%. This indicates imbalance between demand in the labor force in the CSA and the irrigable lands; this reflects the losses and the decreasing productivity in this sector. But in terms of economic returns and water resources allocation, the value added per cubic meter of water in agriculture is \$ 5/m^3. This is a promising solution in the CSA as well as the LJV especially in palm date planting by using fresh or brackish water. Unfortunately now treated effluent is not used in farming applications as irrigation resource.

IV. Protection of the Environment

Regarding environment protection and Response performance indicator, the main threat comes from treated waste water in the CSA. There is no sanitation system the CSA in spite of waste water management policies and standards (PS 743/2003). But basic quantity and quality requirements of water are lacking for the Eco-system in the Palestinian Territory, especially in arid and semi-arid zones like the CSA.

The table below (Table 6.2) explains and illustrates all selected DVs which were modified and developed according to ESCWA IWRM Plan in 2007. It is developed and modified as current status DVs in the CSA. This assessment leads for implementing the Decision Criteria (DC) which is based on measures as Response Performance Indicators that resulted in this assessment.

Table 6.2 Part 1: Modified and Developed Performance Indicators, current status in the CSA

Issue	Sub-issue/Element required to be measured	Current CSA Performance Indicator Covering Issue	Indicator Unit	Type of Indicator (DPSIR)
I. Enabling Environment and Institutional Roles				
Policies	-National water resources policies based on IWRM	- Existence of national water resources policies based on IWRM principles (National water policy and Strategy 2012-2022) -Sustained consumption and production Action Plan (SCPAP,2016) -National Polices Agenda,NPA,2019	Yes	R

Table 6.2 Part 2: Modified and Developed Performance Indicators, current status in the CSA

Legislation	Water rights, Reform of existing legislation, enforcement ,regulation and standards	-Existence of Reforming plan (Water Sector Reform Plan (2014-2016) -Physical properties, Microbial and chemical concentrations in treated waste water, Palestinian standards, PS No.743.2003	Yes	R
Financing & Investment in Water Sector	Investment in sanitation, septic tanks and WWTP	**- Per capita for each m^3 investment in water sector (\$ 180/cap/m^3/a)**	\$/cap/m^3/a	R
	Role of the private sector	**- Percent of domestic water supply operated by private sector (0.0%)**	%	R
Institutional Framework	Fragmentation of water institutions, national apex coordinating body, regulatory and enforcement bodies, …	**- Number of water-related institutions responsible for water resources (surface water, groundwater, desalination, wastewater) (PWA, Jerusalem Water Undertaking (JWU), Jericho Municipality, EQA, MoA** **- Existence of national apex body (e.g., Higher Council for Water Resources)**	5 Y	S + R R
Capacity Building	Investment in capacity development and training	**- Number of water professionals per served population(in the CSA)** **- Number of universities/institutes providing water training in the country (Bir Zeit University, Al-Najah University and Al-Quds University**	3/ 1000 3	S + R S + R
Stakeholders Participation	Community based organizations)	**- Number of community based organization (e.g., Water Users Association), including wells owners and Auja Spring rights in the CSA**	52	R
II. Supply Availability and Management				
Aridity	Long term annual rainfall average	**- Long Term annual average (minimum 20 years)**	120 mm/a.	S
	Rainfall variability	**- Rainfall variability over the mean (research!)**	16%	S
	Scarcity	- Annual per capita water share of renewable water resources: Water Scarcity Indicator	28 m^3/cap/a.	S
	Evaporation rate	**- Evaporation rate**	2,600 mm/a.	S

Table 6.3 Part 3: Modified and Developed Performance Indicators, current status in the CSA

Availability of Water Resources	Available conventional water resources	- Total surface water (The River Jordan) - Available surface water as a % of total renewable water resources	60 Mm^3 0.0%	S
		-Groundwater abstraction - Groundwater recharge - Groundwater recharge as a % of total renewable water resources	11 Mm^3 40 Mm^3 26%	S
		- Total renewable water resources	213 Mm^3	S
	Available Non-conventional water resources	- Desalination production - Desalination as % of total renewable water resources	0.0 Mm^3 0.0%	R R
		- Treated wastewater reuse * - Agricultural drainage reuse - Wastewater and drainage water reuse as % of total renewable water resources	0.0 Mm^3 0.0 Mm^3 0.0%	R R R
		- Total non-conventional water	0.0 Mm^3	R
	Dependency ratio between conventional and non-conventional water resources	- Total non-conventional water as % of total renewable water resources	0.0%	R
	Water harvesting (Dams, storage facilities)	**- Dams capacity (storage/ artificial recharge)** **- Capacity of storage facilities**	0.6Mm^3 0.6Mm^3	R R
Water Use by Sector	Consuming sectors	- Domestic water use - Domestic water use as % of total water demands - Per capita water use of domestic water	116000 Mm^3/a 3% 43800Ltr/ cap/a.	P P P (+R)
		- Agricultural water use - Agricultural water use as % of total water demands (9)	4Mm^3/a 95%	P
		- Total water demands (7)	Mm^3	P
	Use of Sectors by Source	**- Agricultural sector water use by source** **- surface water %** **- groundwater %** **- treated wastewater %**	 0.0% 100% 0.0%	P + S
		- Domestic sector water use by source **- surface water %** **- groundwater %** **- desalinated water %**	 0.0% 100% 0.0%	P + S

Table 6.3 Part 4: Modified and Developed Performance Indicators, current status in the CSA

Resources Dependency	Groundwater dependency	- Total groundwater withdrawal - Groundwater dependency ratio: Annual groundwater withdrawal as % of total renewable water resources	$0.9Mm^3$ 45%	P S + P
Water use Sustainability	Sustainability of water use	- Water sustainability index: Water use/ Renewable water	36%	P
	Groundwater over-exploitation and depletion)	**- Groundwater use/groundwater recharge (or safe/operational yield)**	200%	P
III. Demand Management and Protection				
Efficiency of Water use	Efficiency of water supply systems in different sectors	**- Irrigation system efficiency (Agriculture)**	42%	S + R
		- Unaccounted for water (Domestic)	58%	S + R
	Efficiency of water use in main consuming sectors	**- Irrigation water use efficiency**	40%	S
	Adoption of water saving techniques in main consuming sectors	**- Percentage of irrigated areas using water saving irrigation system**	25%	S + R
		- % of metered groundwater wells	%	R
Economic Tools	Water Pricing in consuming sectors	**- Water pricing in the Agriculture sector**	$0.66/CM	R
		- Water pricing in the Domestic sector **- Tariff structure (Uniform or Block)**	$1.05/CM Block cost	R R
Water Cost Recovery	Cost recovery in different consuming sectors	**- Cost recovery in the Domestic sector**	%	R + S
		- Cost recovery in the Agricultural sector	%	R + S
Economic Returns & Water Resources Allocation	consuming sectors contribution to national economy	- Agriculture GDP as % of total GDP -Agriculture in the LJV % of total GDP - Agriculture labor force as % of total labor force (total labor number is 84000 person)	10% 3% 13%	D D D
	Water productivity and value in consuming sectors .	**- Value added per cubic meter of water in Agriculture**	$ 5/m^3$	S + P

Table 6.3 Part 5: Modified and Developed Performance Indicators, current status in the CSA

Reuse in main water consuming sectors	Extent of treated wastewater reuse in agriculture	**- Percent area irrigated with treated wastewater to total irrigated area**	0.0%	R
Resources Protection	Surface water protection	**- Existence of surface water protection zones**	No	R
	Groundwater vulnerability planning documents	**- Existence of groundwater vulnerability documents for land use**	No	R
IV. Environmental Protection				
Access to sanitation	Total population, Rural in the CSA	- % population with access to improved sanitation facilities	0.0%	S + R
Wastewater Management Policies	Collection, treatment, reuse, sludge disposal	**- wastewater volumes collected**	6MCM/a	R
		- % wastewater treated of total collected	95%	R
		- % wastewater reused of total collected	0.0%	R
Water Pollution	Water bodies conforming with national standards	**- % of water bodies conforming with national standards**	80%	R
Ecosystem protection	Basic water requirements for ecosystem	**- Existence of minimum basic water requirement for ecosystem**	N	R

* **Appendix 10.5 Palestinian Standards of treated waste water quality for irrigation use**

6.5 Decision Criteria (DC)

This section addresses DVs and performance indicators based on current status that developed into the DPSIR approach analysis in which decisions should be made by all those performance indicators after addressing and identifying the triangle Criteria (Environment C1, Economic C2 and C3 criterion). All these criteria should jointly be combined with Scenario 1 (WSI with ADSI), Scenario II (WSII with ADS II), and Scenario 3 (WSIII with ADS III). Rating and comparing these three criteria are divided into sub-criteria regarding measured issues and performance indicators in Section 6.3.

6.5.1 DC Methodology

Decisions involve many intangibles that need to be traded off. To do that, they have to be measured alongside tangibles whose measurement must be evaluated with regards to how they serve a decision-maker's objectives. The Analytic Hierarchy Process (AHP) is a theory of measurement through pair comparisons and relies on the judgments of experts to derive priority scales which measure intangibles in relative terms. Comparisons are made using a scale of absolute judgements that represent how much more. One element dominates another with respect to a given attribute. Judgements may be inconsistent and it is important to know how to measure this inconsistency and improve the judgements when possible. Obtaining better consistency is a concern of the AHP. Derived priority scales are synthesized by multiplying them by the priority of their parent nodes and adding for all such nodes. (Thomas L. Saaty, 2008).

In the above summarization of identifying priorities, the Decision variable which has been classified to DPSIR approach should play the main role in selecting different criteria and sub-criteria for those priority DVs in accordance with our multi-comparison between three Water strategies with Agricultural developing strategies that are linked jointly. Therefore, current performance indicators which resulted into DPSIR approach should define the intensity of importance of Response Variables. This step is implemented for scaling all resulting current performance indicators based on the intensity of importance in Table 6.3.

Table 6.3: The fundamental scale of absolute numbers, Thomas L. Saaty, 2008.

Intensity of Importance	Definition	Explanation
1	Equal Importance	Two activities contribute equally to the objective
2	Weak or slight	
3	Moderate importance	Experience and judgement slightly favor one activity over another
4	Moderate plus	
5	Strong importance	Experience and judgement strongly favor one activity over another
6	Strong plus	
7	Very strong or demonstrated importance	An activity is favored very strongly over another; its dominance demonstrated in practice
8	Very, very strong	
9	Extreme importance	The evidence favoring one activity over another is of the highest possible order of affirmation

6.5.2 Decision Criteria Structure

As for the best water strategy with ADS to be selected, DC structure is based on three main water strategies with three scenarios. Scenario (ScI) represents WSI with ADSI. Scenario II (ScII) which is WSII with ADSII and Scenario III (SCIII) which is WSIII with ADSIII. Each of the three scenarios is linked with an environment aspect with global weight of 0.77, economic aspect with global weight of 0.16, and finally social aspect with global weight of 0.07. These weights form 100% of the total weighted criteria. Each subcreterion of the environment, the economic and the social aspects were divided into new sub-criterion which included water production, water import, water management and agriculture development, in which those sub-criteria were classified into new lower level of DC. This new lower level is based on enabling environment, supply availability, demand management and environment protection (main aspects of DPSIR approach analysis). This kind of criteria interacts to have more accurate weight during scaling of different decision measures (DMs) where they represent the DVs concluded by DPSIR approach. However, figure (6.4) shows the DC structure.

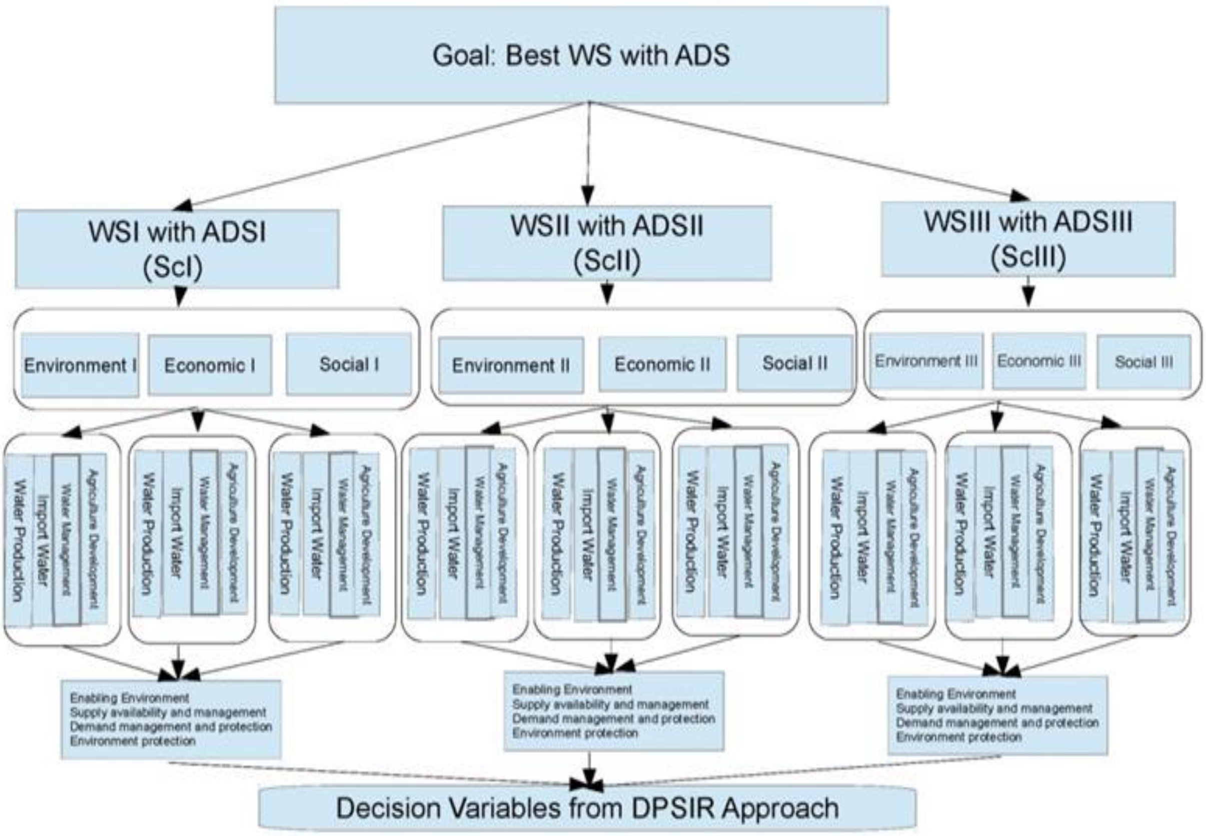


Figure 6.4: Decision Criteria structure which has three sub-criteria levels ,ranking DVs.

6.5.3 Decision Variables (DVs) and Scaling Process:

The lowest level of Decision Criteria structure is the decision variables matrix. Usually this level reflects response variables which resulted by DPSIR approach validation. They represent the IWRM measures which were considered in the suggested intervention during developing the CSA based on water production, water import, water management and agriculture development. Therefore, the following matrix could be produced. This matrix below takes 24 measures represented in the Response variables in DPSIR approach evaluation for Current situation (WSI with ADSI-Do-Nothing strategy). The high scales in Do-nothing approach were found by renewal of water network and rehabilitation of shallow aquifer wells (0.09) and rehabilitation of agriculture ponds. The flood retention has high scale (0.08). All these come under water production, but there is nothing of a high scale like importing water item while in management, mixing of brackish water with fresh water has the highest scale (0.07) in terms of MAR and management. Date palms planting and implementing intensive agriculture (Green House agriculture has the most important scale (0.08 and 0.07 respectively). Table (6.4) explains all those variable measures and their scales.

Table 6.4 Part 1: DVs sub criteria, evaluation of WSI with ADSI, Do-Nothing scenario, (SC1)

main criteria	Sub criteria (Measures from M1….M24)	WSI with ADSI (Do Nothing)																									
	WSI with ADS I Do Nothing	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	Total	scale value
water production	Implementation and renewal of water service network (M1)	1	2	3	1	6	9	9	1	9	9	9	9	0	2	0	6	9	9	8	1	0	9	9	2	123	**0.09**
	Rehabilitation of Shallow aquifer wells(M2)	1	1	7	3	2	9	9	1	9	9	9	9	2	1	6	2	9	9	9	2	1	9	9	2	129	**0.09**
	Treating Auja village Effluent (M3)	0	1	1	0	0	1	0	0	1	1	1	1	0	0	1	0	1	1	1	0	0	0	0	0	12	**0.01**

Table 6.4Part2: DVs sub criteria, WSI with ADSI, Do-Nothing scenario, (SC1)

	Agriculture ponds Rehabilitation(M4)	1	0	5	1	3	9	9	1	9	9	9	9	1	0	9	2	9	9	4	1	1	9	9	4	123	**0.09**
	Retention of flash floods(M5)	0	3	5	0	1	6	6	3	9	9	9	9	2	1	5	3	9	5	2	1	1	9	9	7	114	**0.08**
	Deep wells in the carbonate aquifer – Fresh Water(M6)	1	0	2	0	0	1	1	0	2	2	2	2	0	0	2	0	4	1	1	0	0	2	2	2	28	**0.02**
	Deep wells in the carbonate aquifer – Brackish (M7)	1	0	5	0	0	1	1	0	2	2	2	2	0	0	2	0	4	1	1	0	0	2	2	2	32	**0.02**
	Shallow wells in the alluvium aquifer – Brackish (M8)	1	1	9	1	0	3	3	1	9	9	9	9	2	1	9	4	9	9	2	3	0	9	6	9	119	**0.08**
Water import	Import of treated effluents from El Bireh WWTP (M9)	0	0	1	0	0	1	1	1	1	1	1	1	0	1	1	0	1	1	0	0	0	1	0	0	12	**0.01**
	Import of treated effluent from Jericho WWTP (M10)	0	0	1	0	0	1	1	0	1	1	1	1	0	1	1	0	1	1	0	0	0	1	0	0	12	**0.01**
	Water import from Fashkha (spring) (M11)	0	0	1	0	0	1	1	0	1	1	1	2	0	1	1	0	1	1	1	0	0	1	0	0	13	**0.01**
	New deep wells in Fashkha area(M12)	0	0	1	0	0	5	5	0	1	1	1	1	0	0	1	0	1	1	0	0	0	1	1	0	21	**0.01**

Table 6.4Part3: DVs sub criteria, WSI with ADSI, Do-Nothing scenario, (SC1)

	Fresh water import from Palestinian National Water Carrier(M13)	2	1	1	2	1	3	3	1	5	5	9	9	1	9	9	1	9	9	1	1	0	6	4	3	93	**0.06**
	Export of surplus water (M14)	1	2	9	3	2	3	3	1	2	2	2	2	0	1	1	0	3	7	0	0	0	3	1	1	49	**0.03**
Desalination and management	Groundwat. desalin. (M15)	9	0	1	0	0	1	1	0	2	2	1	1	0	1	1	0	1	1	0	0	0	1	1	1	24	**0.02**
	Mixing of brackish water and fresh water resources (M16)	0	1	5	3	3	3	3	3	9	9	5	9	0	5	9	1	9	9	1	0	1	4	1	3	95	**0.07**
	Mixing of brackish water and treated effluent (M17)	0	0	1	0	0	3	3	0	1	1	1	1	0	3	1	0	1	1	0	0	0	1	0	0	20	**0.01**
	Managed Aquifer Recharge (MAR) – spring discharge & surface runoff (M18)	0	0	1	0	0	1	1	0	1	1	1	1	0	0	1	0	1	1	7	7	8	1	0	3	37	**0.03**
Agriculture Development	Extension of regular irrigated agriculture (M19)	0	0	2	3	1	2	2	1	5	5	2	3	1	9	3	2	5	1	1	0	0	6	3	3	60	**0.04**
	Greenhouse technology implementation(M20)	1	1	9	1	1	3	3	9	9	9	3	2	9	5	5	5	1	4	3	1	1	7	9	1	101	**0.07**

Table 6.4Part4: DVs sub criteria, WSI with ADSI, Do-Nothing scenario, (SC1)

	WSI with ADS I Do Nothing	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	Total	scale value
	Palm tree production salt-resistant high revenue crops, (M21)	5	1	9	1	1	5	5	3	9	9	9	3	3	9	5	1	5	1	5	2	1	9	9	9	119	**0.08**
	Hydroponic (Planting in water of regular vegetables) (M22)	0	0	3	0	0	1	1	0	1	1	2	1	2	0	3	1	3	1	1	2	1	1	0	0	25	**0.02**
	Aquaponic (fish Farms) (M23)	0	0	3	0	0	1	1	2	3	3	5	3	2	2	2	5	3	0	0	0	0	5	1	0	41	**0.03**
	Soil mixing and neutraliz. (M24)	1	1	5	3	1	1	1	0	5	5	5	3	0	1	2	0	3	0	0	1	0	3	5	1	46	**0.03**
																										1448	**1.00**

Scaling procedure in ScII took Retention of flash floods(M5), Which was implemented in WSI regarding what was on the ground(Auja Dam) and MAR by direct injection and MAR (M18) as major DVs ,by this scenario, MAR scale increased from 0.03 in SC1 to 0.07 in ScII, which the percent of MAR scale based on 24 measurements of DVs is (16.8%) in scale degree, while Retention flash floods form (21.6%) of DVs, these figures and percentage indicated the high importance of Retention flash floods and MAR , which were formed (38.4%) in scale degree in this scenario, Table 6.5 shows all these results.

Table 6.5Part1: DVs sub criteria , evaluation of WSII with ADSII (MAR) scenario (SC1I)

main	WSII with ADSII (MAR) :Sub criteria (Measures from M1….M24)																										
	Description of IWRM Measures (WSII with ADSII)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	Total	scale value
water production	Implementation and renewal of water service network (M1)	1	2	3	1	2	9	9	1	9	9	9	9	0	2	0	6	9	0	8	1	0	9	9	2	110	0.08
	Rehabilitation of Shallow aquifer wells (M2)	1	1	7	3	0	9	9	1	9	9	9	9	2	1	6	2	9	1	9	2	1	9	9	2	119	0.08
	Treating Auja village Effluent (M3)	0	1	1	0	0	1	0	0	1	1	1	1	0	0	1	0	1	0	1	0	0	0	0	0	11	0.01
	Agriculture ponds Rehab. (M4)	1	0	5	1	2	9	9	1	9	9	9	9	1	0	9	2	9	0	4	1	1	9	9	4	113	0.08
	Retention of flash floods (M5)	1	3	4	1	1	6	6	5	9	9	9	9	1	9	9	3	9	1	2	1	1	9	9	7	123	0.09
	Deep wells in the carbonate aquifer – Fresh Water (M6)	0	0	2	0	0	1	1	0	2	2	2	2	0	0	2	0	4	0	1	0	0	2	2	2	27	0.02
	Deep wells in the carbonate aquifer – Brackish (M7)	0	0	5	0	0	1	1	0	2	2	2	2	0	0	2	0	4	0	1	0	0	2	2	2	30	0.02
	Shallow wells in the alluvium aquifer – Brackish (M8)	2	1	9	1	0	4	3	1	9	9	9	9	2	1	9	4	9	1	2	3	0	9	6	9	112	0.08
Water import	Import of treated effluents from BWWTP (M9)	0	0	1	0	0	1	1	1	1	1	1	1	0	1	1	0	1	0	0	0	0	1	0	0	11	0.01

Table 6.5Part2: DVs sub criteria, evaluation of WSII with ADSII (MAR) scenario, SCII

	Import of treated effluent from Jericho WWTP (M10)	0	0	1	0	0	1	1	0	1	1	1	1	0	1	1	0	1	0	0	0	0	1	0	0	11	0.01
	Water import from Fashkha (spring)	0	0	1	0	0	1	1	0	1	1	1	2	0	1	1	0	1	0	1	0	0	1	0	0	12	0.01
	(M11)	0	0	1	0	0	5	5	0	1	1	1	1	0	0	1	0	1	0	0	0	0	1	1	0	20	0.01
	New deep wells in Fashkha area (M12)	2	1	1	1	1	3	3	1	5	5	9	9	1	9	9	1	9	2	1	1	0	6	4	3	85	0.06
	Fresh water import from Palestinian National Water Carrier (M13)	1	2	9	3	0	3	3	1	2	2	2	2	0	1	1	0	3	0	0	0	0	3	1	1	40	0.03
Desalination and management	Export of surplus water (M14)	9	0	1	0	0	1	1	0	2	2	1	1	0	1	1	0	1	0	0	0	0	1	1	1	24	0.02
	Groundwat. Desalination (M15)	0	1	5	3	0	3	3	3	9	9	5	9	0	5	9	1	9	1	1	0	1	4	1	3	84	0.06
	Mixing of brackish water and fresh water resources (M16)	0	0	1	0	0	3	3	0	1	1	1	1	0	3	1	0	1	0	0	0	0	1	0	0	19	0.01
	Mixing of brackish water and treated effluent (M17)	5	1	9	5	1	5	9	2	9	9	5	3	1	3	5	2	9	1	2	1	1	9	6	5	108	0.07
A	(MAR) – (M18)	0	0	2	3	1	2	2	1	5	5	2	3	1	9	3	2	5	0	1	0	0	6	3	3	59	[illegible]
	Extension of regular irrigated agriculture (M19)	1	1	9	1	1	3	3	9	9	9	3	2	9	5	5	5	1	1	3	1	1	7	9	1	98	0.07

Table 6.5Part3: DVs sub criteria, evaluation of WSII with ADSII (MAR) scenario, SCII

	Description of IWRM Measures (WSII with ADSII)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	Total	scale value
	Greenhouse technology implementation (M20)	5	1	9	1	1	5	5	3	9	9	9	3	3	9	5	1	5	1	5	2	1	9	9	9	119	0.08
	Palm tree production (salt-resistant high revenue crops) (M21)	0	0	3	0	0	1	1	0	1	1	2	1	2	0	3	1	3	0	1	2	0	1	0	0	23	0.02
	Hydroponic (Planting in water of regular vegetables) (M22)	0	0	3	0	0	1	1	2	3	3	5	3	2	2	2	5	3	0	0	0	0	5	1	0	41	0.03
	Aquaponic (fish Farms) (M23)	1	1	5	3	1	1	1	0	5	5	5	3	0	1	2	0	3	0	0	1	0	3	5	1	46	0.03
	Soil mixing and neutralization (M24)																									1445	1

Third scenario SCIII, which has considered all DVs measures to be implemented, has high scaling of M1, M2, M16 and M20. Those measures have 0.1 value for each one. Those measures are also distributed into Water Production (WP) item, Desalination and MAR (D and M), and Agriculture Development (AD).

Table 6.6 Part1: DVs Sub criteria ,evaluation of WSIII with ADSIII (100%) Scenario (SCIII)

criteria	WSIII with ADSIII(100% IWRM) : Sub criteria (Measures from M1….M24)																										
	Description of IWRM Measures (WSIII with ADSIII)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	Total	scale value
water production	Implementation and renewal of water service network	1	1	5	2	3	3	7	2	7	8	9	9	2	8	3	1	5	2	2	1	1	7	6	3	98	0.10

Table 6.6 Part2: DVs Sub criteria ,evaluation of WSIII with ADSIII (100%) Scenario SCIII

	Rehabilitation of Shallow aquifer wells	1	1	5	2	3	3	7	2	7	8	9	9	2	8	3	1	5	2	2	1	1	7	6	3	98	0.10
	Treating Auja village Effluent	0	0	1	0	1	1	1	0	1	2	2	2	0	2	1	0	1	0	0	0	0	1	1	1	20	0.02
	Agriculture ponds Rehabilitation	1	1	3	1	2	2	4	1	4	4	5	5	1	4	2	1	3	1	1	1	1	4	3	2	49	0.05
	Retention of flash floods	0	0	2	1	1	1	2	1	2	3	3	3	1	3	1	0	3	1	1	0	0	2	2	1	33	0.03
	Deep wells in the carbonate aquifer – Fresh Water	0	0	2	1	1	1	2	1	2	3	3	3	1	3	1	0	3	1	1	0	0	2	2	1	33	0.03
	Deep wells in the carbonate aquifer – Brackish	0	0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	0	14	0.01
	Shallow wells in the alluvium aquifer - Brackish	1	1	3	1	2	2	4	1	4	4	5	5	1	4	2	1	3	1	1	1	1	4	3	2	49	0.05
Water import	Import of treated effluents from El Bireh WWTP	0	0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	0	14	0.01
	Import of treated effluent from Jericho WWTP	0	0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	0	12	0.01
	Water import from Fashkha (spring)	0	0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	0	11	0.01

Table 6.6 Part3: DVs Sub criteria ,evaluation of WSIII with ADSIII (100%) Scenario SCIII

	New deep wells in Fashkha area	0	0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	0	11	0.01
	Fresh water import from Palestinian National Water Carrier	1	1	3	1	2	2	4	1	4	4	5	5	1	4	2	1	3	1	1	1	1	4	3	2	49	0.05
	Export of surplus water	0	0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	0	12	0.01
Desalination and management	Groundwater desalination	0	0	2	1	1	1	2	1	2	3	3	3	1	3	1	0	3	1	1	0	0	2	2	1	33	0.03
	Mixing of brackish water and fresh water resources	1	1	5	2	3	3	7	2	7	8	9	9	2	8	3	1	5	2	2	1	1	7	6	3	98	0.10
	Mixing of brackish water and treated effluent	0	0	1	0	1	1	1	0	1	2	2	2	0	2	1	0	1	0	0	0	0	1	1	1	20	0.02
	Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	1	1	3	1	2	2	4	1	4	4	5	5	1	4	2	1	3	1	1	1	1	4	3	2	49	0.05
Agriculture Development	Extension of regular irrigated agriculture	1	1	3	1	2	2	4	1	4	4	5	5	1	4	2	1	3	1	1	1	1	4	3	2	49	0.05
	Greenhouse technology implementation	1	1	5	2	3	3	7	2	7	8	9	9	2	8	3	1	5	2	2	1	1	7	6	3	98	0.10
	Palm tree production (salt-resistant high revenue crops)	1	1	5	2	3	3	7	2	7	8	9	9	2	8	3	1	5	2	2	1	1	7	6	3	98	0.10
	Hydroponic (Planting in water of regular vegetables)	0	0	1	0	0	0	1	0	1	1	1	1	0	1	0	0	1	0	0	0	0	1	1	0	14	0.01
	Aquaponic (fish Farms)	0	0	1	0	1	1	1	0	1	1	2	2	0	1	1	0	1	0	0	0	0	1	1	1	16	0.02

Table 6.6 Part4: DVs Sub criteria ,evaluation of WSIII with ADSIII (100%) Scenario SCIII

	Description of IWRM Measures (WSIII with ADSIII)	M1	M2	M3	M4	M5	M6	M7	M8	M9	M10	M11	M12	M13	M14	M15	M16	M17	M18	M19	M20	M21	M22	M23	M24	Total	value
	Soil mixing and neutralization	0	0	2	1	1	1	2	1	2	3	3	3	1	3	1	0	3	1	1	0	0	2	2	1	33	0.03
																										1012	1.00

However, figure 6.5 and Table 6.7 summarize all those compared results in the scaling process of the three suggested scenarios.

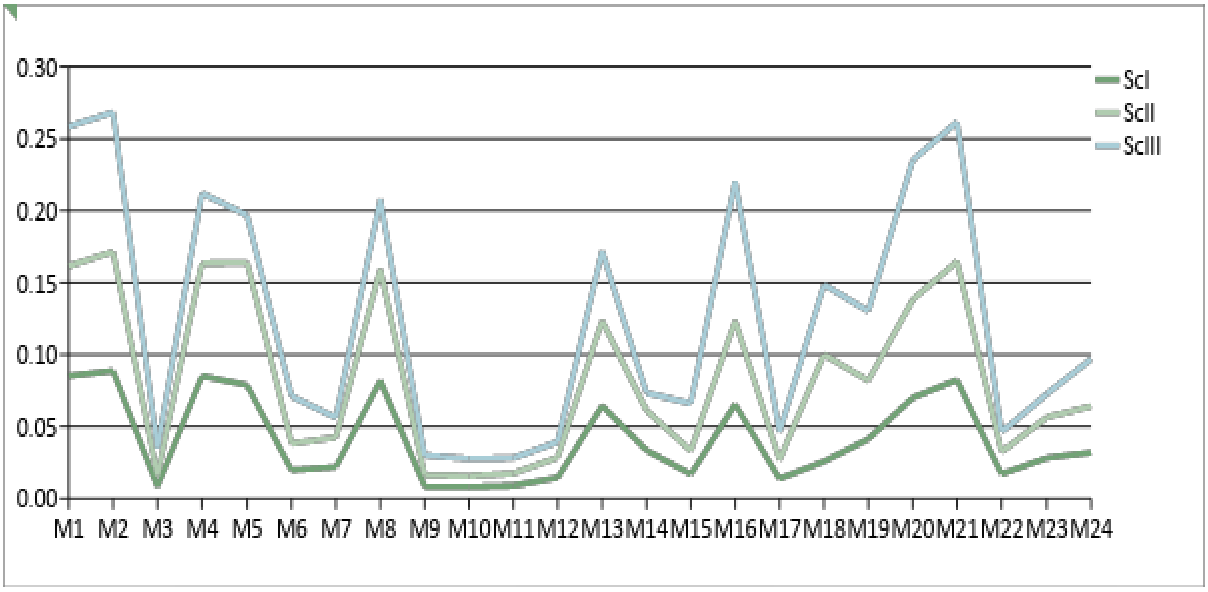


Figure 6.5 Three Scenarios comparing results in scaling procedure.

Table 6.7 part1: Three Scenarios comparing results in scaling procedure.

Main criteria	Sub criteria (Measures from M1….M24)	WS Scenarios			
	Description of IWRM Measures		ScI	ScII	ScIII
water production	Implementation and renewal of water service network	M1	0.09	0.08	0.10
	Rehabilitation of Shallow aquifer wells	M2	0.09	0.08	0.10
	Treating Auja village Effluent	M3	0.01	0.01	0.02
	Agriculture ponds Rehabilitation	M4	0.09	0.08	0.05
	Retention of flash floods	M5	0.08	0.09	0.03
	Deep wells in the carbonate aquifer – Fresh Water	M6	0.02	0.02	0.03
	Deep wells in the carbonate aquifer – Brackish	M7	0.02	0.02	0.01
	Shallow wells in the alluvium aquifer - Brackish	M8	0.08	0.08	0.05
Water import	Import of treated effluents from El Bireh WWTP	M9	0.01	0.01	0.01
	Import of treated effluent from Jericho WWTP	M10	0.01	0.01	0.01
	Water import from Fashkha (spring)	M11	0.01	0.01	0.01
	New deep wells in Fashkha area	M12	0.01	0.01	0.01
	Fresh water import from Palestinian National Water Carrier	M13	0.06	0.06	0.05

Table 6.7part2: Three Scenarios comparing results in scaling procedure

	Export of surplus water	M14	0.03	0.03	0.01
	Mixing of brackish water and fresh water resources	M16	0.07	0.06	0.10
	Mixing of brackish water and treated effluent	M17	0.01	0.01	0.02
	Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	M18	0.03	0.07	0.05
Agriculture Development	Extension of regular irrigated agriculture	M19	0.04	0.04	0.05
	Greenhouse technology implementation	M20	0.07	0.07	0.10
	Palm tree production (salt-resistant high revenue crops)	M21	0.08	0.08	0.10
	Hydroponic (Planting in water of regular vegetables)	M22	0.02	0.02	0.01
	Aquaponic (fish Farms)	M23	0.03	0.03	0.02
	Soil mixing and neutralization	M24	0.03	0.03	0.03

6.5.4 Defining Priorities by Weighting DVs' Resulting Scale Values

In this section of research, weighting different measures defined as DVs in DC matrix should be calculated in accordance with the global weights of environmental, economic and social items regarding their derived definition from DPSIR analysis. In this manner, each of those measures was calculated in its weight individually for this multi criteria analysis. In this phase of investigation, there is no need to make multi-variant analysis; it is only a phase of defining priorities into three WS. Therefore, the following definitions were considered for this weighting procedure:

Weighting the environment aspect, decreasing or increasing recharge percent for each measure could be considered as main variables which linked 100% as total percent for environment aspect. This 100% means 77% environmental weight as global weight. In this context, implementation and renewable of water service network (Domestic and irrigation network), there is 10% recharge and a total of (116,000m^3/a) leakage of network and 4 Mm^3/a of agricultural water use in the CSA. However, the environment aspect weight is (100%-10%)*(77%), which is equal to 69.3%. This could also be applied to rehabilitation of shallow aquifer wells whose abstraction percent increases in case of rehabilitation forms about 15% (PHG, SMART 2011). This percent should affect WT depletion so water Table depletion is calculated on the basis of decreasing by 3 m/a which resulted from new shallow wells with 100,000 m^3/a. What does that mean? It is the new abstraction quantity which reduces WT by 10% (100,000 new abstraction/1000, 000 total yearly abstractions). This will reflect the WT decrease by 10% of the new shallow aquifer well. Finally, calculation of non-treated effluent was assumed as loss quantity of artificial recharge. How can this be possible? It is based on pollution effect percent by recharge in terms of quantity which leads to considering if there is 10% recharge from non-treated effluent (Auja domestic non-treated effluent is 80% of consumed water); therefore, there is 8% that should be recharged and the aquifer water quality to be treated as 8% percent in terms of Quantity. The local environment weight is 77 %*(100-8%); it is 71%.

Economic weight in this criteria increases with decreasing water loss, or increasing of water productivity in term of kg/m^3. This means revenue of each Table 6.7part1: Three Scenarios comparing results in scaling procedure

on agricultural productivity in the CSA. In the context of water resources for irrigation, there are conventional water resources (Underground, fresh or brackish water, and bought fresh water from Israeli Water Company (MEKOROT)), or non-conventional water resources, which are desalinated saline or brackish water and treated effluent. Those water resources could affect the global Economic weight into negative or positive direction with the water cost percentage regarding water resource used into each measure. Weight for defining priorities of each scenario is estimated. Therefore, according to this estimation, economic weight could be calculated regarding this assumed formula: Eco. Weight= (100 % - (water cost/Total water cost) %)*16%, for this formula, for example, Eco. Weight of implementation of water service (irrigation network) = (100% - (0.04*75) / (.04+0.9+0.32+1))*0.16 = 15.78, which cost of one m^3 of fresh water from shallow aquifer is U.S $ 0.04, and the cost of desalinated or treated

floods of one m^3 is U.S $0.9, and the treated effluent is U.S $ 0.32 and finally water bought from MEKOROT is U.S $ 1.

Social indicator weight could be evaluated by stakeholders' acceptance or rejection in the CSA. Usually it has sharp values. For acceptance it is 1 value, and for rejection it is zero value. Some measures are very clear regarding stakeholders position, like reused treated effluent. Stakeholders are strongly against this non-conventional water resource; otherwise, rehabilitation of shallow aquifer wells and new wells in the CSA are highly accepted by the public and stakeholder in the areas. Therefore, in case of reused treated effluent, social weight is zero, and in case of new shallow aquifer wells, the social weight is one. However, Table 6.8 explains all those weighted measures into three main criteria aspects: Environment, Economic and social aspects.

Table 6.8 Part1:Weighted measures by three main criteria aspects: Env., Eco., and socio.

Main criteria	Sub criteria (Measures from M1....M24)	Measures	Env. Ind. (Global 77%)	Eco. Ind. (Global16%)	Socio. In(Global 0.07%
	Description of IWRM Measures				
Water production	Implementation and renewal of water service network	M1	(100%-decreasing of recharge%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Rehabilitation of Shallow aquifer wells	M2	(100%- increasing of abstraction %)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Treating Auja village Effluent	M3	(100-nontreated%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Agriculture ponds Rehabilitation	M4	(100%-decreasing of recharge%)77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Retention of flash floods	M5	(1-decreasing of WT%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Deep wells in the carbonate aquifer – Fresh Water	M6	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Deep wells in the carbonate aquifer – Brackish	M7	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	New Shallow wells in the alluvium aquifer - Brackish	M8	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
Water import	Import of treated effluents from El Bireh WWTP	M9	(100%-non treated%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Import of treated effluent from Jericho WWTP	M10	(100%-non treated%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Water import from Fashkha (spring)	M11	(100%-saline water recharge%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	New deep wells in Fashkha area	M12	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Fresh water import from Palestinian National Water Carrier	M13	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Export of surplus water	M14	100%-Recharge loss%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
Desalination and management	Groundwater desalination	M15	(100%-Recharge from saline water%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%

Table 6.8 Part2:Weighted measures by three main criteria aspects: Env., Eco., and socio

	Mixing of brackish water and fresh water resources	M16	(100%-Recharge from saline water%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Mixing of brackish water and treated effluent	M17	(100%-Recharge from saline water%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	M18	(100%-WT decreasing%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
Agriculture Development	Extension of regular irrigated agriculture	M19	(100%+Recharge %)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Greenhouse technology implementation	M20	(100%+Recharge %)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Palm tree production (salt-resistant high revenue crops)	M21	(100%-Recharge from saline water%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Hydroponic (Planting in water of regular vegetables)	M22	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Aquaponics (fish Farms)	M23	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%
	Soil mixing and neutralization	M24	(100%-WT depletion%)*77%	(100%-(water cost/Total water cost) %)*16%	(Yes=100%.no=0),Conditional 50%

In the context of calculating weight**,** local weighting of the three different scenarios was calculated based on the definition of triangle global weights of environmental, economic and social aspects. The main decision variable depends on water recharge decrease or increase in the environmental aspect, water yield percent in terms of the economic weight, and the public acceptance is the main indicator for weighting social weight. Results are summed up in Table 6.7.

Table 6.9Part1: Weighting results of three WS scenarios by env., eco. and socio aspects.

		WSI (Do-Nothing)			WSII (MAR)			WSIII (100% IWRM)		
Main criteria		Env. I Weight	Econ. I Weight	Soc. I Weight	EnvII. Weight	EcoII. Weight	SocII. Weight	Env.III Weight	Eco.III Weight	ScIII Weight
Water production	M1	0.770	0.160	0.070	0.770	0.160	0.070	0.660	0.157	0.070
	M2	0.655	0.160	0.070	0.655	0.160	0.070	0.700	0.157	0.070
	M3	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.137	0.035
	M4	0.770	0.160	0.070	0.770	0.160	0.070	0.700	0.157	0.070
	M5	0.770	0.160	0.070	0.770	0.096	0.070	0.770	0.137	0.070
	M6	0.000	0.160	0.070	0.000	0.160	0.070	0.700	0.148	0.070

Table 6.9Part2: Weighting results of three WS scenarios by env., eco. and socio aspects.

	M7	0.000	0.160	0.070	0.000	0.160	0.070	0.700	0.100	0.035
	M8	0.000	0.160	0.070	0.000	0.160	0.070	0.650	0.127	0.070
Water import	M9	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.137	0.035
	M10	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.137	0.035
	M11	0.000	0.160	0.070	0.000	0.160	0.070	0.700	0.096	0.070
	M12	0.000	0.160	0.070	0.000	0.160	0.070	0.700	0.074	0.035
	M13	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.090	0.070
	M14	0.000	0.160	0.070	0.000	0.160	0.070	0.700	0.157	0.000
Desalination and management	M15	0.000	0.160	0.070	0.000	0.160	0.070	0.700	0.110	0.035
	M16	0.693	0.160	0.070	0.693	0.160	0.070	0.770	0.157	0.070
	M17	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.147	0.035
	M18	0.000	0.160	0.070	0.770	0.157	0.035	0.770	0.127	0.035
Agriculture Development	M19	0.770	0.160	0.070	0.770	0.160	0.070	0.770	0.100	0.070
	M20	0.770	0.160	0.070	0.770	0.160	0.070	0.770	0.900	0.070
	M21	0.770	0.160	0.070	0.770	0.160	0.070	0.770	0.100	0.070
	M22	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.128	0.000
	M23	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.157	0.035
	M24	0.000	0.160	0.070	0.000	0.160	0.070	0.770	0.090	0.070

6.4.5 Ranking the results and determining the best options

Ranking three water strategies regarding weight and scale values explores priorities in all scenarios. The highest priority in SCIII is Greenhouse Technology (0.169). Mixing brackish water with fresh water took (0.097) on the scale, while the third priority was palm dates farming. The third one was rehabilitation of shallow aquifer wells (0.09), and implementation and renewable water network (0.086).

In the WSII, date palms and retention of flash floods have the first priority (0.082 and 0.08). Retention of flash floods is a component of water production and MAR.

Do-nothing strategy (WSI) keeps the current situation stable without change, like the continuous leakage of the network without retention of flash floods or without rehabilitation of agriculture ponds, has the highest weights (0.085 and 0.079). Palm dates farming regarding the Do-nothing scenario is also a priority according to the current status. Table 6.10 explains all these priorities.

Table 6.10: Priorities defining by rank all three strategies (SCI, SCII, and SCIII)

Main criteria	Description of IWRM Measures	Measures	SCI values	SCII values	SCIII values
water production	Implementation and renewal of water service network	M1	0.085	0.076	0.086
	Rehabilitation of Shallow aquifer wells	M2	0.078	0.073	0.090
	Treating Auja village Effluent	M3	0.002	0.002	0.018
	Agriculture ponds Rehabilitation	M4	0.085	0.078	0.045
	Retention of flash floods	M5	0.079	0.080	0.032
	Deep wells in the carbonate aquifer – Fresh Water	M6	0.005	0.004	0.030
	Deep wells in the carbonate aquifer – Brackish	M7	0.005	0.005	0.012
	Shallow wells in the alluvium aquifer - Brackish	M8	0.019	0.018	0.041
Water import	Import of treated effluents from El Bireh WWTP	M9	0.002	0.002	0.013
	Import of treated effluent from Jericho WWTP	M10	0.002	0.002	0.011
	Water import from Fashkha (spring)	M11	0.002	0.002	0.009
	New deep wells in Fashkha area	M12	0.003	0.003	0.009
	Fresh water import from Palestinian National Water Carrier	M13	0.015	0.014	0.045
	Export of surplus water	M14	0.008	0.006	0.010
Desalination and management	Groundwater desalination	M15	0.004	0.004	0.028
	Mixing of brackish water and fresh water resources	M16	0.061	0.054	0.097
	Mixing of brackish water and treated effluent	M17	0.003	0.003	0.018
	Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	M18	0.006	0.034	0.045
Agriculture Development	Extension of regular irrigated agriculture	M19	0.041	0.041	0.046
	Greenhouse technology implementation	M20	0.070	0.068	0.169
	Date Palm production (salt-resistant high revenue crops)	M21	0.082	0.082	0.091
	Hydroponic (Planting in water of regular vegetables)	M22	0.004	0.004	0.012
	Aquaponic (fish Farms)	M23	0.006	0.006	0.016
	Soil mixing and neutralization	M24	0.007	0.007	0.031

6.6 Discussion and Results

Comparing the different measures of IWRM into three WS with ADS, ScI, ScII and ScIII, increased priorities in agricultural production by green house agriculture and palms date planting which form the highest priorities in developing strategies. Therefore, on the one hand water production techniques, mixing of fresh water with brackish water, and rehabilitation of shallow aquifer wells form the highest prior needs in developing strategies in the CSA, while implementing and renewing water services in irrigation network is the third priority in water production criterion on the other. Figure (6.6) and Figure (6.7) represent the suggested scenarios.

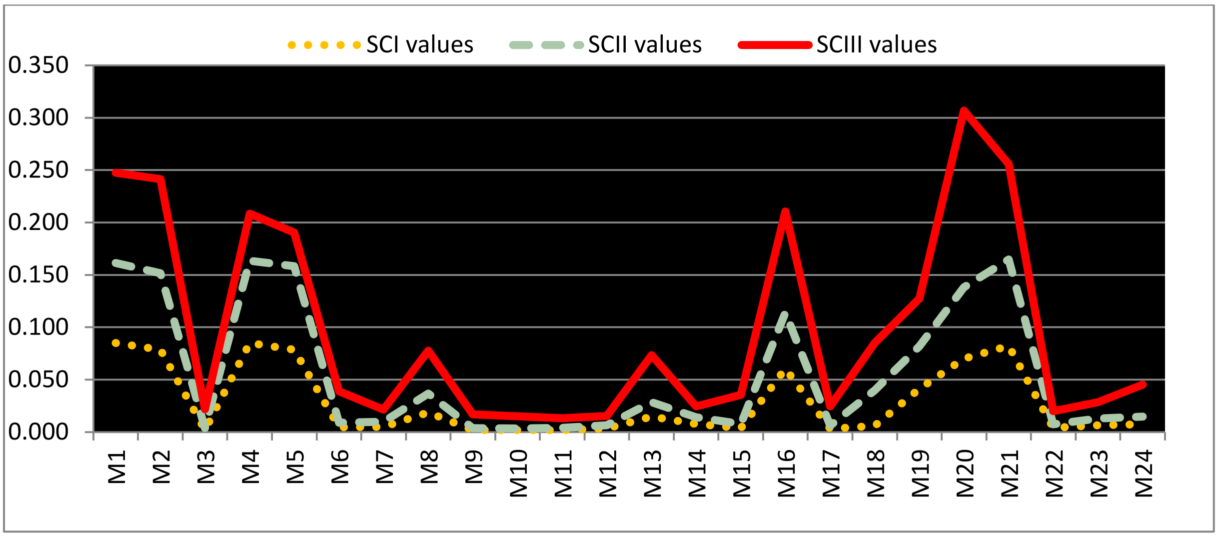


Figure 6.6: Comparing of three suggested Scenarios, ScI, ScII, and ScIII

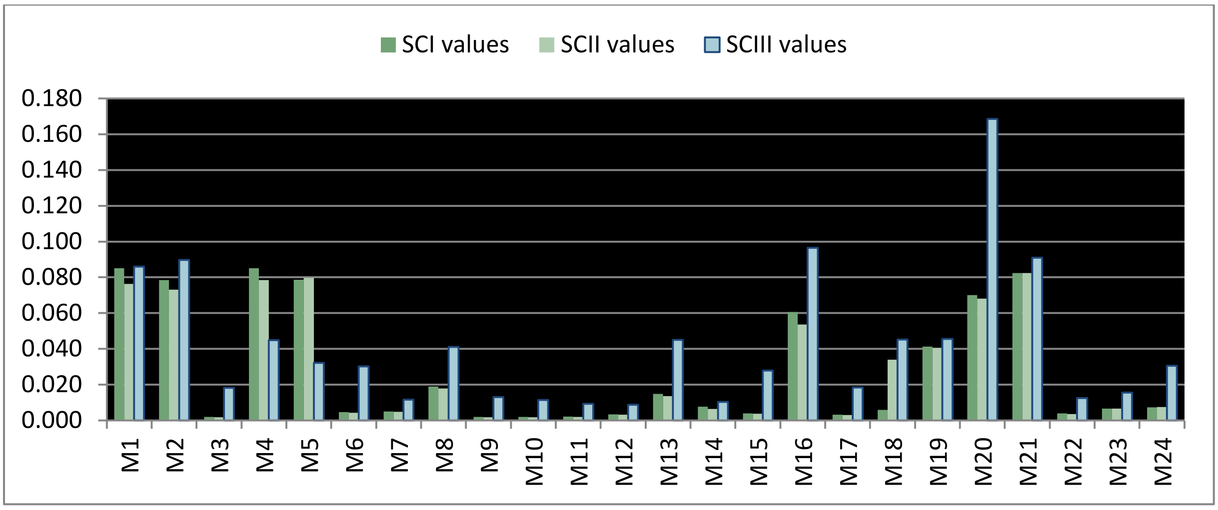


Figure 6.7 Comparing of three suggested scenarios: ScI, ScII and ScIII

In table 6.11 priorities were rearranged into each measured one regarding value increasing from SCI to SCII, and up to SCIII. Clearly, the highest rank is the Green House Technology (0.169) and mixing brackish water with fresh water leads to giving high priority for date palm farming; rehabilitation of shallow aquifer wells in the CSA takes fifth priority. This includes irrigation technique in the CSA and also water distribution through the Auja canal.

Table 6.11Part 1: Priorities of rearrangement of all measures into three scenarios.

Measures	Measures	SCI values	SCII values	SCIII values
Treating Auja village Effluent	M3	0.002	0.002	0.018
Soil mixing and neutralization	M24	0.007	0.007	0.031
Rehabilitation of Shallow aquifer wells	M2	0.078	0.073	0.090
New deep wells in Fashkha area	M12	0.003	0.003	0.009

Table 6.11Part 2: Priorities of rearrangement of all measures into three scenarios

Hydroponic (Planting in water of regular vegetables)	M22	0.004	0.004	0.012
Aquaponic (fish Farms)	M23	0.006	0.006	0.016
Agriculture ponds Rehabilitation	M4	0.085	0.078	0.045
Date Palm production (salt-resistant high revenue crops)	M21	0.082	0.082	0.091
Water import from Fashkha (spring)	M11	0.002	0.002	0.009
Shallow wells in the alluvium aquifer - Brackish	M8	0.019	0.018	0.041
Retention of flash floods	M5	0.079	0.080	0.032
Mixing of brackish water and treated effluent	M17	0.003	0.003	0.018
Mixing of brackish water and fresh water resources	M16	0.061	0.054	0.097
Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	M18	0.006	0.034	0.045
Import of treated effluents from El Bireh WWTP	M9	0.002	0.002	0.013
Import of treated effluent from Jericho WWTP	M10	0.002	0.002	0.011
Implementation and renewal of water service network	M1	0.085	0.076	0.086
Groundwater desalination	M15	0.004	0.004	0.028
Greenhouse technology implementation	M20	0.070	0.068	0.169
Fresh water import from Palestinian National Water Carrier	M13	0.015	0.014	0.045
Extension of regular irrigated agriculture	M19	0.041	0.041	0.046
Export of surplus water	M14	0.008	0.006	0.010
Deep wells in the carbonate aquifer – Fresh Water	M6	0.005	0.004	0.030
Deep wells in the carbonate aquifer – Brackish	M7	0.005	0.005	0.012

6.7 Main Conclusions

By DC analysis implemented by using DPSIR framework to define scales of DV, and by transfer of those DV into AHP under DC Hierarchy, several issues were concluded as follows:

Resulting priorities are not the optimum solution; they may be the best solution regarding the triangle of Environmental-Economic and social aspects.

High priorities were defined under intensive agriculture techniques and Date Palms farming while water production sub-criteria, mixing of brackish water with fresh water, in addition to implementation and renewable of new water networks are found to be high priorities.

Extension of regular agricultural planting is of intermediate priority.

Water importing sub-criterion takes the smallest ranking values indicating latest priorities in the CSA.

Chapter 7

Future Scenarios of Water Strategies

This chapter and the last chapter (Chapter 6) as well evaluated three water strategies with four main criteria: water production, water import, desalination and management and agricultural development. The main criterion included several sub-criteria called measures. These water scenarios were: SCI (WSI with ADSI), SCII (WSII with ADSII), and SCIII (WSIII with ADSIII).

7.1 SCI Water Strategy No.1 (WSI with ADSI); Do-nothing strategy

The first scenario SCI was applied on the current situation of water budget analysis (WSI) based on irrigated area of 3,750 donums in Zone 2 (ADSI). This area is actually cultivated by seven main crops: date palm, regular vegetables, intensive agriculture (green house vegetables), and intensive agriculture by medical herbs, grape farms, banana and corn using French tunnel irrigation. The crop pattern however starts to change because of water scarcity in the CSA. Banana and date palms are good examples of crop pattern change in the CSA, with banana farms replaced by date palms farming using brackish water instead of fresh water. Water budget analysis showed there is a surplus of 1 m^3/a but unfortunately this quantity is wasted. In this case, there are several ADS options which cou1d be applied in terms of crop pattern change on the same irrigated area of (3,750 donums). Such ADS options include:

1-ADIS op1: This option suggests cropping all irrigated area with date palms trees. Available water quantity should be enough for the total irrigated area in the CSA. Irrigation requirement should not exceed 4m^3/a for the total irrigated area. In this case, fresh or brackish water could be used for irrigation.

2- ADI op2: This option suggests crop pattern change to grapes cropping; this crop pattern changing however has a weak chance to succeed because of fresh water none/availability in the Do-nothing scenario. In other words, fresh water is not enough, and the scenario should not be applied completely.

3-ADSI op3: This alternative choice is based on intensive agriculture, i.e. it has to use greenhouse planting for vegetables and medical herbs; however, the same problem will be as in ADSI op2. Quantity of available fresh water is inadequate especially in terms of seasons for each crop. In this case, reduced crop seasons for one season may give partial solutions.

4-ADSI op4 and ADSI op5: These options which depend on fresh water are not good solutions under the Do-nothing approach in which hydroponic agriculture for vegetables save fresh water quantity.

In light of matrix performance evaluation and DC analysis (Chapter6), which was based on water production, water import, agricultural development and desalination and management, joint combined measures were analyzed as sub-criteria for each water strategies relevant to ADS. In this scenario (SCI), including WSI with ADSI (Do-nothing approach), priority indicators were found in these measures (24 measures for IWRM). These priorities give much less water loss and are more efficient in case of holding those priorities. To follow is a description of these measures:

Agriculture ponds rehabilitation (M4): This measure is present in farms on a large scale for each farmer. It is the highest value measure in case of Do-nothing and this leads to water production criterion in case of mismanagement of available water quantity. In the CSA, there are 54 ponds with a total volume of 800,000 m^3. Monthly water deficit in the period from 1977-2013 ranged between 1 M m^3 to 0.2 M m^3 during summer and dry seasons. Monthly surplus exceeded 1.5 M m^3 during wet seasons but with about 20% are lost by infiltration through those insufficient backed ponds and also about other 20% lost by evaporation.

Implementing renewable water services network (M1) has the same weight value as M4. In the current situation, 35% of available water is lost through irrigation network and about 40% is lost by conveying fresh water through Auja Canal.

Date palm production (M21): This measure is a dominant option in terms of popular acceptance and support in the CSA. It is salt-resistant crop and with high cost revenue. Date palm farms cover an area of more than 1,000 donums.

Other measures in this scenario have lower ranking values in order of evaluation by this scenario.

Regarding the scenario (SCI): Lower Jordan valley has more than 250,000 date palm trees and there are more than 13,000 Date Palms trees in the CSA. Available water in the CSA does not exceed 3.5 m^3/a distributed between intensive green house agriculture and date palms. In the next coming years this option will not be satisfactory because of high pressure on water resources in terms of quality and quantity. Therefore, other scenarios should be suggested regarding evaluation results in Chapter 6.

Table 7.1 illustrates all evaluation results of this scenario under WSI with ADSI together with all options.

Table 7.1 Joint combined measures of SCI based on Do-nothing scenario

Measures	Measures	SCI values	ADS Ops	Zone 2 (3750 don.)		
Agriculture ponds rehabilitation	M4	0.085		Crop	Area	CWR (Mm³/a/A)
Implementation and renewal of water service network	M1	0.085	ADS OP1	Date Palm	3750	3.96
Date palm production (salt-resistant high revenue crops)	M21	0.082	ADS OP2	Grape	3750	3.58
Retention of flash floods	M5	0.079	ADS OP3	Veg. Green House	2000	3.1
Rehabilitation of shallow aquifer wells	M2	0.078		Medical Green house	1750	1.83
Greenhouse technology implementation	M20	0.07	ADS OP4	Banana	3750	3.95
Mixing of brackish water with fresh water resources	M16	0.061	ADS OP5	Veg.Hydroponics	2000	1.19
Expansion of regular irrigated agriculture	M19	0.041		Medical Green House	1750	1.83
Shallow wells in the alluvium aquifer - Brackish	M8	0.019				
Fresh water import from Palestinian National Water Carrier	M13	0.015				
Export of surplus water	M14	0.008				
Soil mixing and neutralization	M24	0.007				
Aquaponic (fish Farms)	M23	0.006				
Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	M18	0.006				
Deep wells in the carbonate aquifer – Fresh Water	M6	0.005				
Deep wells in the carbonate aquifer – Brackish	M7	0.005				
Hydroponic (Planting in water of regular vegetables)	M22	0.004				
Groundwater desalination	M15	0.004				
New deep wells in Fashkha area	M12	0.003				
Mixing of brackish water and treated effluent	M17	0.003				
Treating Auja village Effluent	M3	0.002				
Water import from Fashkha (spring)	M11	0.002				
Import of treated effluents from El Bireh WWTP	M9	0.002				
Import of treated effluents from Jericho WWTP	M10	0.002				

7.2 SCII Water Strategy No.2, (WSII with ADSII); MAR including several joint combined measures.

This second scenario which includes WSII with ADSII is based on MAR as one main measure. With the Agriculture Development Strategy, ADSII irrigated lands is doubled. Targeted area in the CSA (zone 2 and zone 1) for irrigation should increase to about 8,000 donums instead of the current 4,000 donums. The new suggested expansion land lies to the east of current irrigated area and is highly fertile soil with sodic and saline properties. For this reason, date palms, which are high salt resistant crop, are a good option for planting in this area.

In Table 7.2, MAR (M18) is the ninth priority in evaluating joint combined measures. This means:

Agriculture Development criteria have high priority under measures (M21 and M20), which are date palms production and green house technology respectively.

Water Production criteria have second priority through retention of flash flood (M5) by constructing a new dam in the area like Auja Dam, agriculture ponds rehabilitation (M4), implementing and renewable water network (M1), and rehabilitation of shallow aquifer wells (M2) (11 wells). They have only 60% of their capacity.

Desalination and management criteria include measures of mixing brackish water with fresh water (M16) and MAR (M18); these two measures (M16 and M18) are supported by other previous measures.

This scenario could offer 7.23 m^3/a for about 7,000 donums (date palms and intensive greenhouse technology) supported by nine joint combined measures (M21, M5, M4, M2, M1, M20, M16, M18 and M19).Those measures have high priorities in implementing this scenario.

MAR is based on other joint combined measures such as infiltration ponds and control flooding by leaky dams which may be constructed to the south of Zone 2 in Wadi Auja. They can collect about 1 m^3/a and recharge about 0.5 m^3/a into shallow aquifer. There is 6 days flooding in a year in winter.

MAR used by flushing of overall the cropping area (Zone2) is about 2.5 Mm^3/a, recharge is estimated at 95% of total flushing quantities (2.4 Mm^3/a). In this manner, recharge by irrigation is estimated at 10%, (0.25 m^3/a) of water used for irrigation.

In this scenario also, Surplus of Auja canal, for wells injection as aquifer Storage and Recovery (ASR) methodology, there is about 12 Km long of Auja Canal distributed into irrigated lands of Auja area. Large quantity of fluctuated water has been wasted because of mismanagement of irrigation. The surplus fluctuated water is distributed into irrigated lands as over needs of irrigation purpose. It is estimated at 50%, i.e. about 2 Mm^3 in wet years. 1 MCM could infiltrate by the agricultural Ponds located over all the irrigated area. In this case about 95% of total quantity could be recharged into the shallow aquifer (Chapter 6), (Marie, A, and Manasrah, K., 2012), Pumping and Storage and Recovery, 2012) with 0.95 Mm^3 and 1Mm could be injected directly into 10 wells in the area. A good assumption is to inject all ten wells with 250 m^3/day over all the year in wet condition as used by model scenario WSII.

Table 7.2 SCII with MAR and several priorities of Joint Combined Measures

Measures	Measures	SCII values	ADS Ops	Zone 1 Crop	Zone 1 Area	Zone 1 CWR(MCM/a/area)	Zone 2 Crop	Zone 2 Area	Zone 2 CWR(Mm³/a/A)
Date Palm production (salt-resistant high revenue crops)	M21	0.082							
Retention of flash floods	M5	0.08	**ADS OP1**	Date Palms	4000	4.23	Date Palm	3750	3.96
Agriculture Ponds Rehabilitation	M4	0.078	**ADS OP2**	Date Palms	4000	4.23	Grape	3750	3.58
Implementation and renewal of water service network	M1	0.076	**ADS OP3**	Date Palms	4000	4.23	Veg. Green House	2000	3.1
Rehabilitation of Shallow aquifer wells	M2	0.073					Medical Green house	1750	1.83
Greenhouse technology implementation	M20	0.068	**ADS OP4**	Date Palms	4000	4.23	Banana	3750	3.95
Mixing of brackish water and fresh water resources	M16	0.054	**ADS OP5**	Date Palms	4000	4.23	Veg.Hydroponics	2000	1.19
Expansion of regular irrigated agriculture	M19	0.041							
Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	M18	0.034							
Shallow wells in the alluvium aquifer - Brackish	M8	0.018							
Fresh water import from Palestinian National Water Carrier	M13	0.014							
Soil mixing and neutralization	M24	0.007							
Aquaponic (fish Farms)	M23	0.006							
Export of surplus water	M14	0.006							
Deep wells in the carbonate aquifer – Brackish	M7	0.005							
Hydroponic (Planting in water of regular vegetables)	M22	0.004							
Groundwater desalination	M15	0.004							
Deep wells in the carbonate aquifer – Fresh Water	M6	0.004							
New deep wells in Fashkha area	M12	0.003							
Mixing of brackish water and treated effluent	M17	0.003							
Treating Auja village Effluent	M3	0.002							
Water import from Fashkha (spring)	M11	0.002							
Import of treated effluents from El Bireh WWTP	M9	0.002							
Import of treated effluent from Jericho WWTP	M10	0.002							

7.3 SCIII (IWRM Strategy (WSIII) towards ADSIII)

This Scenario (SCIII) is formed by WSIII towards ADSIII which is based on land expansion to about 13,000 donums. The suggested irrigated lands include Zone 2 (current irrigated area); Zone 1 is the eastern expansion of current irrigated area;

Zone 3 is the western expansion of Zone 2. Therefore water strategy in this scenario suggests WIRM as the strong scenario for comprehensive and integrated approach to achieve agricultural development in the CSA.

With joint and combined measures into this Scenario, the following statements could be concluded:

IWRM should be applied as soon as all stakeholders in the CSA, i.e. private sector and farmers, governmental bodies and non-governmental organizations (NGOs), should have a master plan for developing the LJV based on IWRM and taking into consideration agricultural development as the core of development in the LJV.

Green house technology has the highest value by DVs evaluation (M20=0.169) and the third priority in this scenario goes to date palm production. This result shows how it is crucial to take these two high productive crops into consideration. On the other hand it shows change in the crop pattern and diversification in the area. This happened because of crop needs for different quality of water for irrigation in which greenhouse technology needs fresh water for irrigation. Date palms have high productivity with brackish water irrigation; each dunom of date palms includes 13 trees which need to be irrigated by about 1000 m^3/a. Besides, date palms are salt resistant crops and irrigation by brackish water and a mixture of fresh and brackish water is a possible and good option for irrigation.

In this Scenario (Sc3), the high priority list for implementation in what is relevant to irrigation comes as a set of joint combined measures (M20, M16, M21, M2, M1, M4), divided into what the dominant crop pattern should be, i.e. green house and date palms, what water quality is required and how much water resources should be provided. Therefore, brackish water from shallow aquifer and fresh water from Auja Spring are main additional water resources in the CSA. They can provide about 3 mm^3/a of additional fresh water. MAR (M18) can use surplus water from Auja Spring during winter seasons; reconstruction of Auja canal and rehabilitation of agricultural ponds in Zone 2 (current irrigated area) make good options for saving 50% of leakage water from Auja canal to provide for new irrigated lands into Zone 3 (western lands of Auja village). This new available water quantity gives about 4,000 donums as new expanded area for irrigation by fresh water for developing regular vegetable cropping and grapes planting in the new area.

Non-conventional water resources in this scenario which were evaluated (Auja treated effluent; M3=0.018, BWWTP; M9=0.013 and Jericho WWTP; M19=0.011), in this manner, by importing treated effluent from those non-conventional resources towards the CSA. About 5 mm^3/a could be available. Actually, this treated effluent could be mixed with fresh or brackish water for irrigation purposes, indeed, in Jericho City; treated effluent by JWWTP was used for date palms. Citrus and tomato vegetables are under pilot experiment supervised by JICA, MoA and Jericho Municipality over two years ago. There are promising results by this pilot experiment which has neither chemical residuals nor biological contamination. Therefore, these results empower this non-conventional water resource option.

IWRM strategy also evaluated combined measures of shallow and deep aquifer new wells (M8 and M6) in the CSA. The last dug well in the CSA was 275 meters deep by Auja Municipality; it is with 1mm^3/a capacity and provides fresh water for domestic use. At this depth, two new wells are much more important for providing additional 2 mm^3/a for green house technology irrigation.

Retention of flush Floods (M5) could provide new water resources in the CSA and in the LJV. In the CSA, Auja Dam was constructed in 2013 with 0.6 mm^3/a capacity, and another one could be suggested on the southern east of Wadi Auja. This area is close to Zone 1 (the current irrigated area). This comes as a natural recharge and also storage lake after recharging at Jericho City. Wadi Quilt could collect about 3 mm^3/a by constructing a new dam at downstream area.

Ground water desalination comes with a moderate value in joint combined measures (M15=0.028). Importing directly from shallow wells in the CSA is more practical than importing saline water from Fashkha (M11 and M12=0.009).

IWRM strategy is based on all water resources (conventional and non-conventional). This strategy WSIII is based on four main criteria (water production, agricultural developing, desalination and management, and water importing). These criteria have 24 joint combined measures (See Table 7.3).By implementing this Scenario (WSIII with ADSIII) in the CSA, about 13 mm^3/a could be provided for irrigating 12,600 donums of date palms, green house and grapes in the CSA.

Table 7.3 SCII (WSIII with ADSIII OpI): All use joint combined measures.

Measures	Measures	SCIII values	ADS Ops	Zone 1+2+3 Total
Greenhouse technology implementation	M20	0.169		CWR(mm^3/a/A)
Mixing of brackish water and fresh water resources	M16	0.097	**ADS OP1**	**13.33**
Date Palm production (salt-resistant high revenue crops)	M21	0.091	**ADS OP2**	**12.45**
Rehabilitation of Shallow aquifer wells	M2	0.09	**ADS OP3**	**14.08**
Implementation and renewal of water service network	M1	0.086		
Expansion of regular irrigated agriculture	M19	0.046	**ADS OP4**	**12.82**
Agriculture ponds Rehabilitation	M4	0.045	**ADS OP5**	**11.89**
Managed Aquifer Recharge (MAR) – spring discharge & surface runoff	M18	0.045		
Fresh water import from Palestinian National Water Carrier	M13	0.045	Total Area (don.)	12615
Shallow wells in the alluvium aquifer - Brackish	M8	0.041		
Retention of flash floods	M5	0.032		
Soil mixing and neutralization	M24	0.031		
Deep wells in the carbonate aquifer – Fresh Water	M6	0.03		
Groundwater desalination	M15	0.028		
Treating Auja village Effluent	M3	0.018		
Mixing of brackish water and treated effluent	M17	0.018		
Aquaponic (fish Farms)	M23	0.016		
Import of treated effluents from El Bireh WWTP	M9	0.013		
Hydroponic (Planting in water of regular vegetables)	M22	0.012		
Deep wells in the carbonate aquifer – Brackish	M7	0.012		
Import of treated effluent from Jericho WWTP	M10	0.011		
Export of surplus water	M14	0.01		
New deep wells in Fashkha area	M12	0.009		
Water import from Fashkha (spring)	M11	0.009		

7.4 Recommendations and Main Conclusions

Three scenarios of water strategies towards Agricultural Development Strategies were evaluated in the CSA. The scenarios addressed water production, water import, management and desalination, and agriculture developing. As for evaluation of those scenarios, the following results were concluded:

Palestinians in the CSA cannot be developed in the context of agriculture development based on SCI (Do-Nothing scenario). Tragic scenarios could happen in case of the current situation remaining unchanged as is. One of those tragic scenarios will decrease vegetables production due to fresh water shortage and sharp scarcity. Using saline and brackish water will increase in the coming years which will affect soil fertility.

In the next five years, SCII, with the expansion of new 4,000 donums, could be applied. MAR and brackish water mixing are key issues into this Scenario, in addition to crop pattern change towards intensive agriculture and date palm farming.

IWRM Scenario (SCIII), which is based on conventional and non-conventional water resources, could provide the CSA by 15 mm³ in the coming 10 years. This strategy comes under Palestinian Sustained Production and Consumption Strategy (SPC strategy, 2015).

Three scenarios are divided into WS and ADS are illustrated in Figure 7.1.

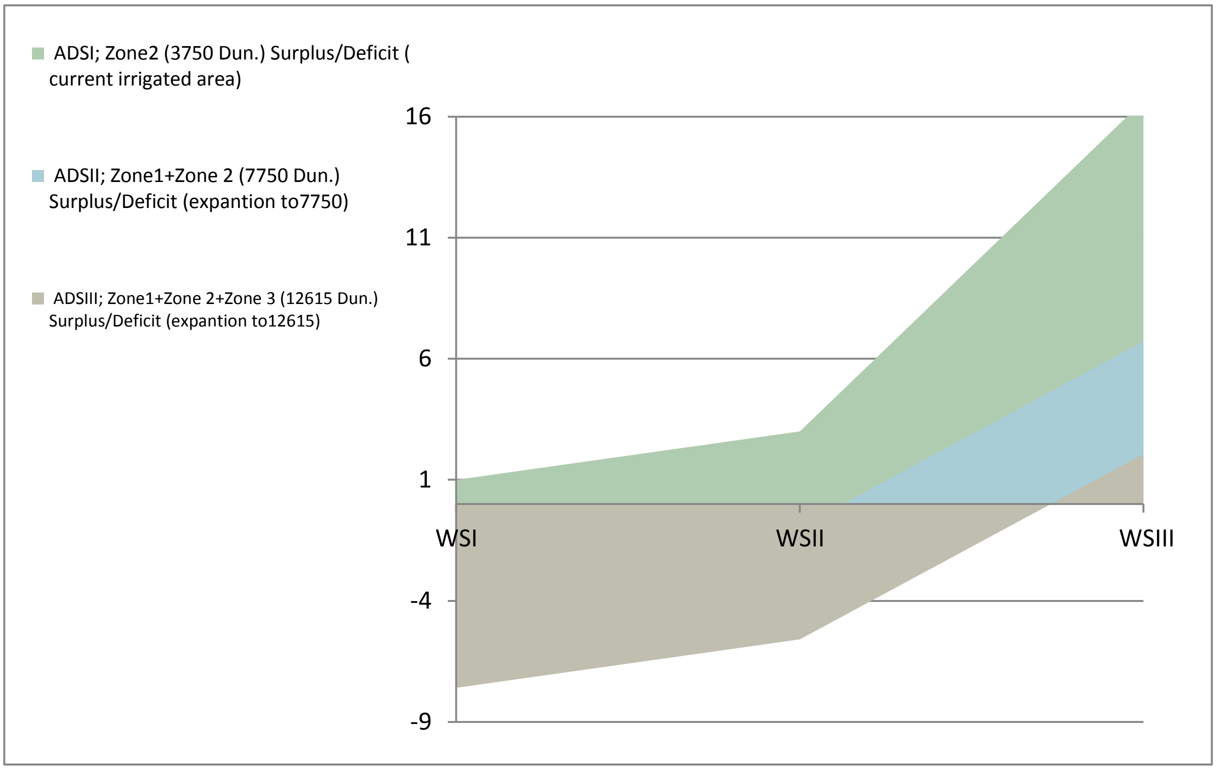


Figure 7.1 WSs versus ADSs

Chapter 8

Discussion and Conclusions

8.1 Methodology and problem statement

This investigation addressed several crucial and main topics relevant with the CSA current situation. The adopted methodology started with historical data and field survey data collection. This approach helped specify the problem and characterize CSA. The main confirmed conclusion was mismanagement of available water in the CSA. Furthermore, scarcity of agricultural water irrigation leads to several specific problems in terms of water quality and quantity and decrease of developing opportunities in the CSA (Auja area) and in the LJV area. Therefore, the investigation characterized the CSA and mapped the land cover.

This mapping gave a clear picture regarding potential plans for future agricultural development strategies and how water strategies in the Case study area could be developed taking into consideration crop water requirements and water quality for crop pattern change in future in case of irrigated lands expansion.

The research linked water budget analysis and agricultural developing strategies (ADS). This dialog started with studying the irrigable lands, soil, and water resources in the area. The irrigated area of no more than 3,000 donums was divided into different seasons with regular vegetables, intensive greenhouse vegetables, and intensive herbal planting and also date palms Such agricultural patterns are dominant in the case study area and use fresh water in irrigation system on a selective basis. In this case, the research advocates the use of non-conventional water resources for irrigation by developing several water strategies based also on several ADSs. Several scenarios are suggested based on soil salinity and land expansion together with several water strategies. These scenarios include Do-Nothing approach, MAR scenario and complete IWRM including non-conventional water resources likes brackish water and treated effluent in the CSA.

By those WS scenarios and ADS, decision-making criteria and performance indicator matrix was built into DPSIR framework with AHP methodology to have multi-criteria decision analysis. In this manner, decision-making criteria (DC) analyze all decision-making variables resulting from performance indicator analysis and gives up the main priorities of water measurements into WSs scenarios.

8.2 Characteristics and Delineation of the Study Area

Many items went into two main directions; the first one was CSA relevant data collection from different sources including farmers, water resources owners or beneficiaries, and governmental and local authorities. The second direction was using field surveys which included soil; agricultural lands cover use and cultivation under the current situation. This may provide a clearer picture to the ground. Many complex issues relate to water ownerships, water rights and distribution; besides, the main irrigation water source comes from Auja Spring and shallow aquifer wells. Water from Auja Spring is divided among Auja families since 1956 (Jordan's Rule on the West Bank: 1950-1967). By time some Auja lands were purchased by new families from Auja or outside Auja, but water rights remained in the hands of old families. In addition, shallow aquifer wells became highly saline water because of CSA overexploitation. To make the picture worse, new agricultural companies started agricultural investments in the CSA which increased water demands by intensive agriculture.

According to collected data from several resources, the irrigable area in the CSA is about 30 donums, but cultivated lands do not exceed 4,000 donums in all seasons, 30% of which is farmed by date palm trees. Banana, the main traditional crop in CSA, disappeared due to decrease of fresh water in the area. However, a new crop pattern was growing in the area, namely, date palm trees, and intensive agriculture herbal plants and vegetables. Companies are changing the crop pattern and small farmers disappear day after day.

Mapping the irrigated and arable area gave three land zones: Zone 1, Zone 2, and Zone 3. The treated zone (Zone 2) contains high to intermediate soil salinity and needs high Leaching Rate (LR). The other two zones 1 and 3 are virgin lands with reasonable soil salinity concentration which provides good opportunity for changing the current crop pattern in the area in case of land expansion towards west or east of the cultivated area. Therefore, ADSs were developed regarding crop salt resistivity and water quality.

Based on growing date palms into land expansion towards the eastern part (Zone 1), grapes and intensive agriculture were grown in the western part (Zone 3), and the treated area (Cultivated area) could change also into date palm planting. These three scenarios expanded the irrigated area from 4,000 donums to about 11,500 donums in tens of years. In this case, water quality and water resources, conventional and nonconventional water resources, could play a crucial role when those ADSs are applied. As a result, the research addressed Water Budget Analysis and Water Strategies Developing Scenarios (WSS).

In the context of ADSs which were jointly linked with WSs scenarios, CropWat model was built and was conducted on main crops which grown in the CSA. Crop factor Evapotranspiration was also calculated. This model calculated irrigation scheme for the main crops in the area (date palms, regular vegetables, vegetables green house, medical herbs green house, corn, banana and grapes). Those real calculations gave monthly Crop Water Requirement (CWR) for each crop. Actually, there is a difference with about 20% of actual provided water for irrigation in the CSA in comparison with those calculations. CropWat model calculation could save 20% of used water in irrigation scheme including LR in the CSA; on other hand, proper water quality could be selected regarding soil calculation and crop pattern in the area.

8.3 Water Budget Analysis and Water Strategies

Analysis of water budget in the CSA is based on water potential resources, both conventional and nonconventional resources. Main conventional resources are represented by Auja Spring and shallow aquifer wells, which are the main used sources in the CSA. Auja Spring fluctuation formed the main source of fresh water in the area and shallow aquifer wells also represent the second source of brackish water. Farmers in the area mix fresh water with brackish in irrigation to save some water quantity for their crops. But this procedure is not a good solution in the farmers' practices in the CSA, especially in summer season. Available fresh water by Auja Spring does not exceed 50% of water potential. There is about 50% of untapped water current (UWC). These are lost quantities, as well as the shallow aquifer wells which they had not abstract 60% of their capacity. This caused, with maintenance needs, these wells, as well as water table depletion and water quality deterioration in summer season which resulted in high saline water production. This worst situation reduced the irrigated lands from 10,000 donums in 2003 to 3,800 donums in 2013. Therefore, the research selected the nonconventional water resources in water budget analysis.

Nonconventional resources include resources inside the CSA and outside. Main components of these new resources are treated effluents, desalination of brackish/saline water and also, new wells into shallow or deep carbonate aquifer. This also means importing water from outside the CSA to form new water production resources. These scenarios of water production and water importing are enough to have a complete IWRM research, therefore, water management included brackish water desalination and MAR to form core component into assumed water strategies scenarios. The Do-Nothing water strategy scenario (WSI), which represents the water strategy in the current situation, gave high water demand deficit into irrigation process. As a result, development of new water strategies was on the way as high priority in our research.

8.4 Developing Water Strategies

In light of the current situation of decreasing irrigated lands from 10,000 donums in 2003 to about 3,800 donums in 2013, aridity and water scarcity in the CSA dominate the agricultural activities in the area. Indeed, if WSI (Do-Nothing scenario) is still the main approach adopted in the CSA, the irrigated lands should be decreasing continuously until we have no irrigated lands in the CSA.

Therefore, other new WSs were developed. WSII which addresses Managing Aquifer Recharge as main technique, and IWRM strategy (WSIII) are also assumed. These WSs are used within terms of thoroughness and integrity of water resources planning.

MAR strategy, which develops new conceptual model based on using CUWR from Auja Spring with direct injection into shallow aquifer wells, as well as the infiltration of flooded surface run-off water from Wadi Auja, formed the second component of MAR. This conceptual model was based on two main layers, the alluvial deposit and Lisan formation. Complexity of lithology formation of the CSA led the investigations to build up this two-layer model without a third layer, inter-fingering and overplayed. In addition to geologic boundary of a third layer (Deep carbonate layer), the model made this choice with two layers and the conceptual model started from a regional model applied on Jericho-Auja model to be Auja Model in lower Auja boundaries.

The model domain was applied on an approximate area of 70 km^2 which includes alluvial deposit area. It borders the River Jordan in the East and the Rift Fault in the west. In the south and north there are respectively Wadi Fascial and wadi Marrar. The model was based on head pressure of monthly historical data of observed wells measurement from 1967 to 2010. This domain boundaries yielded numerical transient model based on Modflow computer source code.

Modflow numerical model simulates as steady state of different observed heads in Jericho-Auja area. This makes the model more certain in having simulation into transient head calibration. It was applied on two main wells: Well No. 19-15/005 and Well No.19-15/023 at the CSA. Simulation by direct injection in ten shallow aquifer wells and infiltration of flooded Wadi Auja surface run-off gave rise to WT by 2 to 3 m. This reflects and offers the ability to have a plan of Aquifer Storage and Recovery (ASR) implementation in irrigation scheme in the CSA. This promising solution provided also a good opportunity to stop water table depletion and water quality deterioration in the CSA.

In the context of managing water resources in the CSA on a comprehensive and integrated basis, IWRM was applied on conventional and non-conventional resources. The third water strategy (WSIII) tried to find a new solution for water scarcity in the CSA besides conventional resources. WSIII has focused on nonconventional water resources which come from desalination of brackish and saline water and also using treated effluents. This integrated vision was an option for water production, water importing, desalination, and MAR. Agricultural development in case of implementing this third strategy, an additional 11,000 donums could be irrigated, which means expanding irrigated lands by 400% with several crop patterns including date palm trees, intensive green houses with vegetables and medical herbs, and also, grapes as one main crop into those strategies.

8.5 Evaluation and Decision Criteria

Last part of this research addressed evaluating those assumed WSs with ADSs. Performance index indicators started to hold all decision variables (DV) which were derived from the joint measure compound of four main criteria: water production, water importing, management and desalination and agricultural development. All these DVs are linked with DPSIR framework analysis. DPSIR frame work approach conducts several variants with each other to conclude the current performance index. This approach gave a clear picture of responses converted from several measures, like Response interventions in DPSIR framework. Responses are also circulated in terms of quantity by the Drivers and Impacts. This approach made DVs more efficient for the scaling of those DVs.

Evaluation followed the forming of the main DVs; AHP was applied on using the resulting DVs with their performance index. This made scaling of DV easier. Thus, comparison took place in scaling evaluation for each DV, and by this approach of pairwise comparison, scale was derived for each DV.

After scaling, it is of paramount importance to weigh these DVs. Several relationships were derived for all those DVs for weighing those DVs based on the Global Weight of Environmental, Economic and Social aspects. DVs were weighted as local with local weights calculated with assumed identification of each DV. Cost and water quantity production regarding the current situation were referenced to those identifications of weight calculation.

Determining priorities by assumed three WSs is coming available in accordance with evaluation, scaling and weighting of several DVs in this research. Definitely, mixing of fresh water with brackish water in the CSA has superiority; then greenhouse techniques and date palms planting are the best priority in term of ADS, but MAR does not have high priority in this analysis; by rank and normalizing the results, it is intermediate.

8.6 Main conclusions

This research concluded the following results:

- Random Agricultural pattern and irrigation scheme mismanagement are main key words of the results of this research.
- Agriculture has suffered from lack of irrigation infrastructure in the LJV as well as in the CSA (Auja area).
- Soil salinity in irrigated area is moderate to high, which would increase in future and have negative impact on different crops including salt-resistant crops like date palm trees.
- CUWR forms a promising resource for providing new water quantity for irrigation; also, using brackish water is a main source by desalination or mixing with fresh water.
- Water storage in winter season is a logical solution to give a partial solution for water scarcity during summer season.
- MAR offers water quantity for irrigated lands expansion; also there is an opportunity for stopping water quality deterioration in shallow aquifer; MAR and ASR need deeper future research.
- Brackish and saline water is main part of a solution in the CSA, as well as the LJV.
- IWRM should be planned and focused on brackish water mixing and desalination; also crop pattern should change to have compatibility with available water quality.
- The social issue is forming high pressure on the use of treated effluent. This needs maximizing revenues to support social acceptance.
- The political situation is a crucial aspect of developing the area.

Further research should be conducted to have optimal solution for each option of the suggested Water Strategy and ADS Scenarios

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10 Appendices

Appendix 10.1 soil sieving analysis

Table 10.1: Texture components of soil analysis in the CSA

0-20cm			20-50cm			50-70cm			70-100cm			100-120cm			110-125cm			
Sand	silt	clay	sand	silt	Clay	sand	silt	clay	sand	silt	clay	sand	silt	clay	sand	silt	clay	Sample Id
49.12	31.90	18.84	56.34	32.48	11.90	51.80	38.36	10.10				61.94	36.34	1.94	69.65	24.20	12.55	s1
36.68	47.26	16.06	24.66	54.34	21.00	77.20	22.00	0.90	68.00	15.30	0.80	77.80	21.10	0.70				s2
49.18	37.34	13.48	64.88	25.42	5.58	77.20	22.00	0.92	68.00	15.36	0.84	77.82	21.14	0.78				s3
31.88	64.38	5.94	59.08	53.42	5.40	54.30	46.08	1.60	41.50	47.69	14.58	53.66	33.70	1.46				s4
63.38	16.68	0.70	87.64	11.94	0.46	95.02	46.80	0.24	96.86	6.54	1.16							s5
36.16	54.76	9.08	57.62	32.84	9.20	57.62	32.84	9.20	61.78	31.38	6.78	61.70	31.30	6.70				s6
40.64	52.94	16.74	47.80	57.80	7.90	56.62	43.18	6.86	49.12	43.10	5.56	53.50	38.54	8.00				s7
39.50	39.80	20.50	15.20	56.70	16.60													s8
41.32	40.18	18.94	51.96	39.88	2.72	53.00	40.40	4.70	47.70	37.90	11.80							s9
53.50	34.00	10.60	54.90	39.50	3.60	58.80	37.20	3.60	56.34	42.26	1.37	49.00	43.26	3.06				s10
57.80	32.20	0.10	41.72	51.18	11.00	56.20	40.20	40.60	47.10	30.30	19.00							s11
39.80	37.30	16.90	52.40	47.20	20.80	59.70	35.60	40.60	75.40	22.40	9.10							s12
66.28	21.55	13.28	56.66	23.88	18.32	54.54	18.92	22.06	57.13	22.85	20.65							s13
38.06	32.02	30.12				59.12	28.04	7.18	43.30	57.94	1.12							s14
60.00	23.04	14.74	83.16	14.08	0.60	72.70	17.05	2.50										s15
76.20	24.00	0.20	66.00	19.20	0.20	51.70	48.40	0.40	66.30	13.42	2.50							s16
40.64	45.30	14.42	45.86	48.32	6.04	53.44	43.32	2.98	55.10	42.04	2.08							s17
30.68	62.16	1.56	37.34	55.64	1.50	20.98	71.06	5.62										s18
21.90	38.00	55.50	21.60	44.90	31.20	14.40	77.90	27.30	64.02	34.00	1.54	71.80	24.61	0.58				s19

Table 10.2 Part 1: Sieve analysis of Sample 1 with several depths

s1(0-20)cm				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.30	654.50	143.20	28.68
1.6mm	507.70	529.30	21.60	4.33
1mm	450.60	495.20	44.60	8.93
710Mm	395.70	431.90	36.20	7.25
500Mm	432.60	465.50	32.90	6.59
250Mm	413.30	479.10	65.80	13.18
200Mm	413.10	446.60	33.50	6.71
160Mm	324.20	351.50	27.30	5.47
90Mm	387.50	433.40	45.90	9.19
75Mm	365.30	391.20	25.90	5.19
63Mm	360.10	371.90	11.80	2.36
<63Mm	304.50	315.10	10.60	2.12
			499.30	100.00
s1(20-50)cm				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.30	689.40	178.10	35.37
1.6mm	507.70	530.10	22.40	4.45
1mm	450.60	495.90	45.30	9.00
710Mm	395.70	431.60	35.90	7.13
500Mm	432.60	464.70	32.10	6.37
250Mm	413.30	476.10	62.80	12.47
200Mm	413.10	451.90	38.80	7.70
160Mm	324.20	352.90	28.70	5.70
90Mm	387.50	424.70	37.20	7.39
75Mm	365.30	377.40	12.10	2.40
63Mm	360.10	366.90	6.80	1.35
<63Mm	304.50	307.90	3.40	0.68
			503.60	100.00
s1(50-70)cm				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.30	662.10	150.80	30.08
1.6mm	507.70	528.90	21.20	4.23
1mm	450.60	497.80	47.20	9.42
710Mm	395.70	435.50	39.80	7.94
500Mm	432.60	471.50	38.90	7.76
250Mm	413.30	501.50	88.20	17.59
200Mm	413.10	447.90	34.80	6.94
160Mm	324.20	354.10	29.90	5.96
90Mm	387.50	422.60	35.10	7.00
75Mm	365.30	373.70	8.40	1.68
63Mm	360.10	364.50	4.40	0.88
<63Mm	304.50	307.10	2.60	0.52

Table 10.2 Part 1: Sieve analysis of Sample 1 with several depths

			501.30	100.00
s1(70-100)cm				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.30	669.60	158.30	31.59
1.6mm	507.70	531.00	23.30	4.65
1mm	450.60	510.00	59.40	11.85
710Mm	395.70	464.40	68.70	13.71
500Mm	432.60	480.80	48.20	9.62
250Mm	413.30	510.90	97.60	19.48
200Mm	413.10	437.70	24.60	4.91
160Mm	324.20	335.50	11.30	2.26
90Mm	387.50	394.00	6.50	1.30
75Mm	365.30	367.10	1.80	0.36
63Mm	360.10	360.90	0.80	0.16
<63Mm	304.50	305.10	0.60	0.12
			501.10	100.00

Table 10.3 Sieve analysis of Sample2 with several depths

s2(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	609.7	98.4	19.68
1.6mm	507.7	507.9	0.2	0.04
1mm	450.6	497.9	47.3	9.46
710Mm	395.7	433.2	37.5	7.5
500Mm	432.6	470.8	38.2	7.64
250Mm	413.3	419.9	6.6	1.32
200Mm	413.1	514.4	101.3	20.26
160Mm	324.2	414.4	90.2	18.04
90Mm	387.5	444.6	57.1	11.42
75Mm	365.3	381.2	15.9	3.18
63Mm	360.1	365	4.9	0.98
<63Mm	304.5	306.9	2.4	0.48
			500	100
s2(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	539.5	28	5.6
1.6mm	507.7	527.3	19.6	3.92
1mm	450.6	494.2	43.6	8.72
710Mm	395.7	427.8	32.1	6.42
500Mm	432.6	463.3	30.7	6.14
250Mm	413.3	487.1	73.8	14.76
200Mm	413.1	488.7	75.6	15.12
160Mm	324.2	415.8	91.6	18.32
90Mm	387.5	425.5	38	7.6
75Mm	365.3	409.7	44.4	8.88
63Mm	360.1	375.5	15.4	3.08
<63Mm	304.5	311.7	7.2	1.44
			500	100

Table10.4 Part 1: Sieve analysis of Sample 3 with several depths

s3(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	635.6	124.3	24.86
1.6mm	507.7	541.9	34.2	6.84
1mm	450.6	500.3	49.7	9.94
710Mm	395.7	433.4	37.7	7.54
500Mm	432.6	465	32.4	6.48
250Mm	413.3	493.9	80.6	16.12
200Mm	413.1	453.4	40.3	8.06
160Mm	324.2	357.6	33.4	6.68
90Mm	387.5	440.5	53	10.6
75Mm	365.3	373.3	8	1.6
63Mm	360.1	363.9	3.8	0.76
<63Mm	304.5	307.1	2.6	0.52
			500	100
s3(20-50)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	721.3	210	43.80476
1.6mm	507.7	531.7	24	5.006258
1mm	450.6	504.1	53.5	11.15978
710Mm	395.7	432.6	36.9	7.697121
500Mm	432.6	464	31.4	6.549854
250Mm	413.3	470.8	57.5	11.99416
200Mm	413.1	432.9	19.8	4.130163
160Mm	324.2	342.6	18.4	3.838131
90Mm	387.5	406.1	18.6	3.87985
75Mm	365.3	370.9	5.6	1.168127
63Mm	360.1	361.6	1.5	0.312891
<63Mm	304.5	306.7	2.2	0.458907
			479.4	100
s3(70-100)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	710.1	198.8	46.4269
1.6mm	507.7	535.9	28.2	6.585708
1mm	450.6	506.6	56	13.078
710Mm	395.7	452.7	57	13.31154
500Mm	432.6	464.5	31.9	7.44979
250Mm	413.3	454.1	40.8	9.528258
200Mm	413.1	416	2.9	0.677254
160Mm	324.2	325.1	0.9	0.210182
90Mm	387.5	388.8	1.3	0.303596
75Mm	365.3	365.7	0.4	0.093414
63Mm	360.1	368.3	8.2	1.914993
<63Mm	304.5	306.3	1.8	0.420364
			428.2	100
s3(100-120)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**

Table10.4 Part 2: Sieve analysis of Sample 3 with several depths

2mm	511.3	771.5	260.2	52.15474
1.6mm	507.7	535.9	28.2	5.652435
1mm	450.6	515.1	64.5	12.92844
710Mm	395.7	432.1	36.4	7.296051
500Mm	432.6	466.1	33.5	6.714772
250Mm	413.3	468.2	54.9	11.00421
200Mm	413.1	426.6	13.5	2.705953
160Mm	324.2	328	3.8	0.761676
90Mm	387.5	389.9	2.4	0.481058
75Mm	365.3	366.1	0.8	0.160353
63Mm	360.1	360.4	0.3	0.060132
<63Mm	304.5	304.9	0.4	0.080176
			498.9	100

Table10.5 Part 1: Sieve analysis of Sample 4 with several depths

s4(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve soil retains**	**soil retained**	**soil retained%**
2mm	511.3	591.5	80.2	15.69472
1.6mm	507.7	528.2	20.5	4.011742
1mm	450.6	480.9	30.3	5.92955
710Mm	395.7	424.1	28.4	5.55773
500Mm	432.6	461	28.4	5.55773
250Mm	413.3	528.6	115.3	22.5636
200Mm	413.1	508.6	95.5	18.68885
160Mm	324.2	406.9	82.7	16.18395
90Mm	387.5	390.2	2.7	0.528376
75Mm	365.3	382.5	17.2	3.365949
63Mm	360.1	369.3	9.2	1.800391
<63Mm	304.5	305.1	0.6	0.117417
			511	100
s4(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve soil retains**	**soil retained**	**soil retained%**
2mm	511.3	782.5	271.2	54.76575
1.6mm	507.7	526.4	18.7	3.776252
1mm	450.6	496.6	46	9.289176
710Mm	395.7	445.5	49.8	10.05654
500Mm	432.6	469.8	37.2	7.512116
250Mm	413.3	470.1	56.8	11.47011
200Mm	413.1	423.1	10	2.019386
160Mm	324.2	325.1	0.9	0.181745
90Mm	387.5	390.3	2.8	0.565428
75Mm	365.3	366.3	1	0.201939
63Mm	360.1	360.5	0.4	0.080775
<63Mm	304.5	304.9	0.4	0.080775
			495.2	100

Table10.5 Part 2: Sieve analysis of Sample 4 with several depths

s4(50-70)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	705.3	194	38.04668
1.6mm	507.7	511.5	3.8	0.745244
1mm	450.6	520	69.4	13.61051
710Mm	395.7	400	4.3	0.843303
500Mm	432.6	498.5	65.9	12.9241
250Mm	413.3	503.6	90.3	17.70935
200Mm	413.1	417.4	4.3	0.843303
160Mm	324.2	394.1	69.9	13.70857
90Mm	387.5	394.2	6.7	1.313983
75Mm	365.3	365.6	0.3	0.058835
63Mm	360.1	360.6	0.5	0.098058
<63Mm	304.5	305	0.5	0.098058
			509.9	100

s4(70-100)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	540.3	29	6.981223
1.6mm	507.7	511.5	3.8	0.914781
1mm	450.6	528.6	78	18.77708
710Mm	395.7	450.9	55.2	13.2884
500Mm	432.6	470.1	37.5	9.027443
250Mm	413.3	486.2	72.9	17.54935
200Mm	413.1	423.6	10.5	2.527684
160Mm	324.2	394.3	70.1	16.8753
90Mm	387.5	445.2	57.7	13.89023
75Mm	365.3	365.4	0.1	0.024073
63Mm	360.1	360.2	0.1	0.024073
<63Mm	304.5	305	0.5	0.120366
			415.4	100

s4(100-120)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	653	141.7	28.67841
1.6mm	507.7	511.4	3.7	0.748836
1mm	450.6	522.2	71.6	14.49099
710Mm	395.7	447	51.3	10.38251
500Mm	432.6	457.1	24.5	4.95851
250Mm	413.3	479.6	66.3	13.41834
200Mm	413.1	423.7	10.6	2.145315
160Mm	324.2	391.3	67.1	13.58025
90Mm	387.5	444.2	56.7	11.47541
75Mm	365.3	365.5	0.2	0.040478
63Mm	360.1	360.2	0.1	0.020239
<63Mm	304.5	304.8	0.3	0.060716
			494.1	100

Table10.6 Part 1: Sieve analysis of Sample5 with several depths

s5(0-20)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	737	225.7	55.76971
1.6mm	507.7	528	20.3	5.016061
1mm	450.6	492.9	42.3	10.45219
710Mm	395.7	424.3	28.6	7.066963
500Mm	432.6	457.6	25	6.177415
250Mm	413.3	464	50.7	12.5278
200Mm	413.1	419.3	6.2	1.531999
160Mm	324.2	326.6	2.4	0.593032
90Mm	387.5	389.2	1.7	0.420064
75Mm	365.3	366.3	1	0.247097
63Mm	360.1	360.5	0.4	0.098839
<63Mm	304.5	304.9	0.4	0.098839
			404.7	100
s5(20-50)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	873.5	362.2	72.41104
1.6mm	507.7	525.3	17.6	3.518593
1mm	450.6	485.5	34.9	6.977209
710Mm	395.7	419.2	23.5	4.698121
500Mm	432.6	452.2	19.6	3.918433
250Mm	413.3	443.8	30.5	6.097561
200Mm	413.1	422.1	9	1.79928
160Mm	324.2	324.8	0.6	0.119952
90Mm	387.5	389	1.5	0.29988
75Mm	365.3	365.5	0.2	0.039984
63Mm	360.1	360.4	0.3	0.059976
<63Mm	304.5	304.8	0.3	0.059976
			500.2	100
s5(50-70)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	918.5	407.2	81.48889
1.6mm	507.7	525.5	17.8	3.562137
1mm	450.6	484.6	34	6.804082
710Mm	395.7	411.8	16.1	3.221933
500Mm	432.6	446.5	13.9	2.781669
250Mm	413.3	422.2	8.9	1.781069
200Mm	413.1	413.5	0.4	0.080048
160Mm	324.2	324.4	0.2	0.040024
90Mm	387.5	388	0.5	0.10006
75Mm	365.3	365.5	0.2	0.040024
63Mm	360.1	360.3	0.2	0.040024
<63Mm	304.5	304.8	0.3	0.060036
			499.7	100

Table10.6 Part 2: Sieve analysis of Sample5 with several depths

s5(70-100)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	928.5	417.2	79.80107
1.6mm	507.7	522.5	14.8	2.83091
1mm	450.6	486.4	35.8	6.847743
710Mm	395.7	412.2	16.5	3.156083
500Mm	432.6	446.3	13.7	2.620505
250Mm	413.3	418.9	5.6	1.071155
200Mm	413.1	413.3	0.2	0.038256
160Mm	324.2	337.4	13.2	2.524866
90Mm	387.5	388	0.5	0.095639
75Mm	365.3	365.5	0.2	0.038256
63Mm	360.1	364.3	4.2	0.803366
<63Mm	304.5	305.4	0.9	0.17215
			522.8	100

Table 10.7 Part 1: sieve analysis of sample 6 with several analysis

s6(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	514.9	3.6	0.72
1.6mm	507.7	607.9	100.2	20.04
1mm	450.6	492.6	42	8.4
710Mm	395.7	430.7	35	7
500Mm	432.6	465.8	33.2	6.64
250Mm	413.3	486.7	73.4	14.68
200Mm	413.1	489.4	76.3	15.26
160Mm	324.2	415.1	90.9	18.18
90Mm	387.5	396.8	9.3	1.86
75Mm	365.3	382.8	17.5	3.5
63Mm	360.1	371.6	11.5	2.3
<63Mm	304.5	311.6	7.1	1.42
			500	100
S6(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	697	185.7	34.78179
1.6mm	507.7	562.1	54.4	10.18917
1mm	450.6	496.2	45.6	8.540925
710Mm	395.7	434.1	38.4	7.192358
500Mm	432.6	465.5	32.9	6.162203
250Mm	413.3	476.9	63.6	11.91234
200Mm	413.1	449.3	36.2	6.780296
160Mm	324.2	355.7	31.5	5.899981
90Mm	387.5	424.2	36.7	6.873946
75Mm	365.3	370.8	5.5	1.030155
63Mm	360.1	362.2	2.1	0.393332
<63Mm	304.5	305.8	1.3	0.243491

Table 10.7 Part 2: sieve analysis of sample 6 with several analysis

			533.9	100
s6(50-70)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	697	185.7	37.26671
1.6mm	507.7	526.1	18.4	3.692555
1mm	450.6	496.2	45.6	9.151114
710Mm	395.7	434.1	38.4	7.706201
500Mm	432.6	465.5	32.9	6.602448
250Mm	413.3	476.9	63.6	12.7634
200Mm	413.1	449.3	36.2	7.2647
160Mm	324.2	355.7	31.5	6.321493
90Mm	387.5	424.2	36.7	7.365041
75Mm	365.3	370.8	5.5	1.103753
63Mm	360.1	362.6	2.5	0.501706
<63Mm	304.5	305.8	1.3	0.260887
			498.3	100
S6(70-100)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	692.5	181.2	36.26176
1.6mm	507.7	532.5	24.8	4.962978
1mm	450.6	508.6	58	11.60696
710Mm	395.7	440.6	44.9	8.985391
500Mm	432.6	465.5	32.9	6.58395
250Mm	413.3	479.2	65.9	13.18791
200Mm	413.1	447.3	34.2	6.844106
160Mm	324.2	348.1	23.9	4.78287
90Mm	387.5	411.7	24.2	4.842906
75Mm	365.3	371	5.7	1.140684
63Mm	360.1	362	1.9	0.380228
<63Mm	304.5	306.6	2.1	0.420252
			499.7	100

Table 10.8 Part 1: sieve analysis of sample 7 with several analysis

s7(0-20)				
Diameter	mass of empty sieve	mass of sieve soil retained	soil retained	soil retained%
2mm	511.3	639.5	128.2	23.24148
1.6mm	507.7	512.4	4.7	0.852067
1mm	450.6	489.1	38.5	6.979695
710Mm	395.7	427.5	31.8	5.765047
500Mm	432.6	463.8	31.2	5.656273
250Mm	413.3	483.8	70.5	12.781
200Mm	413.1	435.3	22.2	4.024656
160Mm	324.2	465	140.8	25.52574
90Mm	387.5	390	2.5	0.453227
75Mm	365.3	415.3	50	9.06454

Table 10.8 Part 2: sieve analysis of sample 7 with several analysis

63Mm	360.1	379	18.9	3.426396
<63Mm	304.5	316.8	12.3	2.229877
			551.6	100
S7(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	668.5	157.2	27.66631
1.6mm	507.7	511.9	4.2	0.739176
1mm	450.6	494.6	44	7.743752
710Mm	395.7	429.5	33.8	5.94861
500Mm	432.6	464.6	32	5.63182
250Mm	413.3	486.2	72.9	12.82999
200Mm	413.1	463.1	50	8.799718
160Mm	324.2	458.7	134.5	23.67124
90Mm	387.5	406.3	18.8	3.308694
75Mm	365.3	375.5	10.2	1.795143
63Mm	360.1	365.2	5.1	0.897571
<63Mm	304.5	310	5.5	0.967969
			568.2	100
s7(50-70)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	705.7	194.4	36.45228
1.6mm	507.7	511.5	3.8	0.712545
1mm	450.6	500	49.4	9.263079
710Mm	395.7	431.2	35.5	6.656666
500Mm	432.6	465	32.4	6.07538
250Mm	413.3	470.9	57.6	10.80068
200Mm	413.1	413.2	0.1	0.018751
160Mm	324.2	450	125.8	23.58897
90Mm	387.5	390	2.5	0.468779
75Mm	365.3	380.8	15.5	2.906432
63Mm	360.1	367.4	7.3	1.368836
<63Mm	304.5	313.5	9	1.687605
			533.3	100
s7(70-100)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	641.6	130.3	26.66257
1.6mm	507.7	529.4	21.7	4.440352
1mm	450.6	503.9	53.3	10.90649
710Mm	395.7	436	40.3	8.246368
500Mm	432.6	471.5	38.9	7.959894
250Mm	413.3	528.6	115.3	23.59321
200Mm	413.1	448.5	35.4	7.243708
160Mm	324.2	350.1	25.9	5.299775
90Mm	387.5	406	18.5	3.785554

Table 10.8 Part 3: sieve analysis of sample 7 with several analysis

75Mm	365.3	370	4.7	0.961735
63Mm	360.1	361.7	1.6	0.327399
<63Mm	304.5	307.3	2.8	0.572949
			488.7	100
s7(100-120)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	570.4	59.1	19.48566
1.6mm	507.7	555.4	47.7	15.727
1mm	450.6	480	29.4	9.693373
710Mm	395.7	420	24.3	8.011869
500Mm	432.6	454.5	21.9	7.220574
250Mm	413.3	458.9	45.6	15.03462
200Mm	413.1	430	16.9	5.572041
160Mm	324.2	355.4	31.2	10.28684
90Mm	387.5	394.1	6.6	2.176063
75Mm	365.3	378.9	13.6	4.484009
63Mm	360.1	363.2	3.1	1.02209
<63Mm	304.5	308.4	3.9	1.285856
			303.3	100

Table 10.9 Part 1: sieve analysis of sample 8 with several analysis

S8(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	624.4	113.1	22.62
1.6mm	507.7	536.3	28.6	5.72
1mm	450.6	473.2	22.6	4.52
710Mm	395.7	429.3	33.6	6.72
500Mm	432.6	471.9	39.3	7.86
250Mm	413.3	508.6	95.3	19.06
200Mm	413.1	457.4	44.3	8.86
160Mm	324.2	344.6	20.4	4.08
90Mm	387.5	435.9	48.4	9.68
75Mm	365.3	394.7	29.4	5.88
63Mm	360.1	373.9	13.8	2.76
<63Mm	304.5	315.7	11.2	2.24
			500	100
S8(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve soil retained**	**soil retained**	**soil retained%**
2mm	511.3	516.6	5.3	1.195579
1.6mm	507.7	520	12.3	2.774645
1mm	450.6	478.8	28.2	6.361381
710Mm	395.7	426.1	30.4	6.857658

Table 10.9 Part 2: sieve analysis of sample 8 with several analysis

500Mm	432.6	486.4	53.8	12.13625
250Mm	413.3	558.8	145.5	32.82202
200Mm	413.1	462.5	49.4	11.1437
160Mm	324.2	359.3	35.1	7.917889
90Mm	387.5	429.1	41.6	9.384164
75Mm	365.3	383.9	18.6	4.195804
63Mm	360.1	374.4	14.3	3.225806
<63Mm	304.5	313.3	8.8	1.985112
			443.3	100

Table 10.10 Part 1 sieve analysis of sample 9 with several analysis

s9(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	621.5	110.2	21.94345
1.6mm	507.7	524.8	17.1	3.405018
1mm	450.6	495.7	45.1	8.980486
710Mm	395.7	429.9	34.2	6.810036
500Mm	432.6	467.7	35.1	6.989247
250Mm	413.3	501.1	87.8	17.48307
200Mm	413.1	457.9	44.8	8.920749
160Mm	324.2	357.4	33.2	6.610912
90Mm	387.5	456.1	68.6	13.6599
75Mm	365.3	381.2	15.9	3.166069
63Mm	360.1	366.1	6	1.194743
<63Mm	304.5	308.7	4.2	0.83632
			502.2	100
s9(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	651.7	140.4	29.69543
1.6mm	507.7	530.3	22.6	4.780034
1mm	450.6	504.3	53.7	11.35787
710Mm	395.7	438.8	43.1	9.115905
500Mm	432.6	473.9	41.3	8.735195
250Mm	413.3	492.1	78.8	16.66667
200Mm	413.1	470.1	57	12.05584
160Mm	324.2	346.5	22.3	4.716582
90Mm	387.5	390.3	2.8	0.592217
75Mm	365.3	372.3	7	1.480541
63Mm	360.1	362	1.9	0.401861
<63Mm	304.5	306.4	1.9	0.401861
			472.8	100
S9(50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	646.3	135	27.48371
1.6mm	507.7	532.3	24.6	5.008143

Table 10.10 Part 2: sieve analysis of sample 9 with several analysis

1mm	450.6	509.5	58.9	11.99104
710Mm	395.7	442.3	46.6	9.486971
500Mm	432.6	477.8	45.2	9.201954
250Mm	413.3	503.5	90.2	18.36319
200Mm	413.1	462.9	49.8	10.13844
160Mm	324.2	341.2	17	3.460912
90Mm	387.5	401.8	14.3	2.911238
75Mm	365.3	369.3	4	0.814332
63Mm	360.1	362.6	2.5	0.508958
<63Mm	304.5	307.6	3.1	0.631107
			491.2	100
S9(70-100)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	634.1	122.8	25.20525
1.6mm	507.7	530.6	22.9	4.700328
1mm	450.6	501.7	51.1	10.48851
710Mm	395.7	437.6	41.9	8.600164
500Mm	432.6	474.8	42.2	8.661741
250Mm	413.3	490.2	76.9	15.78407
200Mm	413.1	454.9	41.8	8.579639
160Mm	324.2	352.8	28.6	5.870279
90Mm	387.5	431.9	44.4	9.1133
75Mm	365.3	375.7	10.4	2.134647
63Mm	360.1	361.6	1.5	0.307882
<63Mm	304.5	307.2	2.7	0.554187
			487.2	100

Table 10.11 Part 1: sieve analysis of sample 10 with several analysis

S10(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**Diameter**
2mm	511.3	673.2	161.9	32.94668
1.6mm	507.7	528.2	20.5	4.171754
1mm	450.6	498.5	47.9	9.74766
710Mm	395.7	433.1	37.4	7.610908
500Mm	432.6	466.4	33.8	6.878307
250Mm	413.3	474.4	61.1	12.43386
200Mm	413.1	441	27.9	5.677656
160Mm	324.2	371.8	47.6	9.68661
90Mm	387.5	423.1	35.6	7.244607
75Mm	365.3	375.1	9.8	1.994302
63Mm	360.1	365.1	5	1.017501
<63Mm	304.5	307.4	2.9	0.590151
			491.4	100
S10(20-50)				

Table 10.11 Part 2: sieve analysis of sample 10 with several analysis

Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	Diameter
2mm	511.3	642.8	131.5	26.79845
1.6mm	507.7	532.1	24.4	4.972488
1mm	450.6	511.4	60.8	12.39046
710Mm	395.7	453.7	58	11.81985
500Mm	432.6	483.3	50.7	10.33218
250Mm	413.3	502.3	89	18.13735
200Mm	413.1	452.5	39.4	8.029346
160Mm	324.2	342.9	18.7	3.810882
90Mm	387.5	400.3	12.8	2.608518
75Mm	365.3	368.5	3.2	0.65213
63Mm	360.1	361.4	1.3	0.264928
<63Mm	304.5	305.4	0.9	0.183411
			490.7	100
S10(50-70)				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	Diameter
2mm	511.3	663.1	151.8	30.43914
1.6mm	507.7	531.7	24	4.812513
1mm	450.6	509.4	58.8	11.79066
710Mm	395.7	455.5	59.8	11.99118
500Mm	432.6	478.1	45.5	9.123722
250Mm	413.3	495	81.7	16.38259
200Mm	413.1	455.8	42.7	8.562262
160Mm	324.2	340.6	16.4	3.28855
90Mm	387.5	400.1	12.6	2.526569
75Mm	365.3	368.4	3.1	0.621616
63Mm	360.1	361.3	1.2	0.240626
<63Mm	304.5	305.6	1.1	0.220573
			498.7	100
S10(70-100)				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	Diameter
2mm	511.3	640.6	129.3	25.87553
1.6mm	507.7	530.1	22.4	4.48269
1mm	450.6	511.5	60.9	12.18731
710Mm	395.7	464.8	69.1	13.8283
500Mm	432.6	490.9	58.3	11.667
250Mm	413.3	519.2	105.9	21.19272
200Mm	413.1	447.9	34.8	6.964179
160Mm	324.2	336.5	12.3	2.461477
90Mm	387.5	391.6	4.1	0.820492
75Mm	365.3	366.9	1.6	0.320192
63Mm	360.1	360.7	0.6	0.120072
<63Mm	304.5	304.9	0.4	0.080048
			499.7	100

Table 10.11 Part 3: sieve analysis of sample 10 with several analysis

S10 (100-120)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**Diameter**
2mm	511.3	588.8	77.5	27.0979
1.6mm	507.7	519.6	11.9	4.160839
1mm	450.6	480.2	29.6	10.34965
710Mm	395.7	423.7	28	9.79021
500Mm	432.6	463.1	30.5	10.66434
250Mm	413.3	472.5	59.2	20.6993
200Mm	413.1	436.2	23.1	8.076923
160Mm	324.2	341.2	17	5.944056
90Mm	387.5	394.2	6.7	2.342657
75Mm	365.3	366.5	1.2	0.41958
63Mm	360.1	360.8	0.7	0.244755
<63Mm	304.5	305.1	0.6	0.20979
			286	100

Table 10.12Part 1: sieve analysis of sample 11 with several analysis

S11(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**Diameter**
2mm	511.3	689.3	178	35.55733
1.6mm	507.7	527.4	19.7	3.935278
1mm	450.6	503.4	52.8	10.54734
710Mm	395.7	434.6	38.9	7.770675
500Mm	432.6	469.4	36.8	7.351179
250Mm	413.3	478.7	65.4	13.06432
200Mm	413.1	446.5	33.4	6.671994
160Mm	324.2	349.7	25.5	5.093887
90Mm	387.5	415.9	28.4	5.673192
75Mm	365.3	376	10.7	2.137435
63Mm	360.1	366.9	6.8	1.35837
<63Mm	304.5	308.7	4.2	0.838993
			500.6	100
s11(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retaind**	**soil retaind%**
2mm	511.3	640.4	129.1	24.85082
1.6mm	507.7	511.8	4.1	0.78922
1mm	450.6	492.6	42	8.084697
710Mm	395.7	429.1	33.4	6.429259
500Mm	432.6	465.5	32.9	6.333013
250Mm	413.3	481.2	67.9	13.07026
200Mm	413.1	430.2	17.1	3.291627
160Mm	324.2	462.2	138	26.564
90Mm	387.5	394.6	7.1	1.366699

Table 10.12 Part 2: sieve analysis of sample 11 with several analysis

75Mm	365.3	395.9	30.6	5.890279
63Mm	360.1	368.3	8.2	1.578441
<63Mm	304.5	313.6	9.1	1.751684
			519.5	100
S11 (50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	674.3	163	32.43136
1.6mm	507.7	526.1	18.4	3.660963
1mm	450.6	502.6	52	10.3462
710Mm	395.7	443.5	47.8	9.510545
500Mm	432.6	478.9	46.3	9.212097
250Mm	413.3	513.4	100.1	19.91643
200Mm	413.1	448.7	35.6	7.083168
160Mm	324.2	343.3	19.1	3.800239
90Mm	387.5	399.9	12.4	2.467171
75Mm	365.3	367.5	2.2	0.437724
63Mm	360.1	361.2	1.1	0.218862
<63Mm	304.5	309.1	4.6	0.915241
			502.6	100
S11 (70-100)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	642.8	131.5	33.10675
1.6mm	507.7	522.8	15.1	3.801611
1mm	450.6	499.7	49.1	12.36153
710Mm	395.7	435.9	40.2	10.12085
500Mm	432.6	472.5	39.9	10.04532
250Mm	413.3	491.8	78.5	19.76334
200Mm	413.1	434.7	21.6	5.438066
160Mm	324.2	336	11.8	2.970796
90Mm	387.5	394.4	6.9	1.73716
75Mm	365.3	367	1.7	0.427996
63Mm	360.1	361	0.9	0.226586
<63Mm	304.5	304.5	0	0
			397.2	100

Table 10.13 Part 1: sieve analysis of sample 12 with several analysis

S12 (0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	614.4	103.1	21.9082
1.6mm	507.7	525.3	17.6	3.739907
1mm	450.6	494.7	44.1	9.371016
710Mm	395.7	430.1	34.4	7.309817
500Mm	432.6	466	33.4	7.097323
250Mm	413.3	503.8	90.5	19.23077

Table 10.13 Part 2: sieve analysis of sample 12 with several analysis

200Mm	413.1	472.8	59.7	12.68593
160Mm	324.2	327.1	2.9	0.616235
90Mm	387.5	442.1	54.6	11.60221
75Mm	365.3	374.3	9	1.912452
63Mm	360.1	380.2	20.1	4.271143
<63Mm	304.5	305.7	1.2	0.254994
			470.6	100
S12 (20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	614.2	102.9	17.07884
1.6mm	507.7	531.6	23.9	3.966805
1mm	450.6	517.9	67.3	11.17012
710Mm	395.7	463.6	67.9	11.26971
500Mm	432.6	512.8	80.2	13.3112
250Mm	413.3	544	130.7	21.69295
200Mm	413.1	436.7	23.6	3.917012
160Mm	324.2	325.9	1.7	0.282158
90Mm	387.5	466.4	78.9	13.09544
75Mm	365.3	389.7	24.4	4.049793
63Mm	360.1	360.6	0.5	0.082988
<63Mm	304.5	305	0.5	0.082988
			602.5	100
S12(50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	612.7	101.4	14.91615
1.6mm	507.7	536.5	28.8	4.23654
1mm	450.6	539	88.4	13.00382
710Mm	395.7	475.6	79.9	11.75346
500Mm	432.6	512.7	80.1	11.78288
250Mm	413.3	498.2	84.9	12.48897
200Mm	413.1	424.9	11.8	1.735805
160Mm	324.2	325.6	1.4	0.205943
90Mm	387.5	467.3	79.8	11.73875
75Mm	365.3	487.7	122.4	18.0053
63Mm	360.1	360.6	0.5	0.073551
<63Mm	304.5	304.9	0.4	0.058841
			679.8	100
S12(70-100)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	740.7	229.4	42.86248
1.6mm	507.7	535.5	27.8	5.19432
1mm	450.6	528.5	77.9	14.55531
710Mm	395.7	438	42.3	7.903587
500Mm	432.6	480.4	47.8	8.931241

Table 10.13 Part 3: sieve analysis of sample 12 with several analysis

250Mm	413.3	430.4	17.1	3.195067
200Mm	413.1	420.3	7.2	1.345291
160Mm	324.2	364.4	40.2	7.511211
90Mm	387.5	425	37.5	7.006726
75Mm	365.3	372.4	7.1	1.326607
63Mm	360.1	360.5	0.4	0.074738
<63Mm	304.5	305	0.5	0.093423
			535.2	100

Table 10.14 Part 1: sieve analysis of sample 13 with several analysis

s13(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	675.3	164	40.55391
1.6mm	507.7	532.3	24.6	6.083086
1mm	450.6	494.5	43.9	10.85559
710Mm	395.7	428.3	32.6	8.061325
500Mm	432.6	458	25.4	6.28091
250Mm	413.3	454.4	41.1	10.1632
200Mm	413.1	423.7	10.6	2.621167
160Mm	324.2	333.3	9.1	2.250247
90Mm	387.5	408.6	21.1	5.217606
75Mm	365.3	371.3	6	1.48368
63Mm	360.1	367.7	7.6	1.879327
<63Mm	304.5	322.9	18.4	4.549951
			404.4	100
s13(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	673.4	162.1	32.79385
1.6mm	507.7	532.5	24.8	5.017196
1mm	450.6	508.6	58	11.73376
710Mm	395.7	434.1	38.4	7.768562
500Mm	432.6	466.6	34	6.878414
250Mm	413.3	469.9	56.6	11.45054
200Mm	413.1	428.9	15.8	3.196439
160Mm	324.2	337.2	13	2.629982
90Mm	387.5	419	31.5	6.372648
75Mm	365.3	378.8	13.5	2.731135
63Mm	360.1	371.3	11.2	2.26583
<63Mm	304.5	339.9	35.4	7.161643
			494.3	100
s13 (50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	680.7	169.4	35.46901
1.6mm	507.7	532.4	24.7	5.171692
1mm	450.6	498.7	48.1	10.07119

Table 10.14 Part 2: sieve analysis of sample 13 with several analysis

710Mm	395.7	426.2	30.5	6.386097
500Mm	432.6	461.3	28.7	6.009213
250Mm	413.3	457.7	44.4	9.296482
200Mm	413.1	424.5	11.4	2.386935
160Mm	324.2	334.3	10.1	2.11474
90Mm	387.5	421.7	34.2	7.160804
75Mm	365.3	384.3	19	3.978224
63Mm	360.1	382.9	22.8	4.773869
<63Mm	304.5	338.8	34.3	7.181742
			477.6	100
s13 (70-100)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	636.8	125.5	31.18012
1.6mm	507.7	530.8	23.1	5.73913
1mm	450.6	497.4	46.8	11.62733
710Mm	395.7	428.8	33.1	8.223602
500Mm	432.6	459.3	26.7	6.63354
250Mm	413.3	454.5	41.2	10.23602
200Mm	413.1	425.5	12.4	3.080745
160Mm	324.2	335.3	11.1	2.757764
90Mm	387.5	409.9	22.4	5.565217
75Mm	365.3	383.2	17.9	4.447205
63Mm	360.1	378.8	18.7	4.645963
<63Mm	304.5	328.1	23.6	5.863354
			402.5	100

Table 10.15 Part 1: sieve analysis of sample 14 with several analysis

s14 (0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	624.5	113.2	22.59481
1.6mm	507.7	523.2	15.5	3.093812
1mm	450.6	485.2	34.6	6.906188
710Mm	395.7	422.7	27	5.389222
500Mm	432.6	458.9	26.3	5.249501
250Mm	413.3	475	61.7	12.31537
200Mm	413.1	445.9	32.8	6.546906
160Mm	324.2	363.5	39.3	7.844311
90Mm	387.5	472.3	84.8	16.92615
75Mm	365.3	404.4	39.1	7.804391
63Mm	360.1	377.2	17.1	3.413174
<63Mm	304.5	314.1	9.6	1.916168
			501	100
s14(20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	724.8	213.5	45.10881

Table 10.15 Part 2: sieve analysis of sample 14 with several analysis

1.6mm	507.7	530.9	23.2	4.901754
1mm	450.6	500.3	49.7	10.50074
710Mm	395.7	426.6	30.9	6.528629
500Mm	432.6	470.4	37.8	7.986478
250Mm	413.3	474.2	60.9	12.8671
200Mm	413.1	431.9	18.8	3.972111
160Mm	324.2	338.2	14	2.957955
90Mm	387.5	404.7	17.2	3.634059
75Mm	365.3	369.6	4.3	0.908515
63Mm	360.1	361.9	1.8	0.380308
<63Mm	304.5	305.7	1.2	0.253539
			473.3	100
s14 (50-70)				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.3	714.3	203	43.03583
1.6mm	507.7	527.9	20.2	4.282383
1mm	450.6	491.1	40.5	8.585966
710Mm	395.7	427.6	31.9	6.762773
500Mm	432.6	460.7	28.1	5.957176
250Mm	413.3	444.3	31	6.571974
200Mm	413.1	461.9	48.8	10.34556
160Mm	324.2	356.5	32.3	6.847573
90Mm	387.5	414.1	26.6	5.639177
75Mm	365.3	370.5	5.2	1.102396
63Mm	360.1	362.4	2.3	0.487598
<63Mm	304.5	306.3	1.8	0.381598
			471.7	100

Table 10.16 Part 1: sieve analysis of sample 15 with several analysis

s15 (0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retaind**	**soil retaind%**
2mm	511.3	681.2	169.9	34.75148
1.6mm	507.7	532.3	24.6	5.031704
1mm	450.6	511.2	60.6	12.39517
710Mm	395.7	440.6	44.9	9.183882
500Mm	432.6	468.3	35.7	7.302107
250Mm	413.3	466.7	53.4	10.92248
200Mm	413.1	425.5	12.4	2.536306
160Mm	324.2	337.9	13.7	2.802209
90Mm	387.5	425.3	37.8	7.731642
75Mm	365.3	382.4	17.1	3.497648
63Mm	360.1	369.3	9.2	1.881775
<63Mm	304.5	314.1	9.6	1.963592
			488.9	100
s15 (20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**

Table 10.16 Part 2: sieve analysis of sample 15 with several analysis

2mm	511.3	799.6	288.3	58.93295
1.6mm	507.7	534.4	26.7	5.45789
1mm	450.6	515.8	65.2	13.32788
710Mm	395.7	431.3	35.6	7.277187
500Mm	432.6	459.3	26.7	5.45789
250Mm	413.3	451.3	38	7.767784
200Mm	413.1	417.4	4.3	0.878986
160Mm	324.2	325.6	1.4	0.286182
90Mm	387.5	389.7	2.2	0.449714
75Mm	365.3	365.8	0.5	0.102208
63Mm	360.1	360.2	0.1	0.020442
<63Mm	304.5	304.7	0.2	0.040883
			489.2	100
s15 (50-70)				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.3	611.1	99.8	52.9443
1.6mm	507.7	517.1	9.4	4.986737
1mm	450.6	472.2	21.6	11.45889
710Mm	395.7	410.3	14.6	7.745358
500Mm	432.6	444.6	12	6.366048
250Mm	413.3	431.3	18	9.549072
200Mm	413.1	418.2	5.1	2.70557
160Mm	324.2	327.2	3	1.591512
90Mm	387.5	390.9	3.4	1.803714
75Mm	365.3	366.1	0.8	0.424403
63Mm	360.1	360.5	0.4	0.212202
<63Mm	304.5	304.9	0.4	0.212202
			188.5	100

Table 10.17 Part 1: sieve analysis of sample 16 with several analysis

S16(0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	733.9	222.6	44.28969
1.6mm	507.7	538	30.3	6.028651
1mm	450.6	536.3	85.7	17.05133
710Mm	395.7	438.4	42.7	8.495822
500Mm	432.6	492.5	59.9	11.91803
250Mm	413.3	470.9	57.6	11.46041
200Mm	413.1	415	1.9	0.378034
160Mm	324.2	324.9	0.7	0.139276
90Mm	387.5	388.2	0.7	0.139276
75Mm	365.3	365.5	0.2	0.039793
63Mm	360.1	360.3	0.2	0.039793
<63Mm	304.5	304.6	0.1	0.019897
			502.6	100
S16 (20-50)				

Table 10.17 Part 2: sieve analysis of sample 16 with several analysis

Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.3	661.6	150.3	35.16612
1.6mm	507.7	538.9	31.2	7.299953
1mm	450.6	530.1	79.5	18.60084
710Mm	395.7	464.7	69	16.14413
500Mm	432.6	509.1	76.5	17.89892
250Mm	413.3	428.4	15.1	3.53299
200Mm	413.1	416.4	3.3	0.77211
160Mm	324.2	325.3	1.1	0.25737
90Mm	387.5	388.3	0.8	0.187178
75Mm	365.3	365.5	0.2	0.046795
63Mm	360.1	360.3	0.2	0.046795
<63Mm	304.5	304.7	0.2	0.046795
			427.4	100
S16 (50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	594.5	83.2	16.54404
1.6mm	507.7	521.6	13.9	2.763969
1mm	450.6	519.5	68.9	13.70054
710Mm	395.7	488.3	92.6	18.4132
500Mm	432.6	601.3	168.7	33.54544
250Mm	413.3	484.8	71.5	14.21754
200Mm	413.1	414.4	1.3	0.258501
160Mm	324.2	324.9	0.7	0.139193
90Mm	387.5	389.1	1.6	0.318155
75Mm	365.3	365.5	0.2	0.039769
63Mm	360.1	360.2	0.1	0.019885
<63Mm	304.5	304.7	0.2	0.039769
			502.9	100
S16 (70-100)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	566.7	55.4	10.82454
1.6mm	507.7	515.5	7.8	1.524033
1mm	450.6	492.5	41.9	8.186792
710Mm	395.7	507.1	111.4	21.76631
500Mm	432.6	623.6	191	37.31927
250Mm	413.3	497	83.7	16.35404
200Mm	413.1	426.8	13.7	2.676827
160Mm	324.2	325.5	1.3	0.254005
90Mm	387.5	391.8	4.3	0.840172
75Mm	365.3	365.8	0.5	0.097694
63Mm	360.1	360.5	0.4	0.078156
<63Mm	304.5	304.9	0.4	0.078156
			511.8	100
S16(100-120)				

Table 10.17 Part 3: sieve analysis of sample 16 with several analysis

Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.3	547.2	35.9	7.12019
1.6mm	507.7	514.1	6.4	1.269338
1mm	450.6	472.4	21.8	4.323681
710Mm	395.7	447	51.3	10.17453
500Mm	432.6	608.4	175.8	34.86712
250Mm	413.3	595.5	182.2	36.13645
200Mm	413.1	429.3	16.2	3.213011
160Mm	324.2	331.7	7.5	1.487505
90Mm	387.5	393.3	5.8	1.150337
75Mm	365.3	365.8	0.5	0.099167
63Mm	360.1	360.5	0.4	0.079334
<63Mm	304.5	304.9	0.4	0.079334
			504.2	100

Table 10.18 Part 1: sieve analysis of sample 17 with several analysis

s17 (0-20)				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.3	623.7	112.4	22.39936
1.6mm	507.7	525.4	17.7	3.527302
1mm	450.6	489.4	38.8	7.732164
710Mm	395.7	430	34.3	6.835393
500Mm	432.6	468.4	35.8	7.134316
250Mm	413.3	501.9	88.6	17.65644
200Mm	413.1	467.1	54	10.76126
160Mm	324.2	372.3	48.1	9.585492
90Mm	387.5	433.7	46.2	9.206855
75Mm	365.3	380.6	15.3	3.049024
63Mm	360.1	366.8	6.7	1.335193
<63Mm	304.5	308.4	3.9	0.777202
			501.8	100
s17 (20-50)				
Diameter	mass of empty sieve	mass of sieve+soil retained	soil retained	soil retained%
2mm	511.3	617	105.7	21.09359
1.6mm	507.7	528.6	20.9	4.170824
1mm	450.6	502.6	52	10.37717
710Mm	395.7	446.4	50.7	10.11774
500Mm	432.6	484.3	51.7	10.3173
250Mm	413.3	516.3	103	20.55478
200Mm	413.1	471.9	58.8	11.73418
160Mm	324.2	352.3	28.1	5.607663
90Mm	387.5	405.5	18	3.592097
75Mm	365.3	371.6	6.3	1.257234

Table 10.18 Part 2: sieve analysis of sample 17 with several analysis

63Mm	360.1	363.6	3.5	0.698463
<63Mm	304.5	306.9	2.4	0.478946
			501.1	100
s17 (50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	645.3	134	26.86986
1.6mm	507.7	530.8	23.1	4.632043
1mm	450.6	504.2	53.6	10.74794
710Mm	395.7	452.2	56.5	11.32946
500Mm	432.6	487.5	54.9	11.00862
250Mm	413.3	514.1	100.8	20.21255
200Mm	413.1	456.6	43.5	8.722679
160Mm	324.2	341.6	17.4	3.489072
90Mm	387.5	397.3	9.8	1.965109
75Mm	365.3	368.7	3.4	0.681773
63Mm	360.1	361.1	1	0.200521
<63Mm	304.5	305.2	0.7	0.140365
			498.7	100
s17(70-100)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	669.4	158.1	31.86857
1.6mm	507.7	530.6	22.9	4.616005
1mm	450.6	502.6	52	10.48176
710Mm	395.7	438.2	42.5	8.566821
500Mm	432.6	474	41.4	8.345092
250Mm	413.3	522.6	109.3	22.03185
200Mm	413.1	456.9	43.8	8.828865
160Mm	324.2	339.9	15.7	3.164685
90Mm	387.5	393	5.5	1.108647
75Mm	365.3	368.3	3	0.604717
63Mm	360.1	361	0.9	0.181415
<63Mm	304.5	305.5	1	0.201572
			496.1	100

Table10.19 Part 1: sieve analysis of sample 18 with several analysis

s18 (0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	560.9	49.6	10.50847
1.6mm	507.7	511.5	3.8	0.805085
1mm	450.6	496.4	45.8	9.70339
710Mm	395.7	449.9	54.2	11.48305
500Mm	432.6	481.9	49.3	10.44492
250Mm	413.3	561.4	148.1	31.37712

Table10.19 Part 2: sieve analysis of sample 18 with several analysis

200Mm	413.1	436.7	23.6	5
160Mm	324.2	414	89.8	19.02542
90Mm	387.5	394.3	6.8	1.440678
75Mm	365.3	365.8	0.5	0.105932
63Mm	360.1	360.1	0	0
<63Mm	304.5	305	0.5	0.105932
			472	100
s18 20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	607.5	96.2	20.3641
1.6mm	507.7	511.7	4	0.84674
1mm	450.6	493.5	42.9	9.081287
710Mm	395.7	439.3	43.6	9.229467
500Mm	432.6	494.4	61.8	13.08213
250Mm	413.3	496	82.7	17.50635
200Mm	413.1	457.7	44.6	9.441152
160Mm	324.2	413.3	89.1	18.86113
90Mm	387.5	394.2	6.7	1.41829
75Mm	365.3	365.5	0.2	0.042337
63Mm	360.1	360.3	0.2	0.042337
<63Mm	304.5	304.9	0.4	0.084674
			472.4	100
s18 (50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	554.3	43	8.770141
1.6mm	507.7	511.5	3.8	0.775036
1mm	450.6	498.1	47.5	9.687946
710Mm	395.7	406.3	10.6	2.161942
500Mm	432.6	466.3	33.7	6.873343
250Mm	413.3	442.2	28.9	5.89435
200Mm	413.1	545.2	132.1	26.94269
160Mm	324.2	486.8	162.6	33.16337
90Mm	387.5	414.2	26.7	5.445646
75Mm	365.3	366	0.7	0.14277
63Mm	360.1	360.2	0.1	0.020396
<63Mm	304.5	305.1	0.6	0.122374
			490.3	100
s18 (70-120)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	679.4	168.1	33.82294
1.6mm	507.7	534.1	26.4	5.311871
1mm	450.6	524.9	74.3	14.9497
710Mm	395.7	448.9	53.2	10.70423
500Mm	432.6	470.8	38.2	7.686117
250Mm	413.3	503.2	89.9	18.08853
200Mm	413.1	445.3	32.2	6.478873
160Mm	324.2	335.5	11.3	2.273642

Table10.19 Part 3: sieve analysis of sample 18 with several analysis

90Mm	387.5	390	2.5	0.503018
75Mm	365.3	365.8	0.5	0.100604
63Mm	360.1	360.3	0.2	0.040241
<63Mm	304.5	304.7	0.2	0.040241
			497	100

Table 10.20 Part 1: sieve analysis of sample 19 with several analysis

S19 (0-20)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	573.1	61.8	10.70315
1.6mm	507.7	510.2	2.5	0.432975
1mm	450.6	477.3	26.7	4.624177
710Mm	395.7	414.3	18.6	3.221337
500Mm	432.6	451.8	19.2	3.325251
250Mm	413.3	482.4	69.1	11.96744
200Mm	413.1	461.6	48.5	8.399723
160Mm	324.2	377.5	53.3	9.231036
90Mm	387.5	480.7	93.2	16.14132
75Mm	365.3	409.9	44.6	7.724281
63Mm	360.1	473.2	113.1	19.58781
<63Mm	304.5	331.3	26.8	4.641496
			577.4	100
S19 (20-50)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	572	60.7	12.40294
1.6mm	507.7	518.1	10.4	2.125051
1mm	450.6	472.2	21.6	4.413568
710Mm	395.7	411.3	15.6	3.187577
500Mm	432.6	448.4	15.8	3.228443
250Mm	413.3	479.5	66.2	13.52677
200Mm	413.1	474.3	61.2	12.50511
160Mm	324.2	405.7	81.5	16.65304
90Mm	387.5	487.4	99.9	20.41275
75Mm	365.3	389.8	24.5	5.00613
63Mm	360.1	374.7	14.6	2.983245
<63Mm	304.5	321.9	17.4	3.555374
			489.4	100
S19 (50-70)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	541.3	30	5.009184
1.6mm	507.7	516.9	9.2	1.53615
1mm	450.6	468	17.4	2.905326
710Mm	395.7	411.5	15.8	2.63817
500Mm	432.6	450.1	17.5	2.922024
250Mm	413.3	583.9	170.6	28.48556

Table 10.20 Part 2: sieve analysis of sample 19 with several analysis

200Mm	413.1	539.4	126.3	21.08866
160Mm	324.2	399.4	75.2	12.55635
90Mm	387.5	418.4	30.9	5.159459
75Mm	365.3	369.1	3.8	0.634497
63Mm	360.1	461.6	101.5	16.94774
<63Mm	304.5	305.2	0.7	0.116881
s19 (70-100)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	646.9	135.6	27.23986
1.6mm	507.7	541.3	33.6	6.749699
1mm	450.6	539.2	88.6	17.79831
710Mm	395.7	458	62.3	12.51507
500Mm	432.6	484.2	51.6	10.36561
250Mm	413.3	441.3	27	5.423865
200Mm	413.1	431.3	18.2	3.656087
160Mm	324.2	397.4	73.2	14.7047
90Mm	387.5	394.3	6.8	1.36601
75Mm	365.3	365.7	0.4	0.080354
63Mm	360.1	360.3	0.2	0.040177
<63Mm	304.5	304.8	0.3	0.060265
			497.8	100
s19 (100-120)				
Diameter	**mass of empty sieve**	**mass of sieve+soil retained**	**soil retained**	**soil retained%**
2mm	511.3	658.4	147.1	27.31662
1.6mm	507.7	545.8	38.1	7.075209
1mm	450.6	552.5	101.9	18.92293
710Mm	395.7	467.6	71.9	13.3519
500Mm	432.6	492.1	59.5	11.04921
250Mm	413.3	511.8	98.5	18.29155
200Mm	413.1	428.9	15.8	2.934076
160Mm	324.2	327	2.8	0.519963
90Mm	387.5	389.5	2	0.371402
75Mm	365.3	365.8	0.5	0.092851
63Mm	360.1	360.3	0.2	0.03714
<63Mm	304.5	304.7	0.2	0.03714
			538.5	100

Appendix 10.2 Particle Size Frequency Curves of the CSA

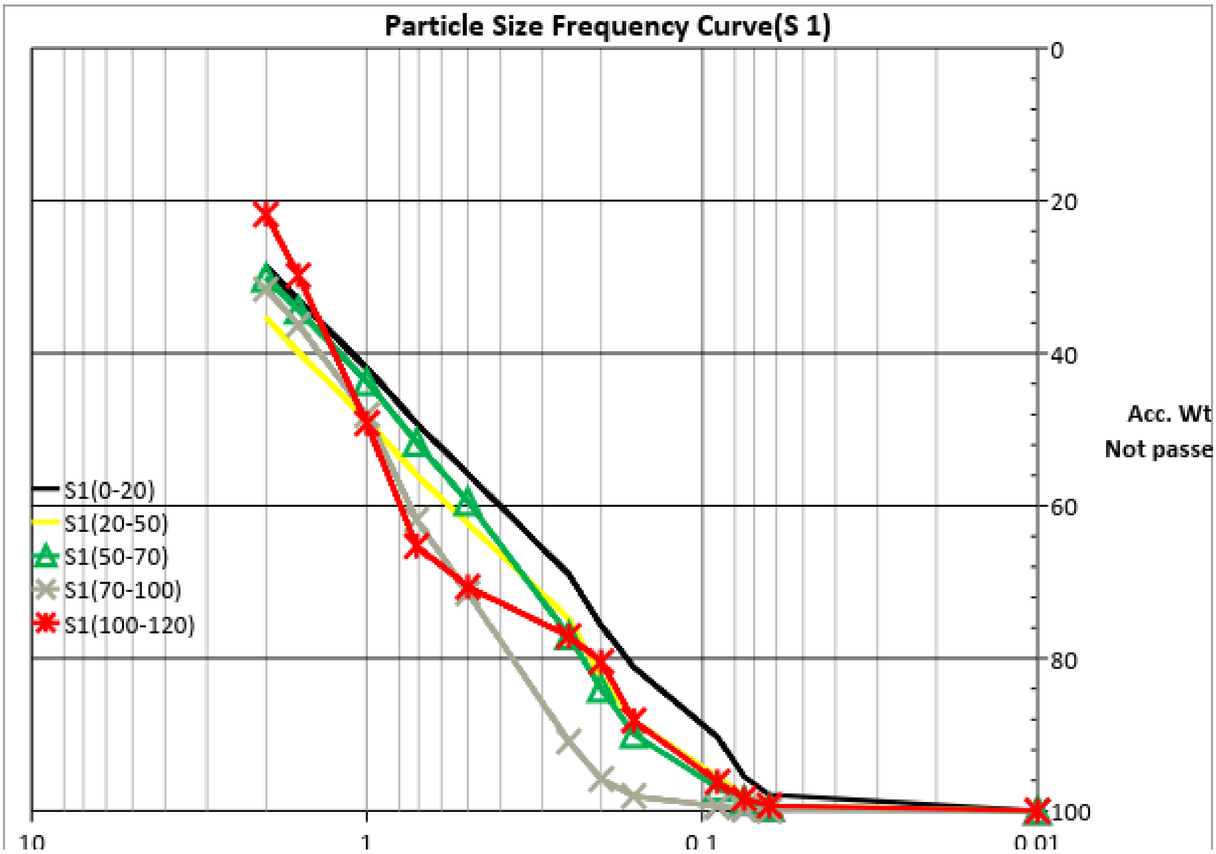

Figure 10.1: Particle size Frequency cure of Sample no.1, (S1)

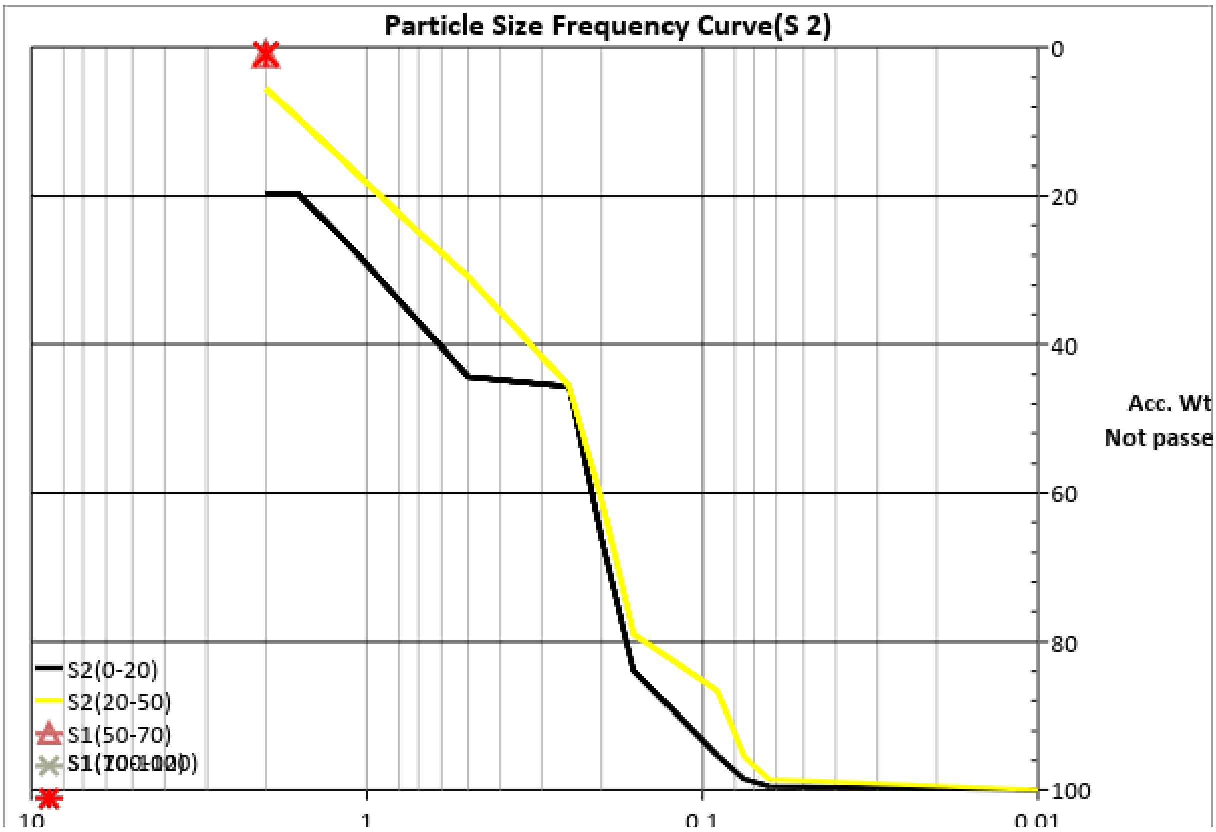

Figure 10.2: Particle size Frequency cure of Sample no.2, (S1)

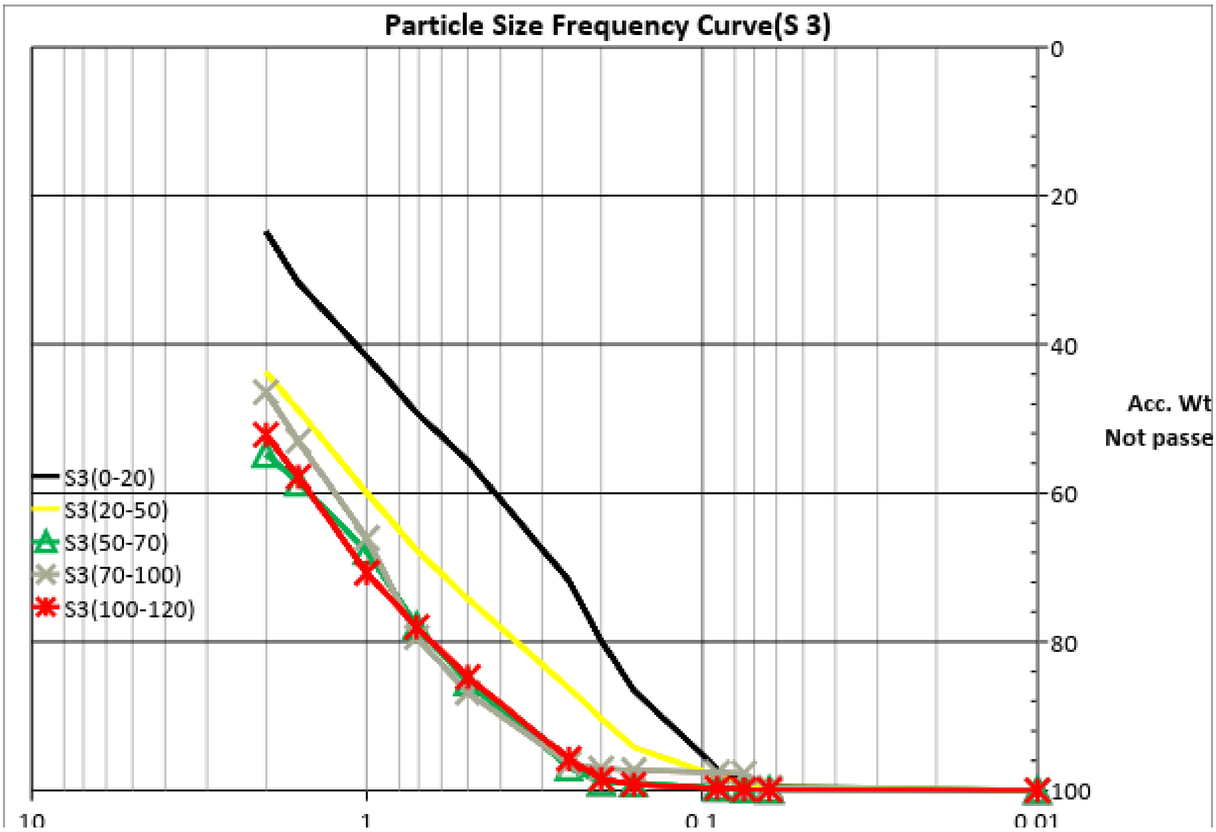

Figure 10.3: Particle size Frequency cure of Sample no.3, (S3)

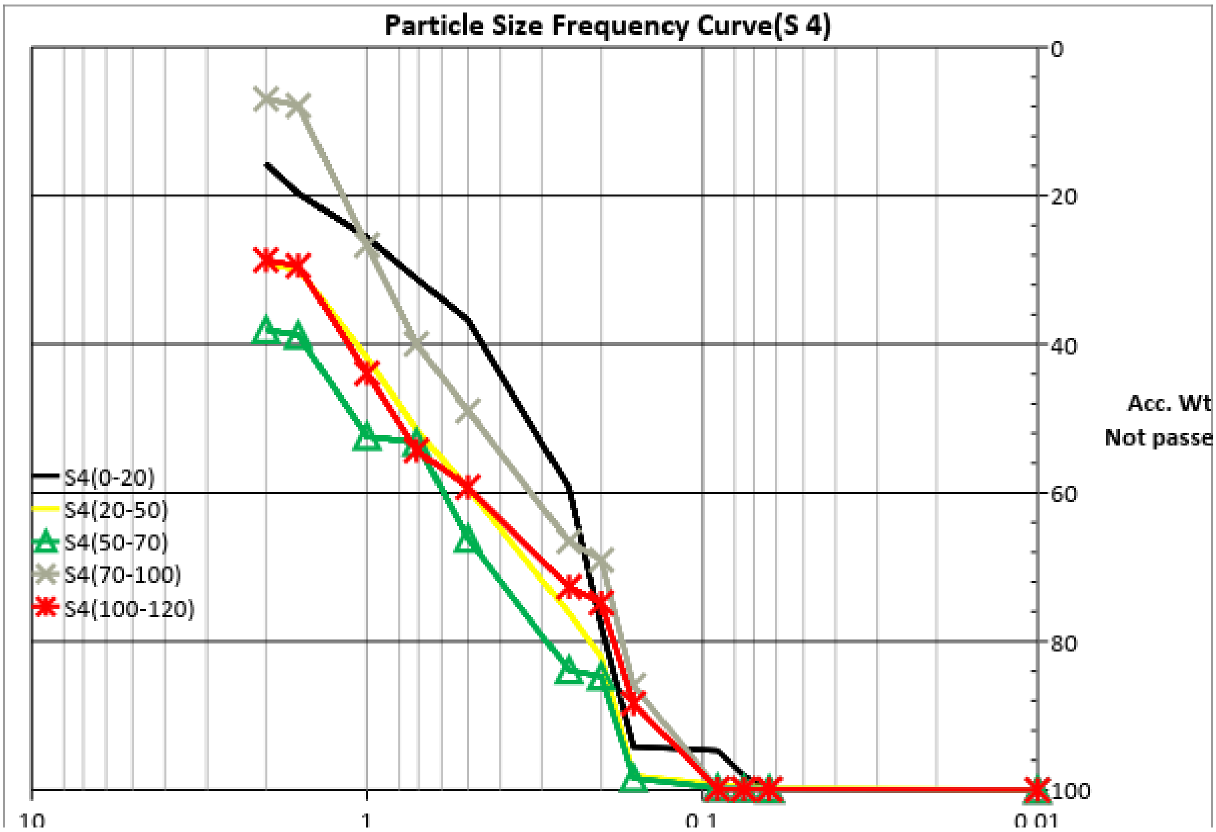

Figure 10.4: Particle size Frequency cure of Sample no.4, (S4)

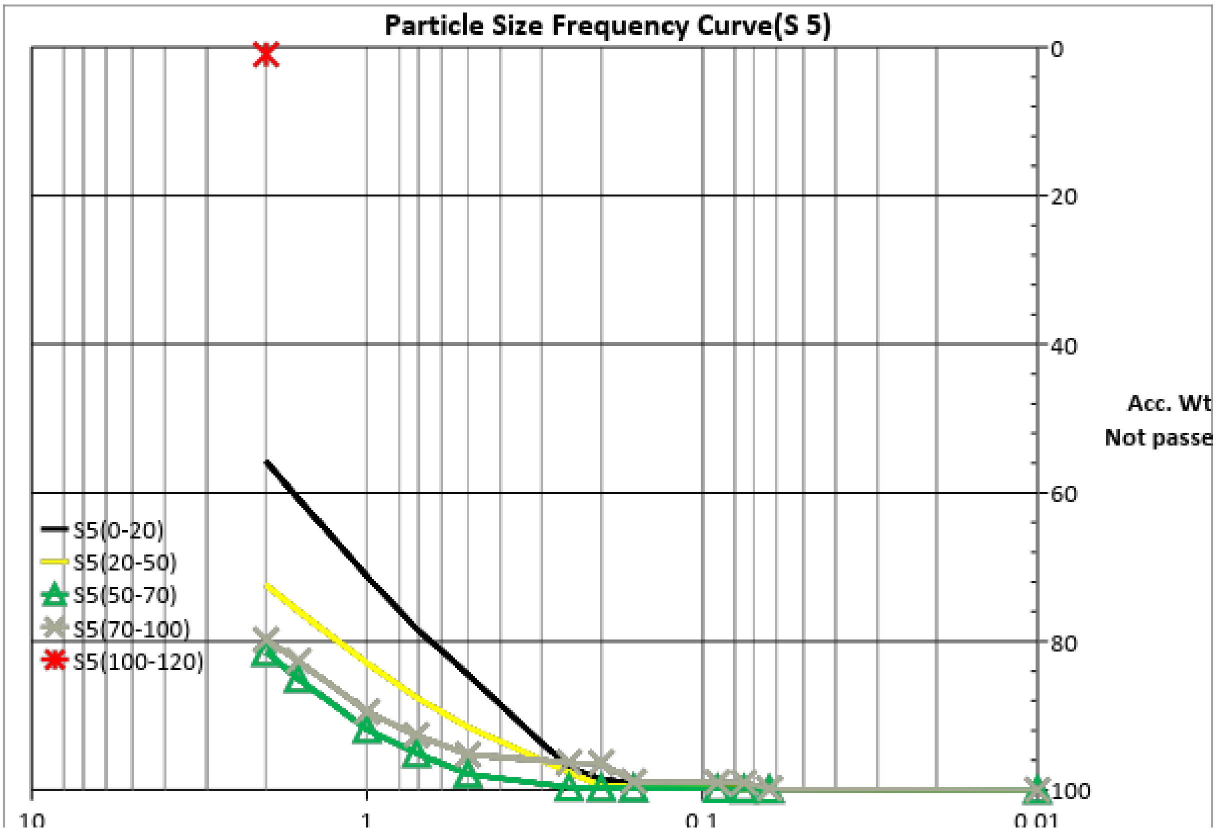

Figure 10.5: Particle size Frequency cure of Sample no.5, (S5)

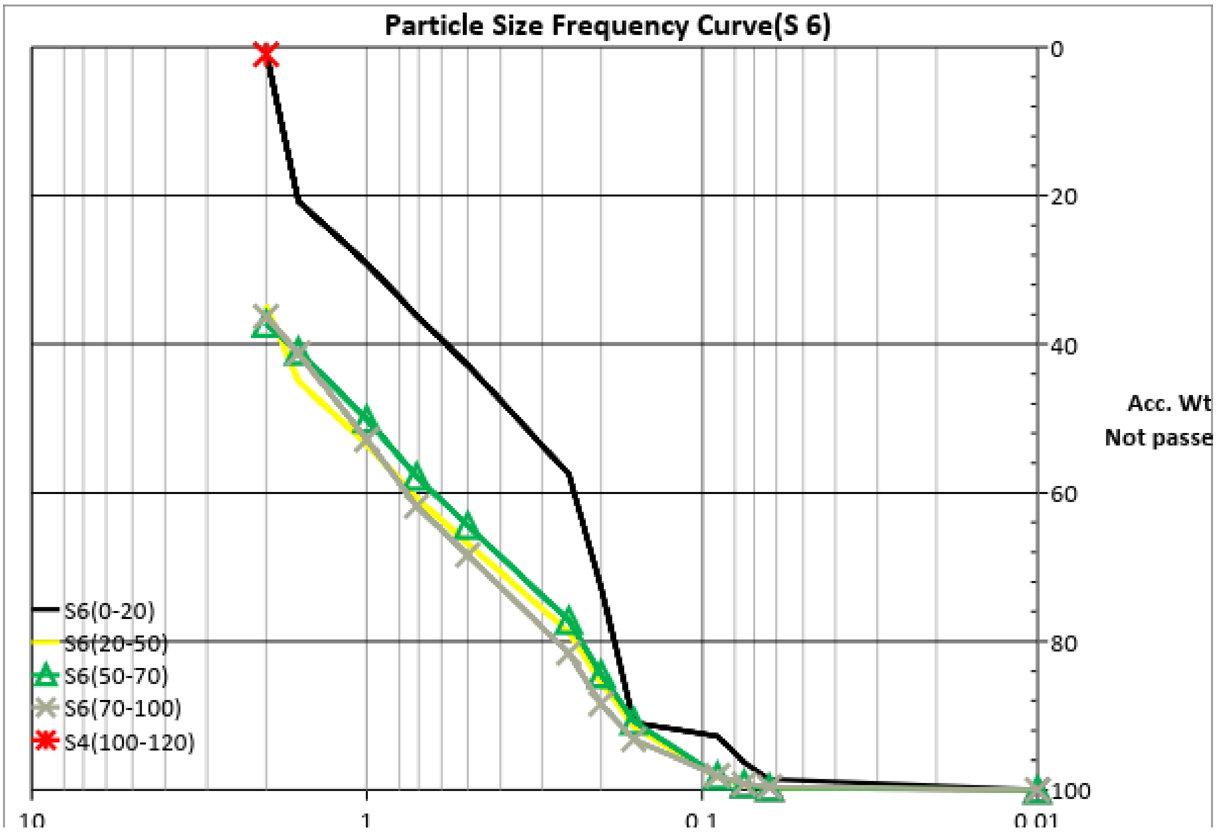

Figure 10.6: Particle size Frequency cure of Sample no.6, (S6)

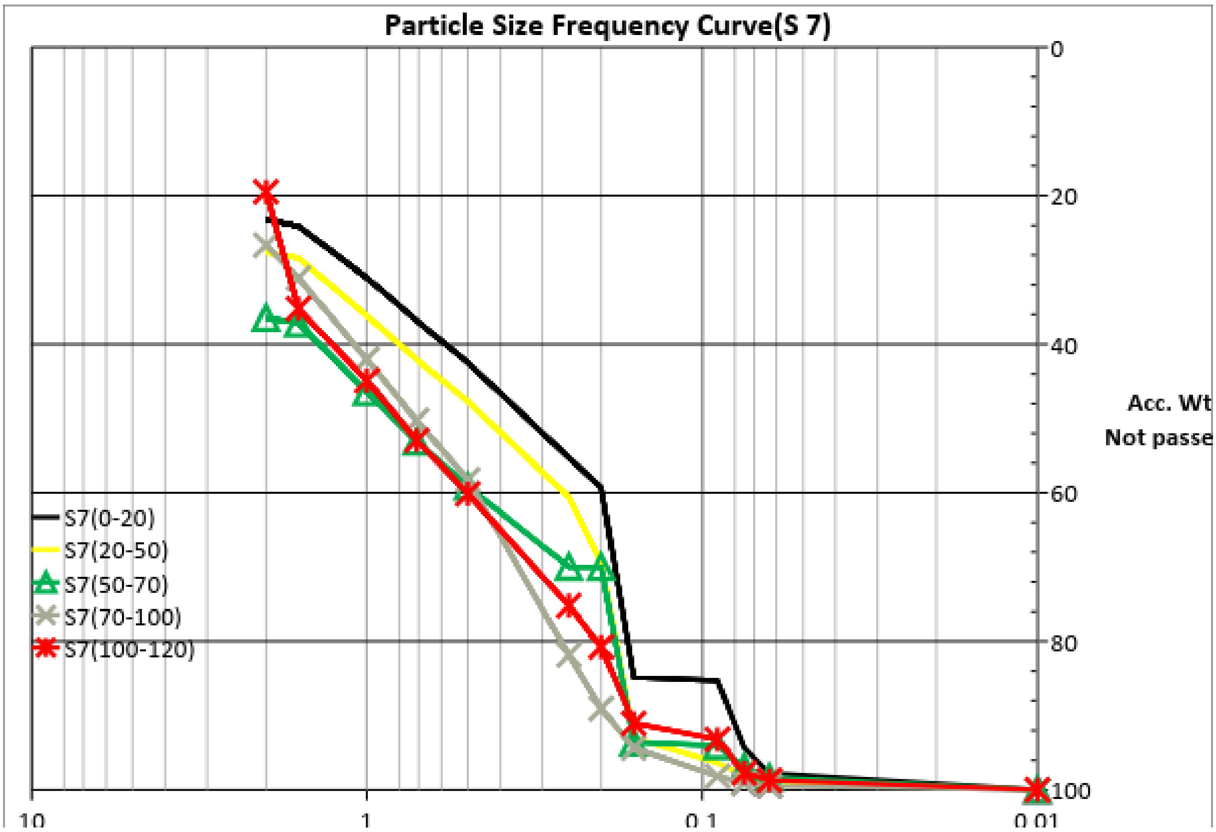

Figure 10.7: Particle size Frequency cure of Sample no.7, (S7)

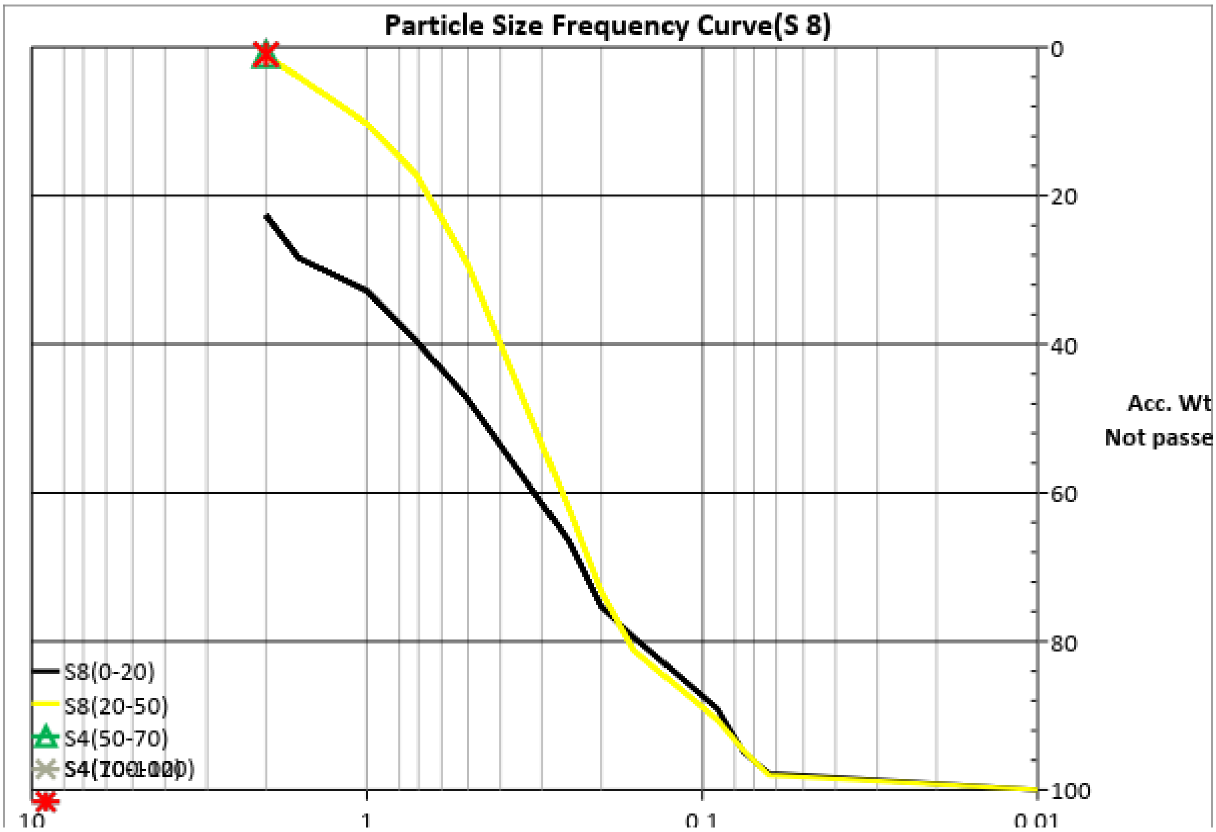

Figure 10.8: Particle size Frequency cure of Sample no.8, (S8)

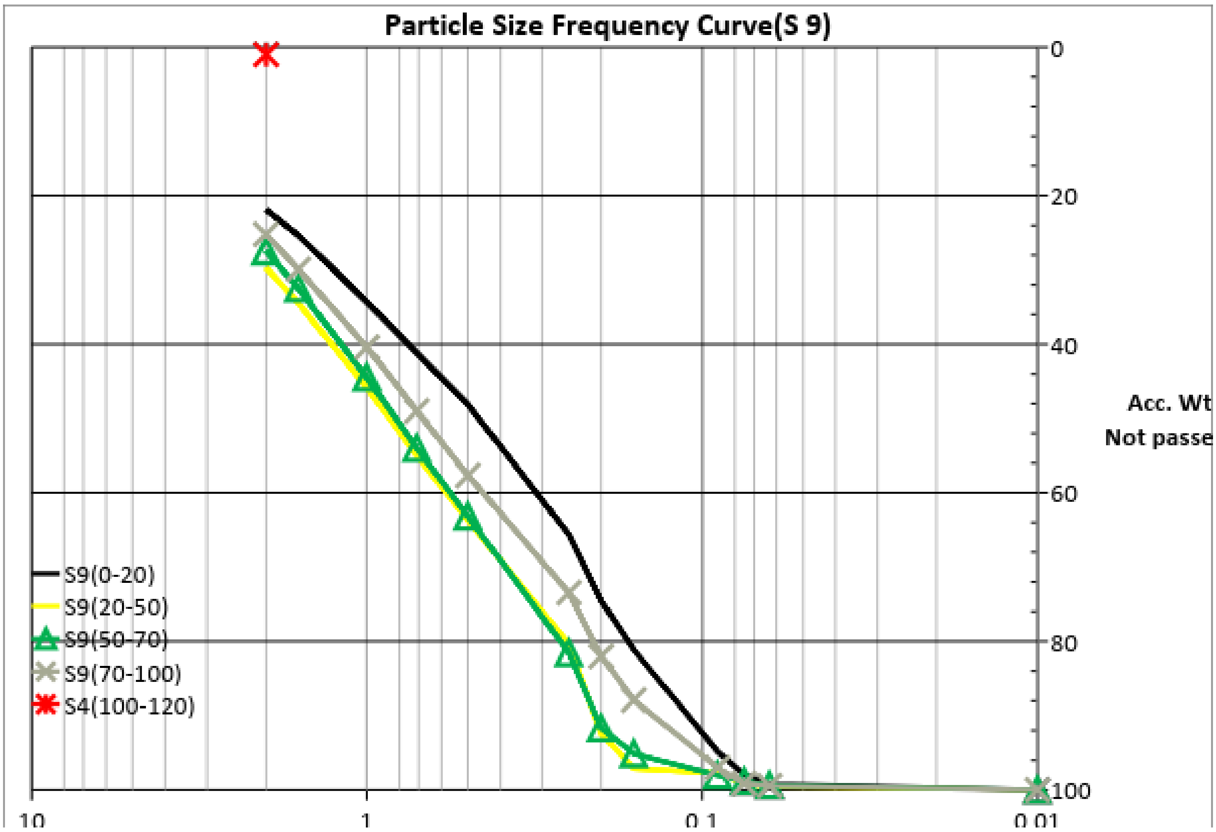

Figure 10.9: Particle size Frequency cure of Sample no.9, (S9)

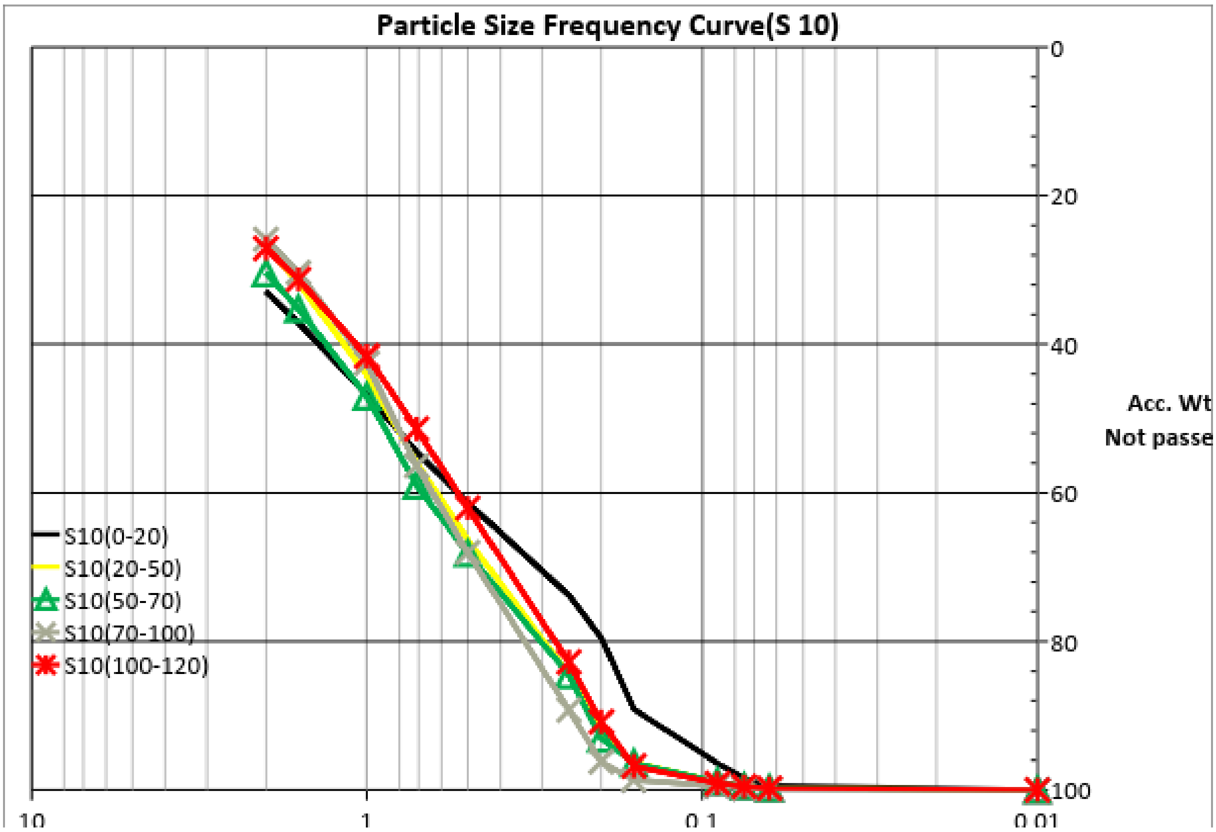

Figure 10.10: Particle size Frequency cure of Sample no.10, (S10)

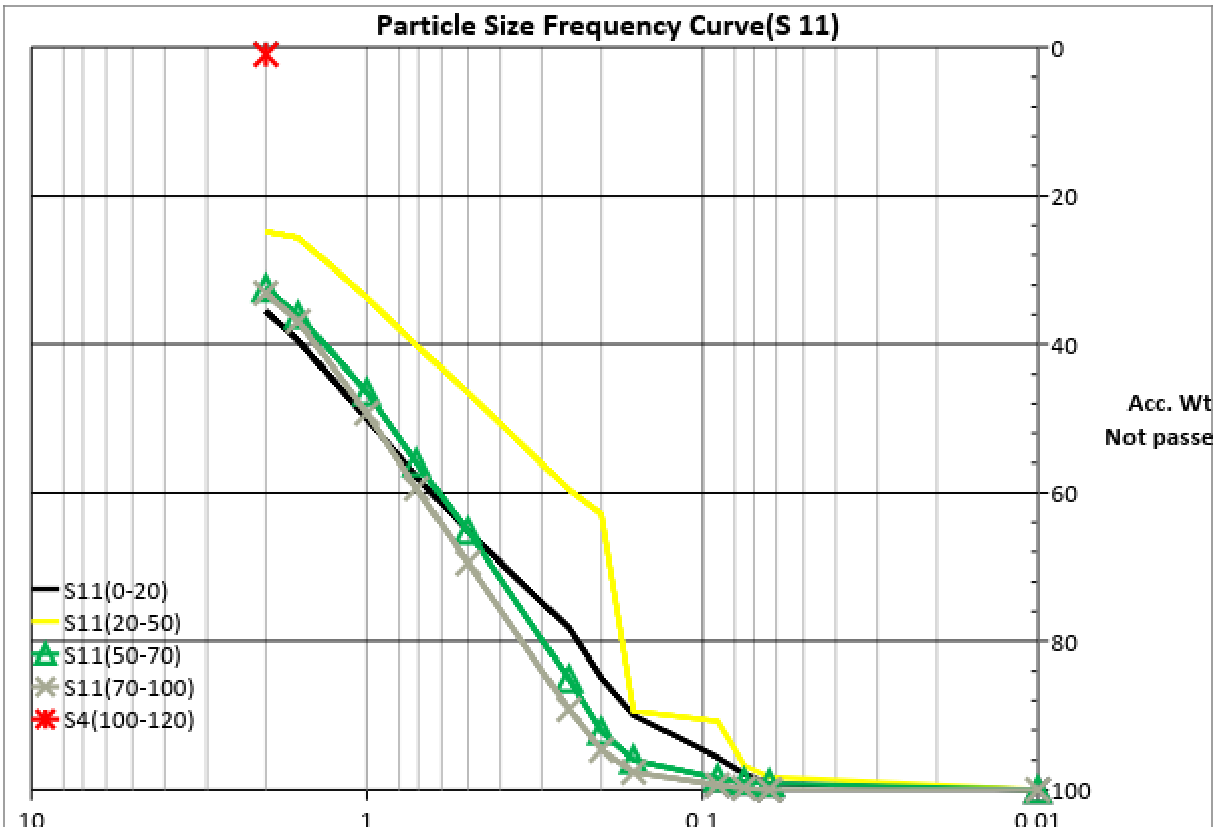

Figure 10.11: Particle size Frequency cure of Sample no.11, (S11)

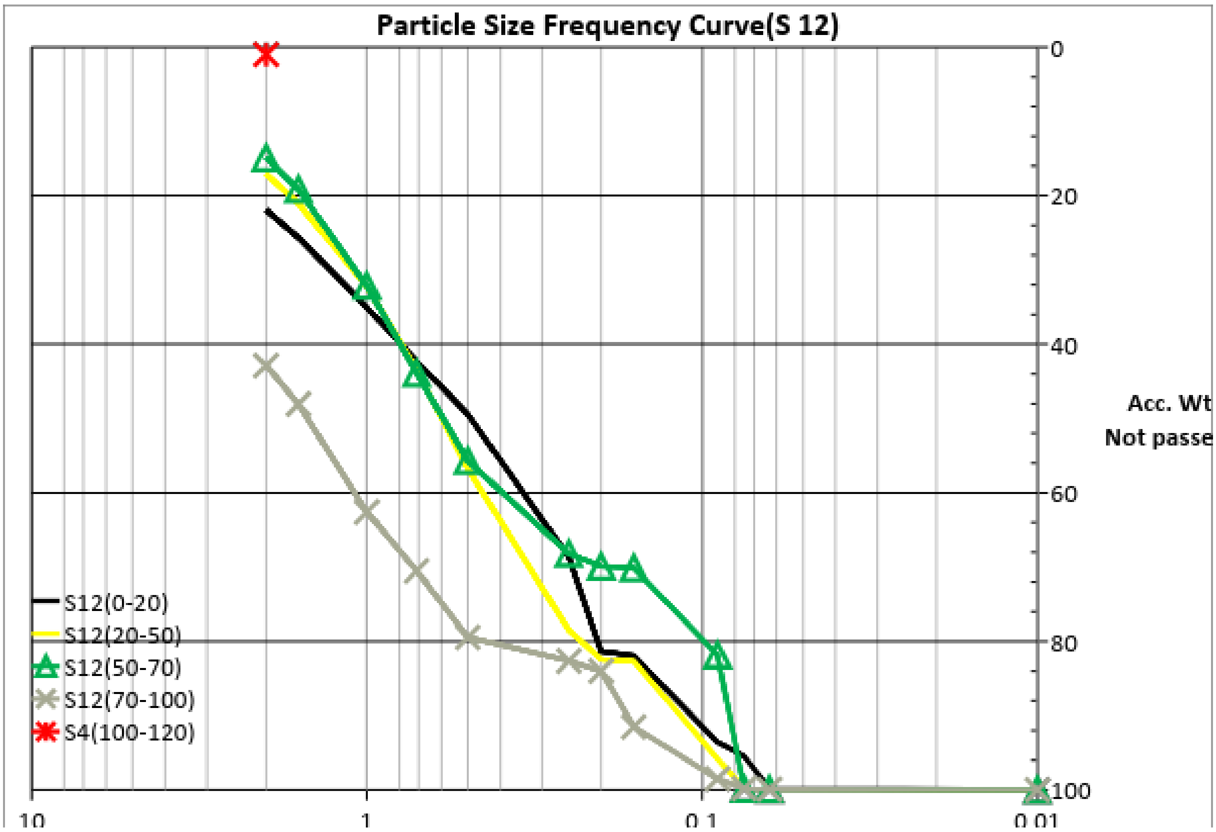

Figure 10.12: Particle size Frequency cure of Sample no.12, (S12)

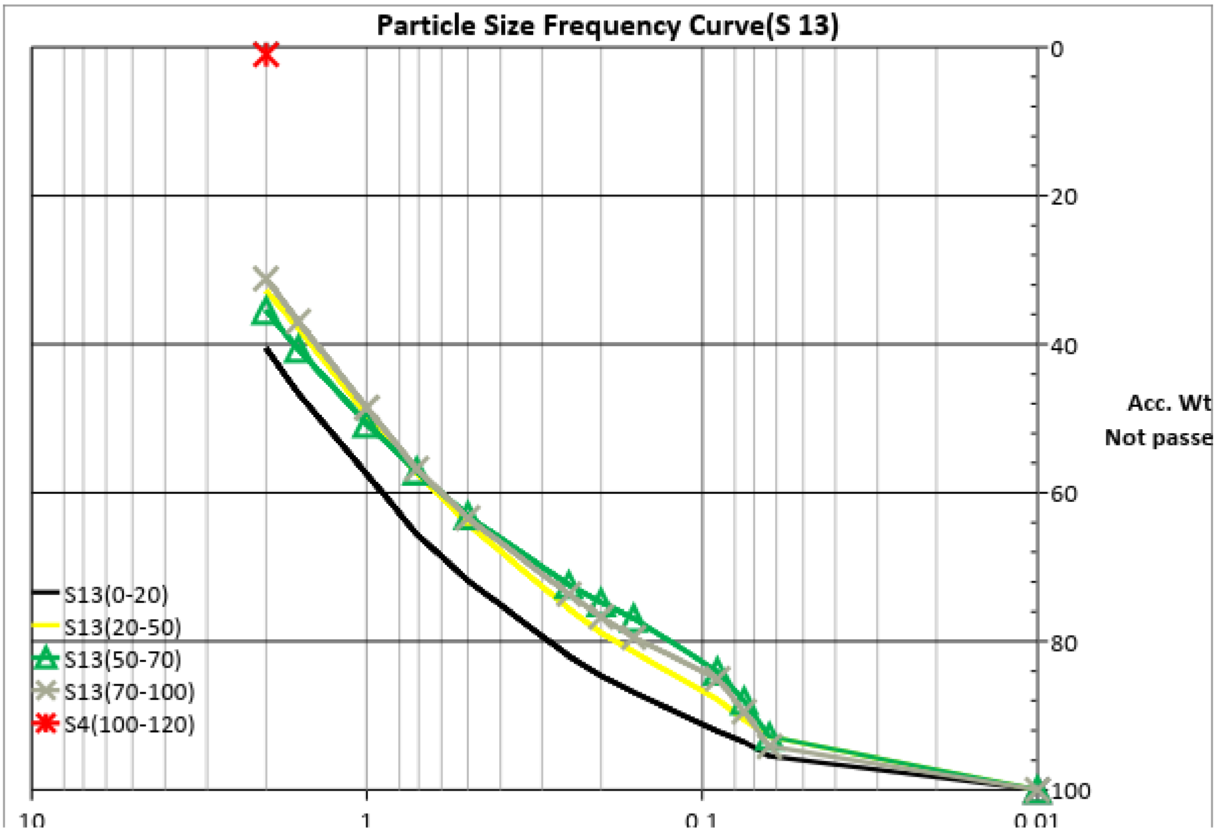

Figure 10.13: Particle size Frequency cure of Sample no.13, (S13)

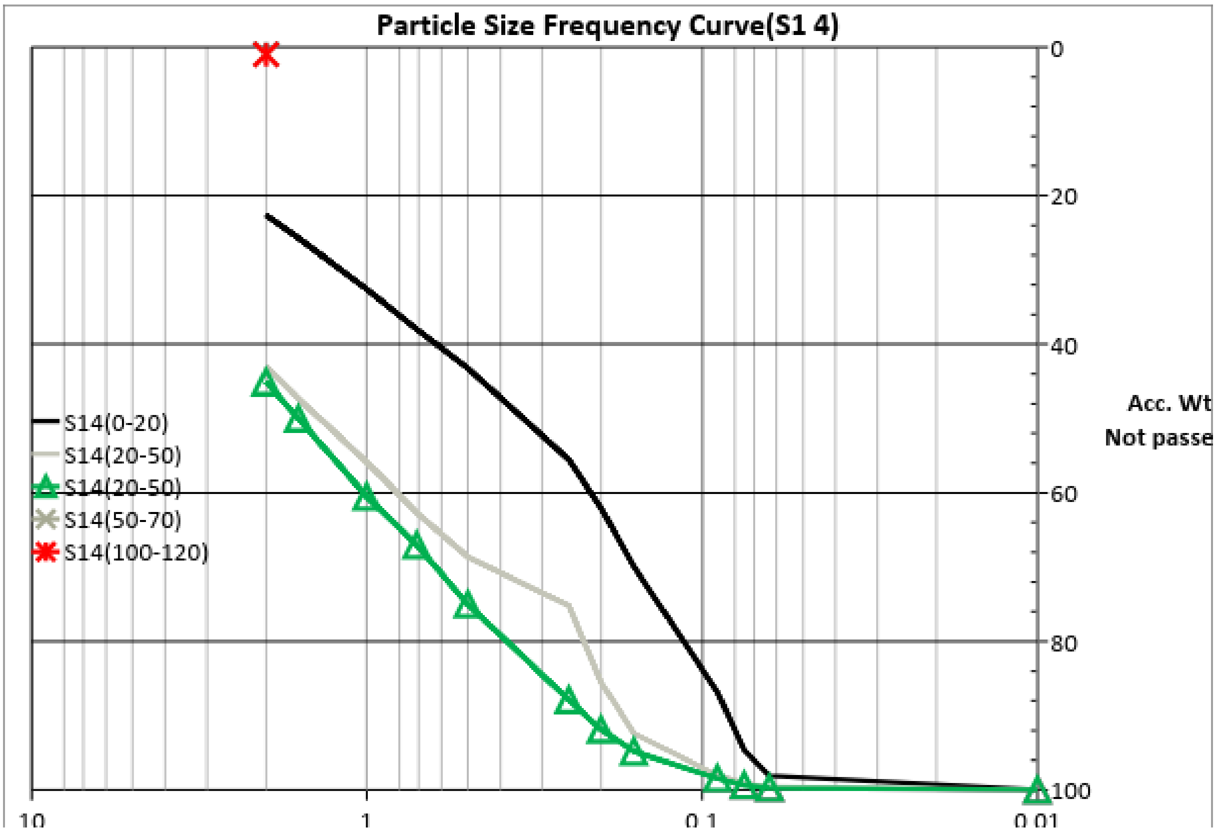

Figure 10.14: Particle size Frequency cure of Sample no.14, (S14)

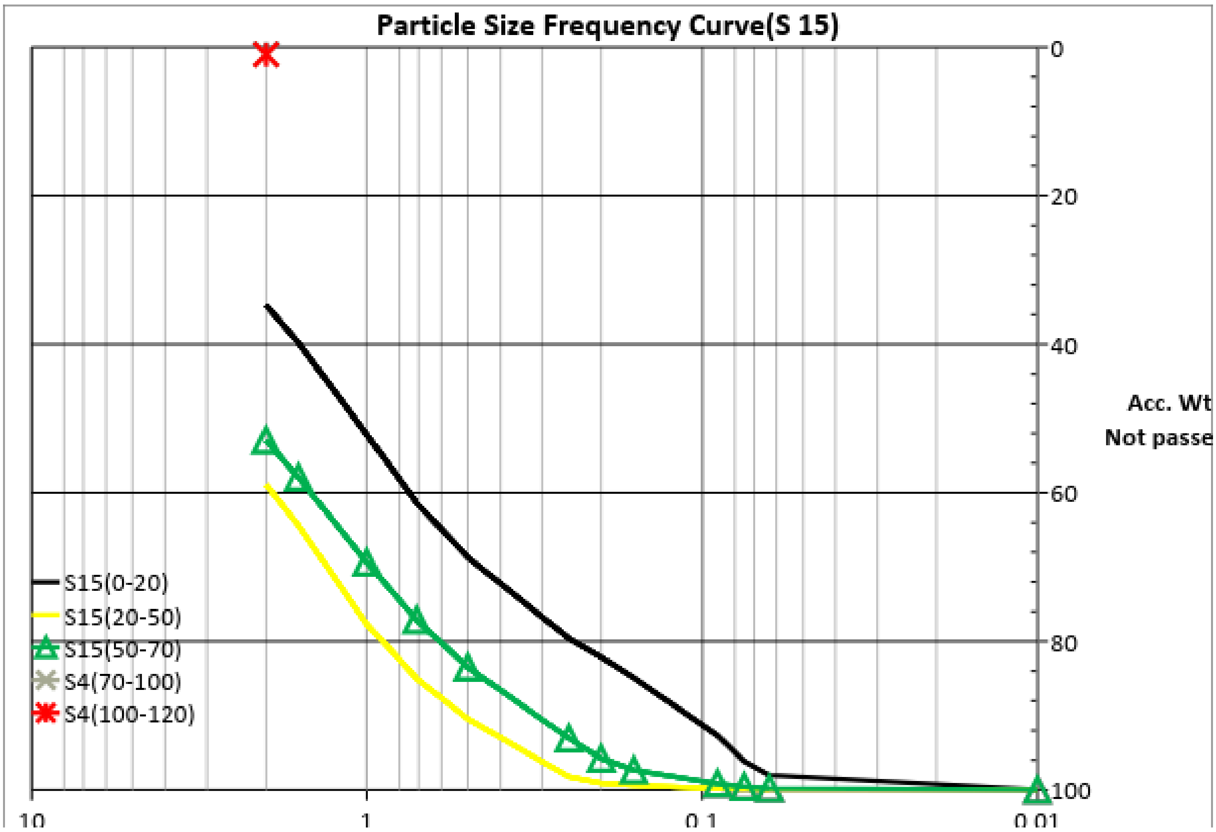

Figure 10.15: Particle size Frequency cure of Sample no.15, (S15)

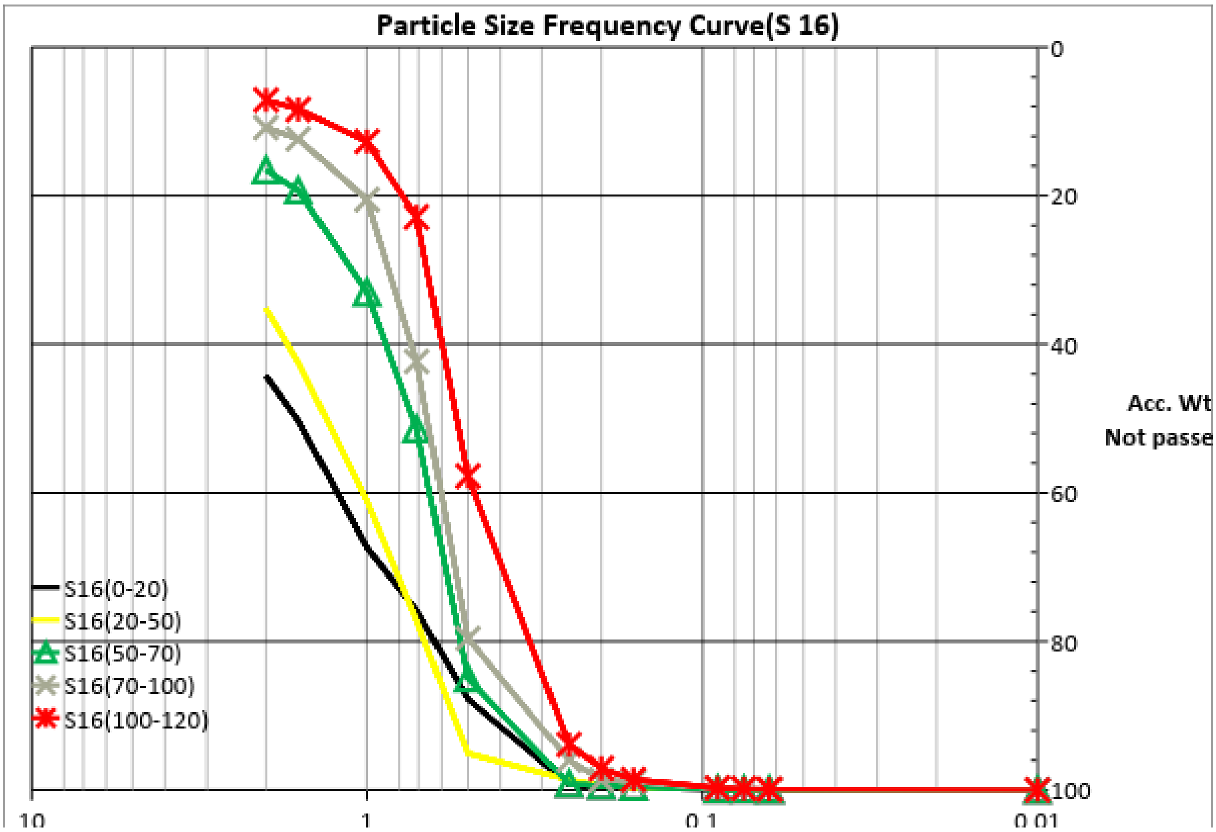

Figure 10.16: Particle size Frequency cure of Sample no.16, (S16)

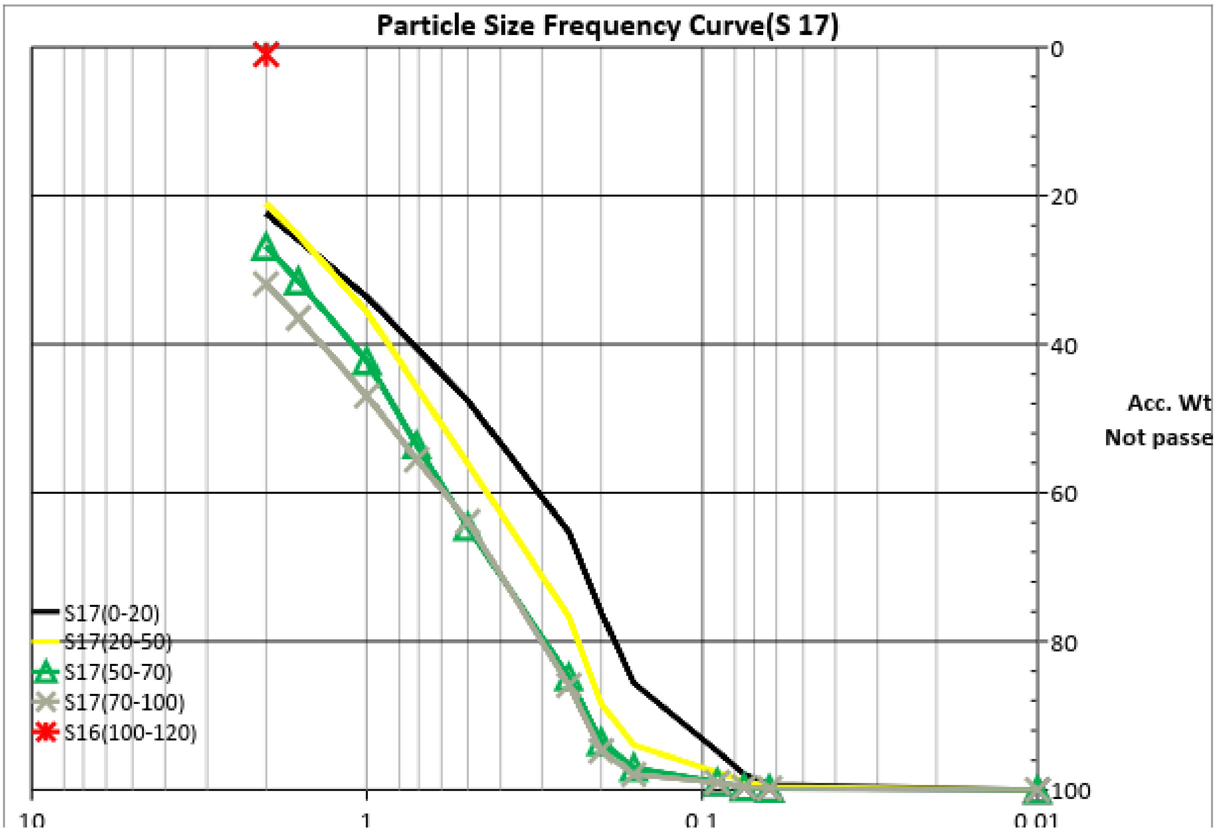

Figure 10.17: Particle size Frequency cure of Sample no.17, (S17)

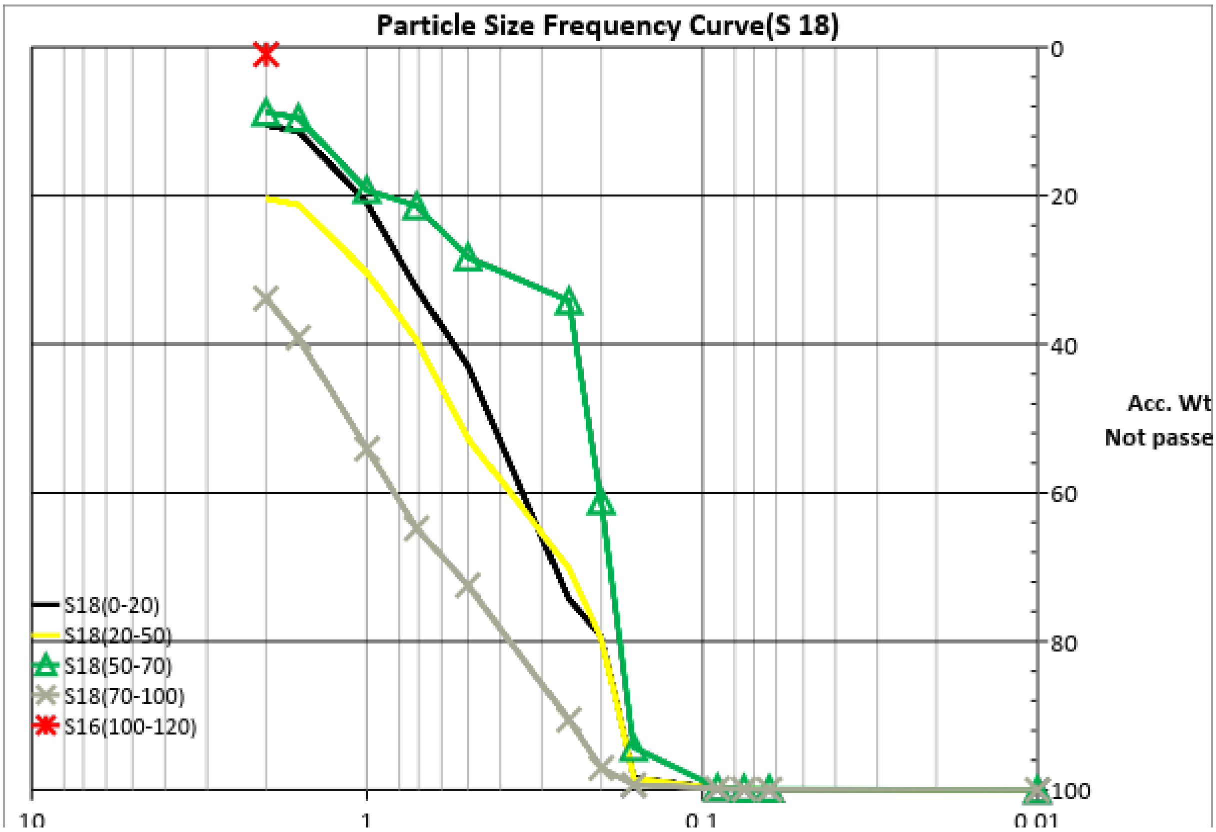

Figure 10.18: Particle size Frequency cure of Sample no.18, (S18)

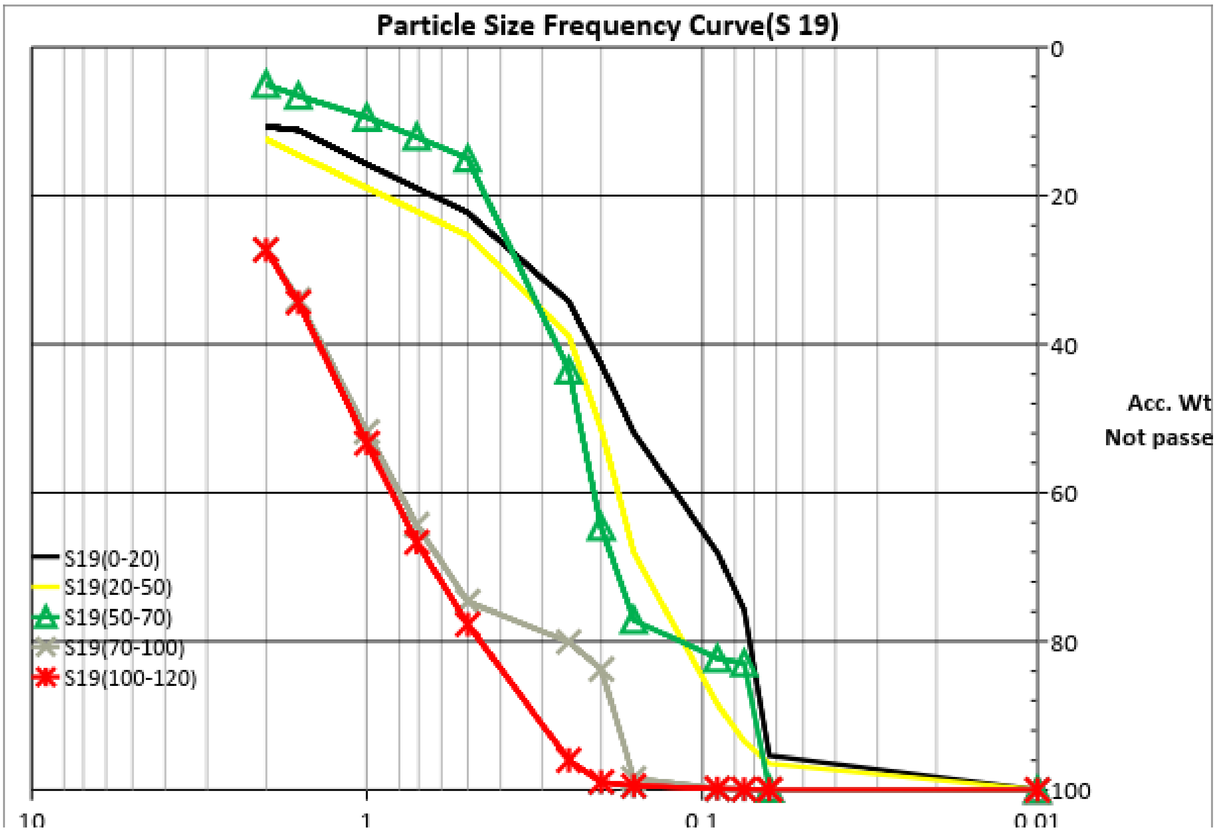

Figure 10.19: Particle size Frequency cure of Sample no.19, (S19)

Appendix 10.3 Hydrochemistry of soil samples in the CSA

Table 10.21: Salinity and hydrochemistry of soil samples in the CSA (0-20 cm depth)

Sample Code	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	Cl (mg/L)	K mg/l	Ece (ms/cm)	PH	Na (meq/L)	Mg (meq/L)	Ca (meq/L)	K (meq/l)	SAR (meq/L)	CEC	ESP
S1	21.3	13.8	11.9	17.7	20.5	0.2	8.7	0.9	1.1	0.6	0.5	1.0	6.4	29.1
s2	34.5	18.2	13.8	124.1	7.3	0.3	8.7	1.5	1.5	0.7	0.2	1.4	7.7	38.7
s3	46.3	31.1	24.4	141.8	21.0	0.7	8.5	2.0	2.6	1.2	0.5	1.5	8.6	0.0
s4	56.3	49.6	387.5	1418.0	39.9	4.5	8.2	2.4	4.1	19.3	1.0	0.7	53.9	9.1
s5	44.1	7.9	4.7	141.8	29.1	0.5	9.2	1.9	0.6	0.2	0.7	2.9	7.1	54.1
s6	29.0	33.4	24.1	81.5	28.5	0.5	8.5	1.3	2.7	1.2	0.7	0.9	11.9	21.2
s7	28.0	18.7	14.6	31.9	21.2	0.3	8.8	1.2	1.5	0.7	0.5	1.1	8.1	30.2
s8	13.6	19.3	16.4	35.5	12.8	0.3	8.0	0.6	1.6	0.8	0.3	0.5	6.7	17.8
s9	42.4	27.6	27.9	99.3	21.8	0.6	8.5	1.8	2.3	1.4	0.6	1.4	12.1	30.4
s10	15.3	20.9	12.3	177.3	29.2	0.3	8.5	0.7	1.7	0.6	0.7	0.6	7.5	17.8
s11	25.5	26.4	19.6	70.9	23.7	0.4	8.5	1.1	2.2	1.0	0.6	0.9	9.7	22.8
S12	31.3	25.3	18.5	106.4	12.1	0.5	8.7	1.4	2.1	0.9	0.3	1.1	9.4	29.1
s13	30.6	17.3	10.7	42.5	12.2	0.3	8.7	1.3	1.4	0.5	0.3	1.3	7.2	37.0
s14	17.9	26.4	22.1	141.8	x	0.4	8.8	0.8	2.2	1.1	0.0	0.6	8.1	19.2
s15	49.1	7.9	0.1	35.5	6.2	0.1	9.1	2.1	0.6	0.0	0.2	3.7	5.9	72.4
s16	17.3	25.6	22.8	3013.3	32.1	8.6	8.1	0.8	2.1	1.1	0.8	0.6	9.7	15.6
s17	52.7	47.6	110.2	35.5	15.5	0.4	8.9	2.3	3.9	5.5	0.4	1.1	24.2	18.9
s18	50.1	41.3	77.5	531.8	22.4	1.5	8.5	2.2	3.4	3.9	0.6	1.1	20.1	21.7
s19	33.8	13.2	12.1	70.9	26.7	0.3	9.1	1.5	1.1	0.6	0.7	1.6	7.7	38.2

Table 10.22: Salinity and hydrochemistry of soil samples in the CSA (20-50 cm depth)

Sampe Code	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	Cl (mg/L)	K (mg/l)	Ece (ms/cm)	PH	Na (meq/L)	Mg (meq/L)	Ca (meq/L)	K mg/l	SAR (meq/L)	CEC	ESP
S1	14.0	9.7	10.0	21.3	13.9	0.1	8.8	0.6	0.8	0.5	0.4	0.8	4.5	26.8
s2	32.1	13.2	13.7	53.2	13.5	0.2	9.8	1.4	1.1	0.7	0.3	1.5	7.0	39.7
s3	40.3	10.7	6.0	67.4	7.9	0.3	8.9	1.8	0.9	0.3	0.2	2.3	6.3	55.9
s4	56.3	48.1	149.8	1240.8	30.7	0.4	8.3	2.4	4.0	7.5	0.8	1.0	29.4	16.7
s5	42.6	7.8	31.5	106.4	28.6	0.4	9.3	1.9	0.6	1.6	0.7	1.8	9.6	38.6
s6	23.9	19.2	10.5	24.8	11.0	0.2	8.8	1.0	1.6	0.5	0.3	1.0	6.8	30.4
s7	20.6	17.3	11.5	28.4	10.7	0.2	8.9	0.9	1.4	0.6	0.3	0.9	6.3	28.3
s8	15.5	11.4	14.4	35.5	26.2	0.2	8.7	0.7	0.9	0.7	0.7	0.7	6.0	22.4
s9	45.5	16.0	8.4	92.2	15.2	0.4	8.7	2.0	1.3	0.4	0.4	2.1	8.2	48.2
s10	11.4	21.2	10.2	70.9	21.4	0.2	8.6	0.5	1.7	0.5	0.5	0.5	6.6	15.0
s11	18.3	17.4	12.2	24.8	11.1	0.2	8.8	0.8	1.4	0.6	0.3	0.8	6.3	25.5
S12	39.2	41.0	32.1	212.7	24.7	0.8	8.6	1.7	3.4	1.6	0.6	1.1	14.6	23.3
s13	34.2	20.1	11.9	53.2	20.9	0.4	8.6	1.5	1.7	0.6	0.5	1.4	8.6	34.7
s14	40.5	17.9	9.4	212.7	20.7	0.7	8.9	1.8	1.5	0.5	0.5!	1.8	8.6	34.7
s15	18.9	9.7	11.7	70.9	5.6	0.4	8.7	0.8	0.8	0.6	0.1	1.0	4.7	34.9
s16	53.0	53.7	692.0	3013.3	25.8	7.1	8.2	2.3	4.4	34.5	0.7	0.5	84.0	5.5
s17	30.1	45.0	102.3	35.5	7.0	0.2	8.9	1.3	3.7	5.1	0.2	0.6	20.6	12.7
s18	50.7	45.0	84.1	992.6	19.2	2.8	8.5	2.2	3.7	4.2	0.5	1.1	21.2	20.8
S19	48.2	44.9	114.7	283.6	28.9	1.8	8.5	2.1	3.7	5.7	0.7	1.0	24.5	17.1

Table 10.23: Salinity and hydrochemistry of soil samples in the CSA (50-70 cm depth)

Sampe Code	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	Cl (mg/L)	K (mg/l)	Ece (ms/cm)	PH	Na (meq/L)	Mg (meq/L)	Ca (meq/L)	K mg/l	SAR (meq/L)	CEC	ESP
S1	10.9	10.1	11.2	17.7	11.0	0.1	8.9	0.5	0.8	0.6	0.3	0.6	4.3	22.1
s2	x	x	x	x	x	x	x	x	x	x	x	x	x	x
s3	40.9	8.8	6.5	49.6	8.8	0.3	9.0	1.8	0.7	0.3	0.2	2.5	6.1	58.2
s4	56.9	49.1	100.5	1099.0	31.5	3.9	8.2	2.5	4.0	5.0	0.8	1.2	24.7	20.0
s5	44.3	7.5	2.0	70.9	15.1	0.4	9.3	1.9	0.6	0.1	0.4	3.2	6.1	63.6
s6	24.8	17.6	13.2	28.4	9.4	0.2	8.8	1.1	1.4	0.7	0.2	1.1	6.9	31.4
s7	15.9	18.1	10.7	21.3	9.6	0.2	8.8	0.7	1.5	0.5	0.2	0.7	5.9	23.3
s8	x	x	x	x	x	x	x	x	x	x	x	x	x	x
s9	43.4	14.1	13.0	70.9	14.0	0.4	8.9	1.9	1.2	0.7	0.4	2.0	8.1	46.5
s10	10.8	22.3	9.8	35.5	13.5	0.2	8.6	0.5	1.8	0.5	0.3	0.4	6.3	15.0
s11	17.7	17.1	13.6	17.7	19.7	0.2	8.9	0.8	1.4	0.7	0.5	0.8	6.7	22.9
S12	45.6	42.3	30.8	354.5	21.3	1.1	8.5	2.0	3.5	1.5	0.5	1.3	15.1	26.3
s13	15.5	9.6	8.3	21.3	6.2	0.1	8.8	0.7	0.8	0.4	0.2	0.9	4.1	33.1
s14	47.9	16.9	6.0	212.7	x	0.7	9.0	2.1	1.4	0.3	x	2.3	7.5	55.2
s15	20.4	30.2	30.4	70.9	3.9	0.3	8.7	0.9	2.5	1.5	0.1	0.6	10.0	17.8
s16	59.8	52.2	576.9	1878.9	22.3	5.4	8.3	2.6	4.3	28.8	0.6	0.6	72.6	7.2
s17	21.5	28.9	26.5	35.5	5.9	0.2	9.1	0.9	2.4	1.3	0.1	0.7	9.6	19.5
s18	54.4	44.2	44.0	1063.5	16.6	3.1	8.4	2.4	3.6	2.2	0.4	1.4	17.3	27.4
s19	51.6	37.8	23.1	779.9	21.5	2.3	3.6	2.2	3.1	1.2	0.5	1.5	14.1	31.8

Table 10.24: Salinity and hydrochemistry of soil samples in the CSA (70-100 cm depth)

Sample Code	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	Cl (mg/L)	K mg/l	Ece (ms/cm)	PH	Na (meq/L)	Mg (meq/L)	Ca (meq/L)	K meq/l	SAR (meq/L)	CEC	ESP
S1	10.8	9.3	11.3	14.2	9.4	0.1	8.9	0.5	0.8	0.6	0.2	0.6	3.1	30.8
s2	x	x	x	x	x	x	x	x	x	x	x	x	x	x
s3	38.8	7.0	2.3	39.0	8.4	0.3	8.9	1.7	0.6	0.1	0.2	2.9	4.6	73.9
s4	57.4	48.9	171.1	1063.5	27.9	3.7	8.3	2.5	4.0	8.5	0.7	1.0	58.8	8.5
s5	44.6	4.4	1.5	70.9	9.5	0.5	9.2	1.9	0.4	0.1	0.2	4.1	3.5	111.9
s6	23.7	14.6	9.6	24.8	11.0	0.2	9.0	1.0	1.2	0.5	0.3	1.1	6.5	31.8
s7	15.1	22.6	15.8	17.7	9.2	0.2	8.9	0.7	1.9	0.8	0.2	0.6	6.9	18.9
s8	x	x	x	x	x	x	x	x	x	x	x	x	x	x
s9	39.1	16.0	11.2	53.2	15.5	0.3	9.0	1.7	1.3	0.6	0.4	1.8	10.9	31.2
s10	11.1	19.5	7.7	35.5	14.1	0.2	8.7	0.5	1.6	0.4	0.4	0.5	4.6	21.1
s11	14.9	14.3	10.7	14.2	15.2	0.1	9.0	0.6	1.2	0.5	0.4	0.7	4.9	26.5
S12	46.6	45.2	24.3	425.4	26.2	1.7	8.5	2.0	3.7	1.2	0.7	1.3	34.0	11.9
s13	27.9	11.4	8.0	21.3	6.8	0.2	8.2	1.2	0.9	0.4	0.2	1.5	5.7	42.5
s14	46.3	10.0	1.3	177.3		0.8	9.1	2.0	0.8	0.1	x	3.0	6.8	59.6
s15	x	x	x	x	x	x	x	x	x	x	x	x	x	x
s16	54.0	50.6	351.9	1666.2	19.8	3.9	8.4	2.3	4.2	17.6	0.5	0.7	75.4	6.2
s17	14.3	13.8	12.4	70.9	5.9	0.2	9.0	0.6	1.1	0.6	0.2	0.7	4.4	28.5
s18	55.0	46.3	41.0	1240.8	15.4	3.4	8.4	2.4	3.8	2.0	0.4	1.4	41.4	11.6
s19	58.1	41.0	21.3	1205.3	24.1	3.3	8.6	2.5	3.4	1.1	0.6	1.7	37.5	13.5

Table 10.25: Salinity and hydrochemistry of soil samples in the CSA 100-120 cm depth)

Sample Code	Na (mg/L)	Mg (mg/L)	Ca (mg/L)	Cl (mg/L)	K (mg/l)	Ece (ms/cm)	PH	Na (meq/L)	Mg (meq/L)	Ca (meq/L)	[K] meq/l	SAR (meq/L)	CEC	ESP
S1	10.6	9.6	10.1	14.2	10.4	0.1	9.0	0.5	0.8	0.5	0.3	0.6	4.0	22.8
s2	x	x	x	x	x	x	x	x	x	x	0.0	x	x	X
s3	38.1	7.7	2.7	46.1	9.4	0.2	9.0	1.7	0.6	0.1	0.2	2.7	5.3	62.1
s4	57.8	48.8	146.0	1134.4	29.3	3.6	8.3	2.5	4.0	7.3	0.7	1.1	29.2	17.2
s5	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s6	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s7	14.8	24.1	11.3	21.3	10.5	0.2	8.8	0.6	2.0	0.6	0.3	0.6	6.9	18.6
s8	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s9	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s10	12.6	20.2	9.0	35.5	10.9	0.2	8.8	0.5	1.7	0.4	0.3	0.5	5.9	18.6
s11	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
S12	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s13	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s14	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s15	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s16	51.9	48.5	161.2	1063.5	19.6	3.3	8.5	2.3	4.0	8.0	0.5	0.9	29.6	15.2
s17	x	x	x	x	x	x	x	x	x	x	0.0	x	x	x
s18	56.8	48.0	80.5	1347.1	18.9	4.0	8.4	2.5	3.9	4.0	0.5	1.2	21.9	22.6
s19	58.1	41.3	18.5	1453.5	25.9	3.6	8.6	2.5	3.4	0.9	0.7	1.7	15.0	33.6

Appendix 10.4 Soil sample 3 D analysis using GIS of all sampling Depths and location.

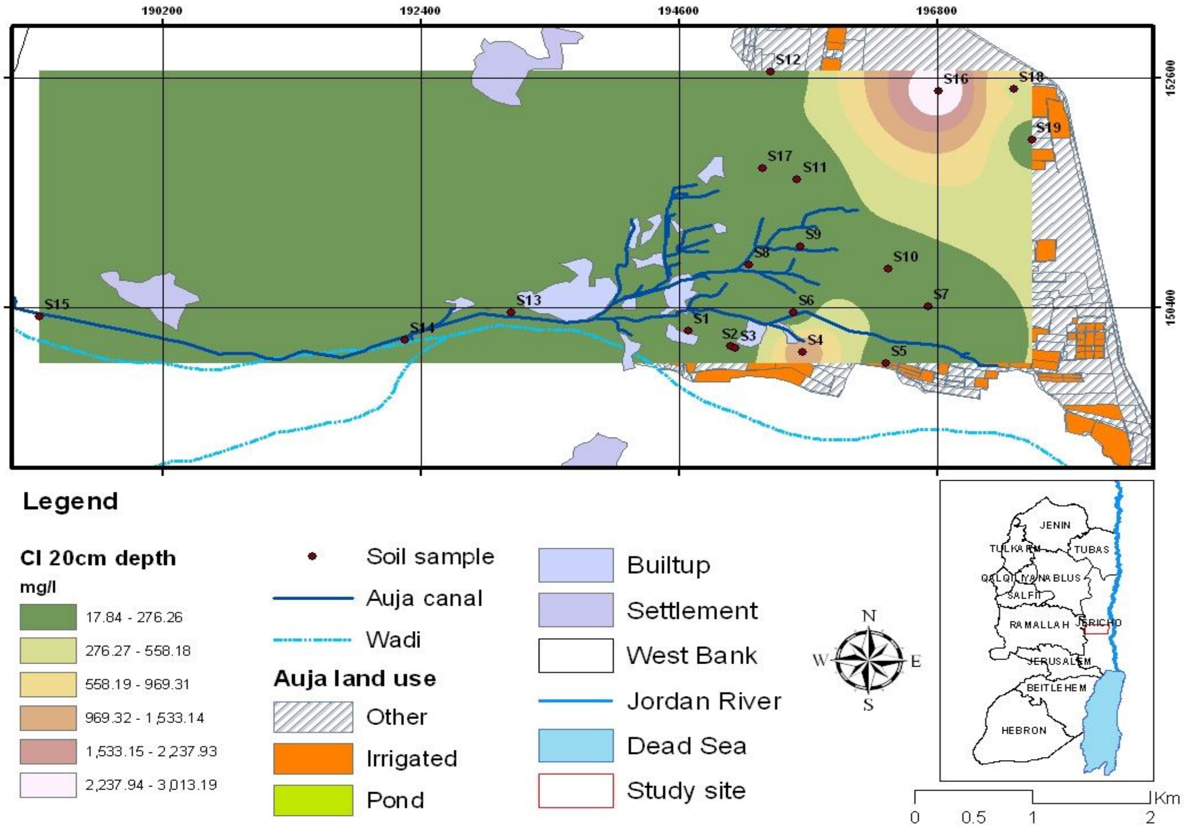

Figure10.20: Chloride concentration of (0-20 cm) depth at the CSA.

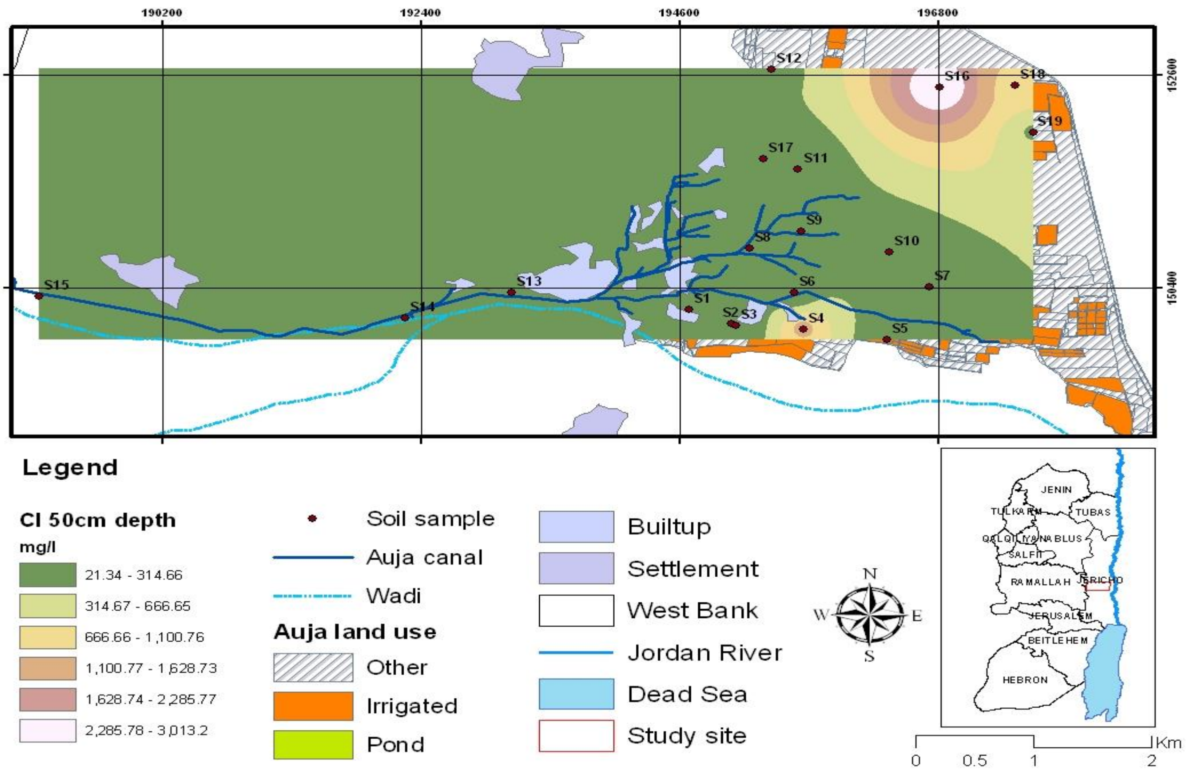

Figure10.21: Chloride concentration of (20-50 cm) depth at the CSA.

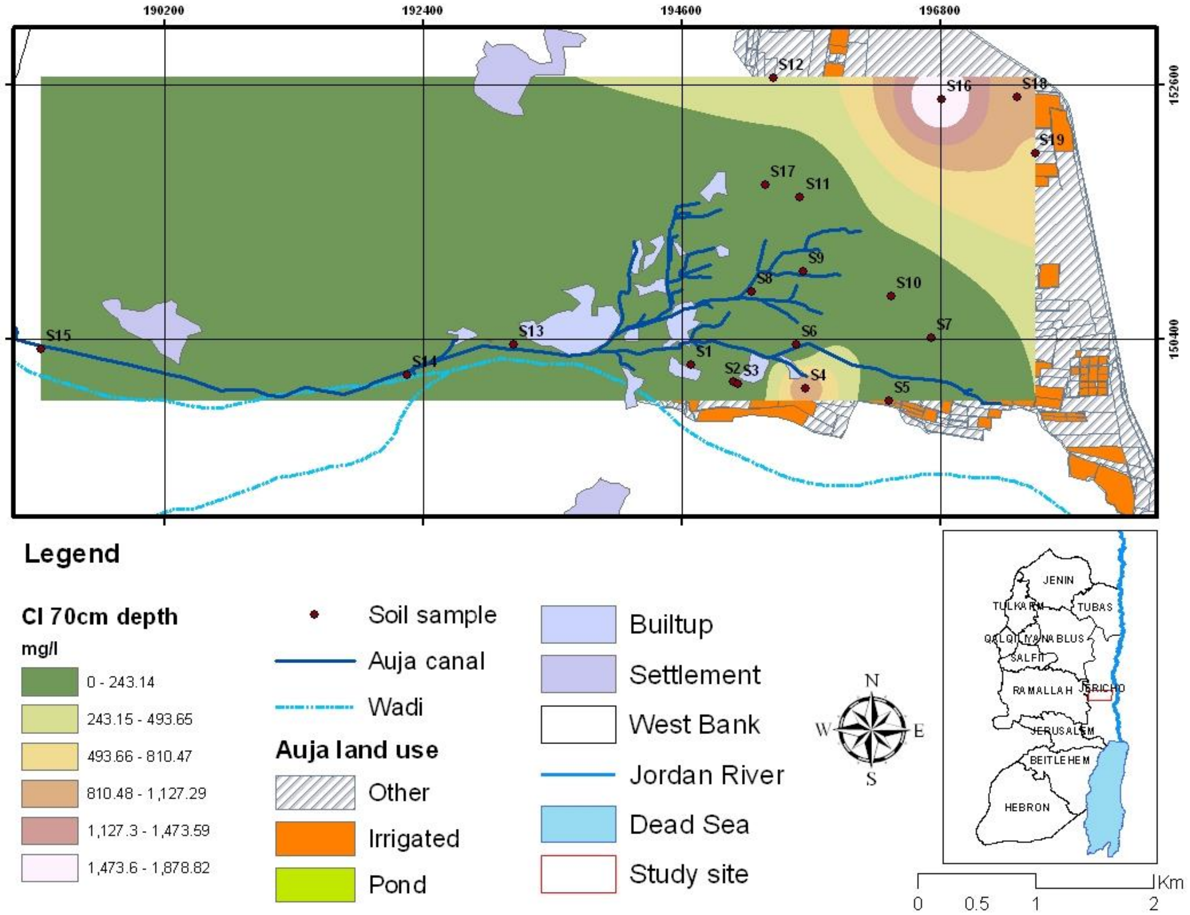

Figure10.22: Chloride concentration of (50-70 cm) depth at the CSA.

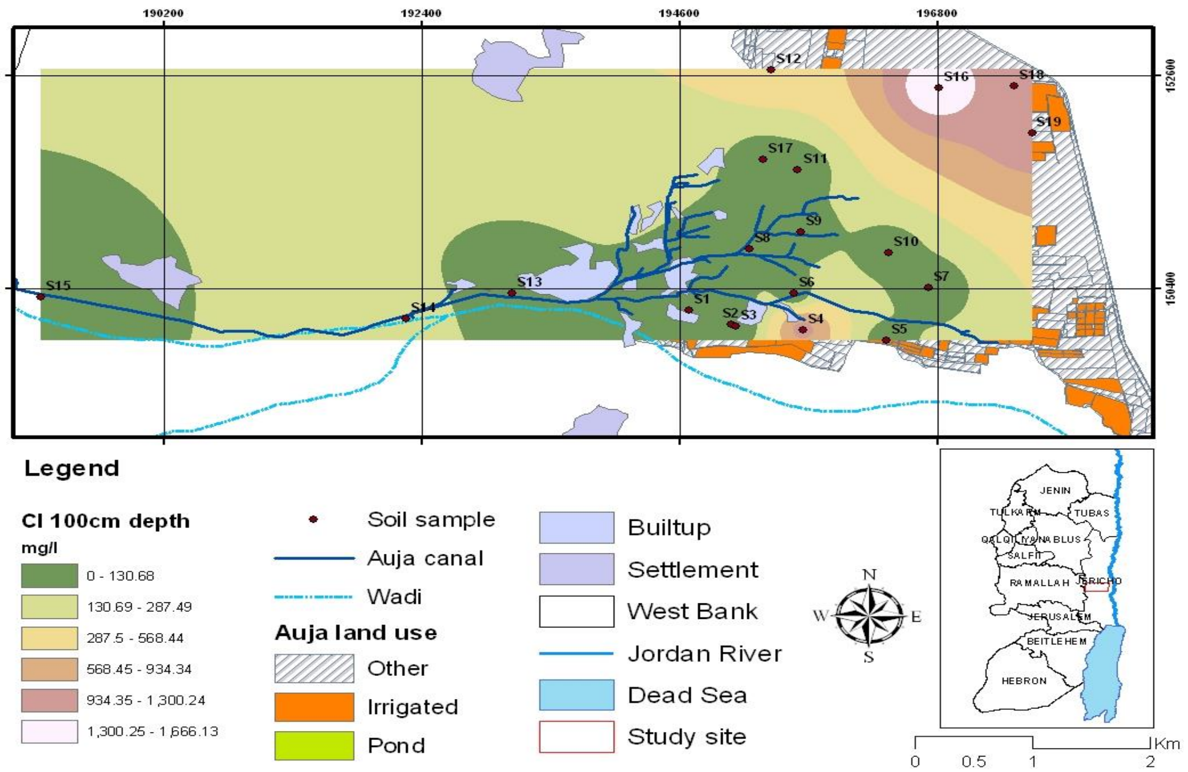

Figure10.23: Chloride concentration of (70-100 cm) depth at the CSA.

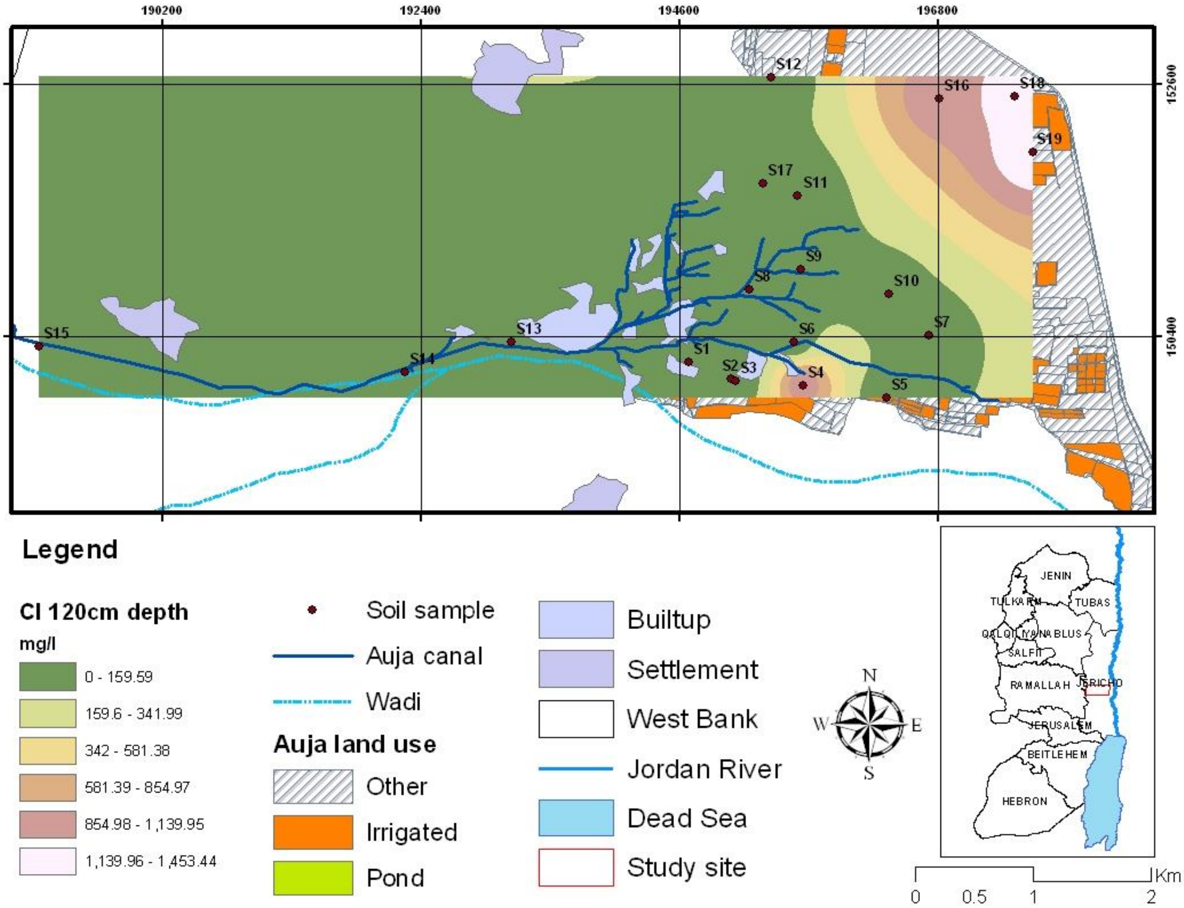

Figure10.24: Chloride concentration of (100-120 cm) depth at the CSA.

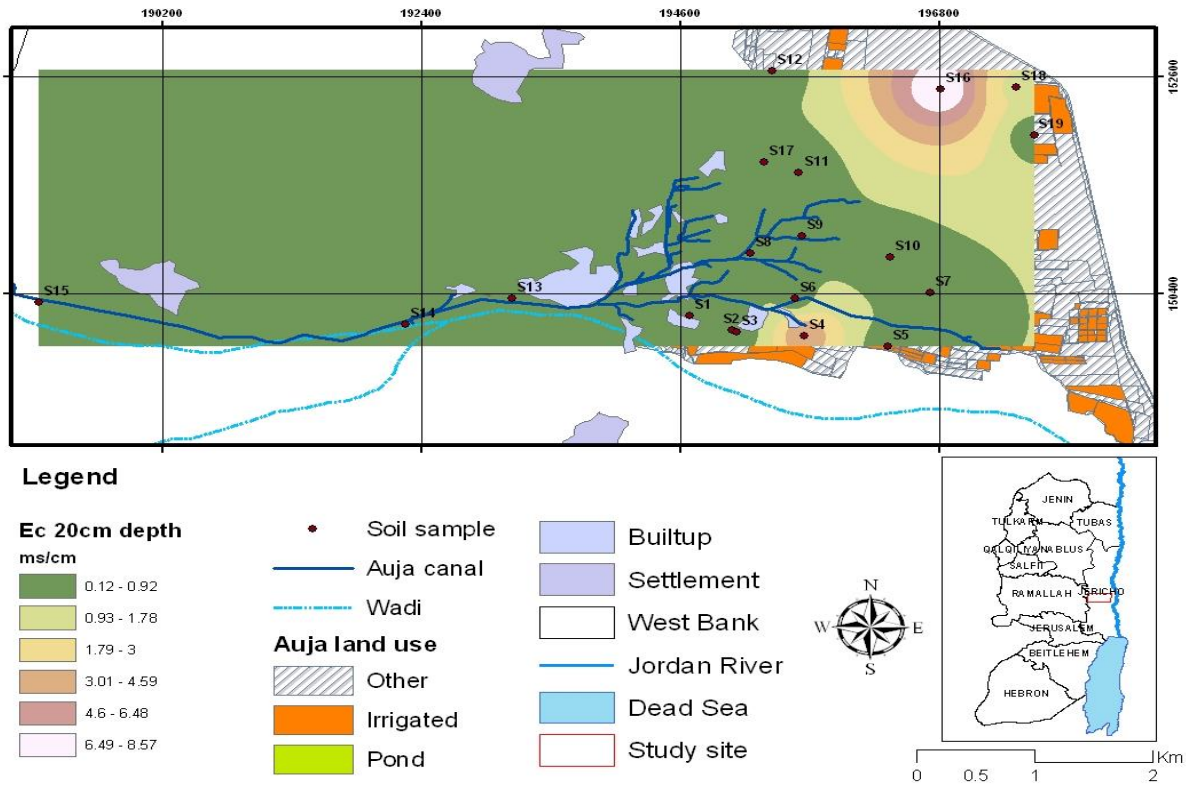

Figure10.25: Electrical conductivity Value of (0-20 cm) depth at the CSA.

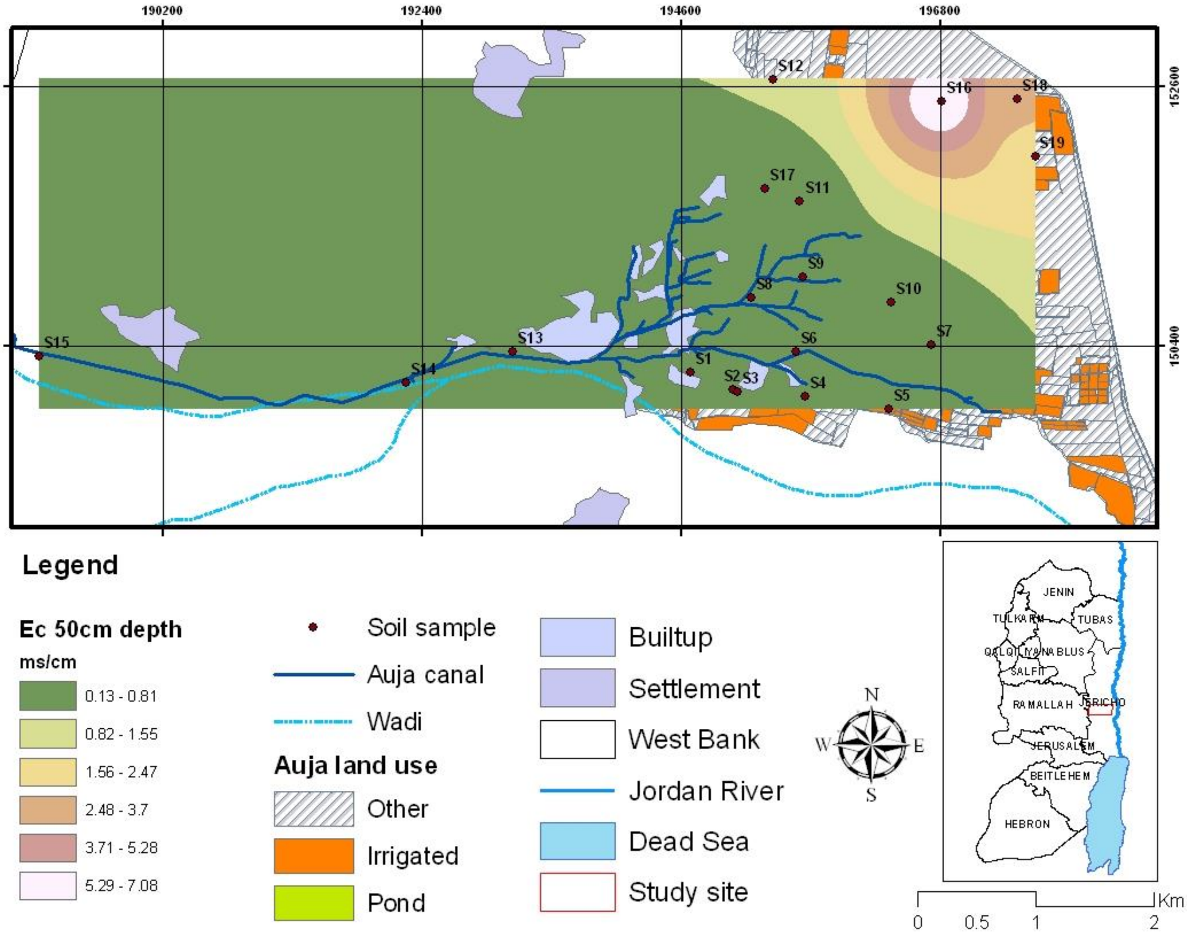

Figure10.26: Electrical conductivity Value of (20-50 cm) depth at the CSA.

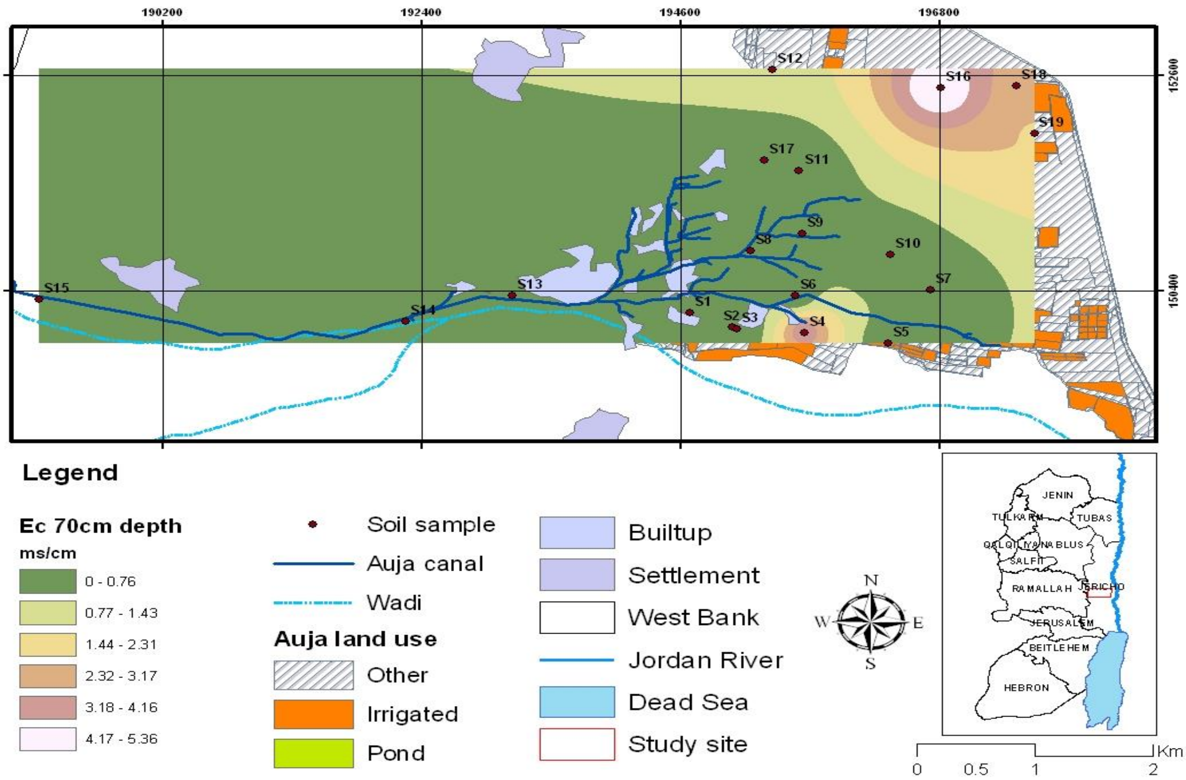

Figure10.27: Electrical conductivity Value of (50-70 cm) depth at the CSA.

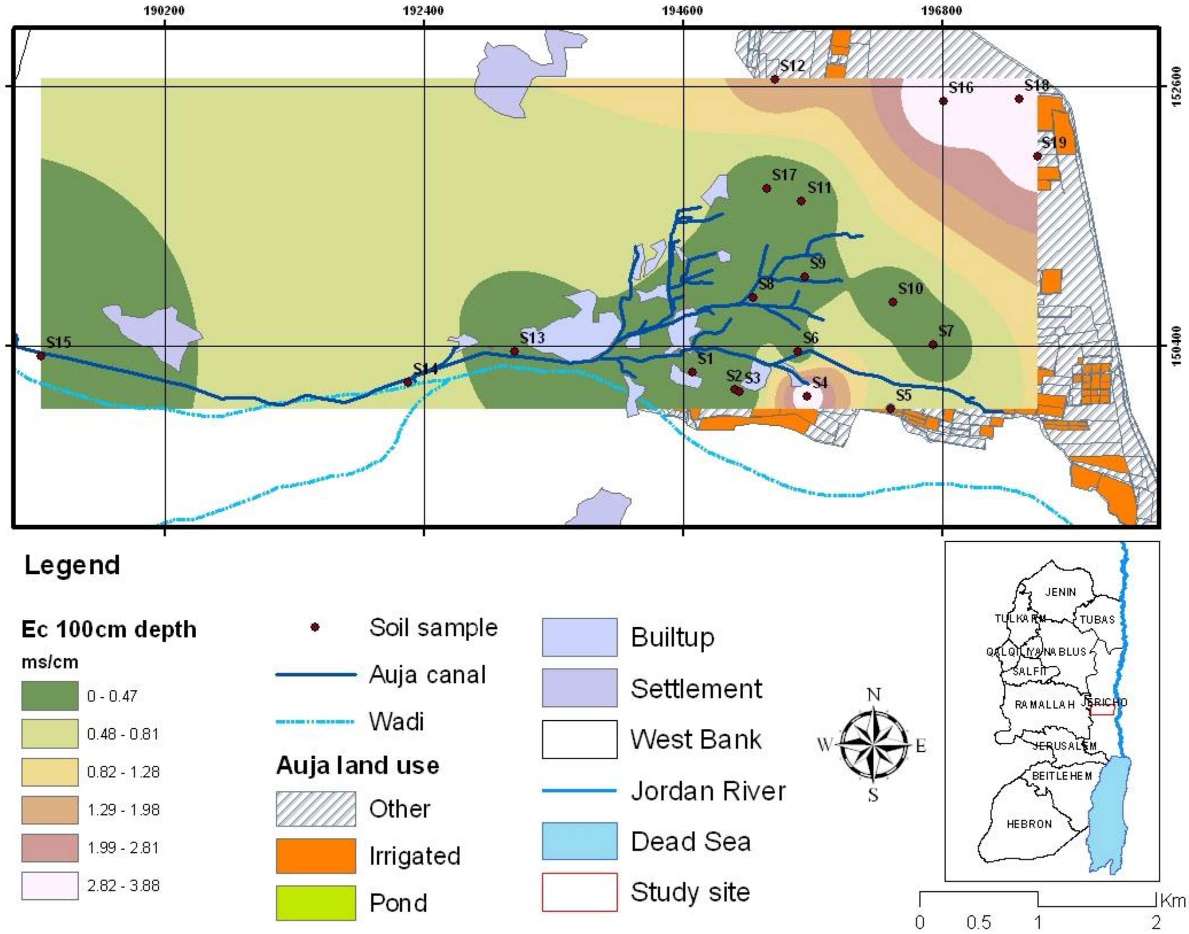

Figure10.28: Electrical conductivity Value of (70-100 cm) depth at the CSA.

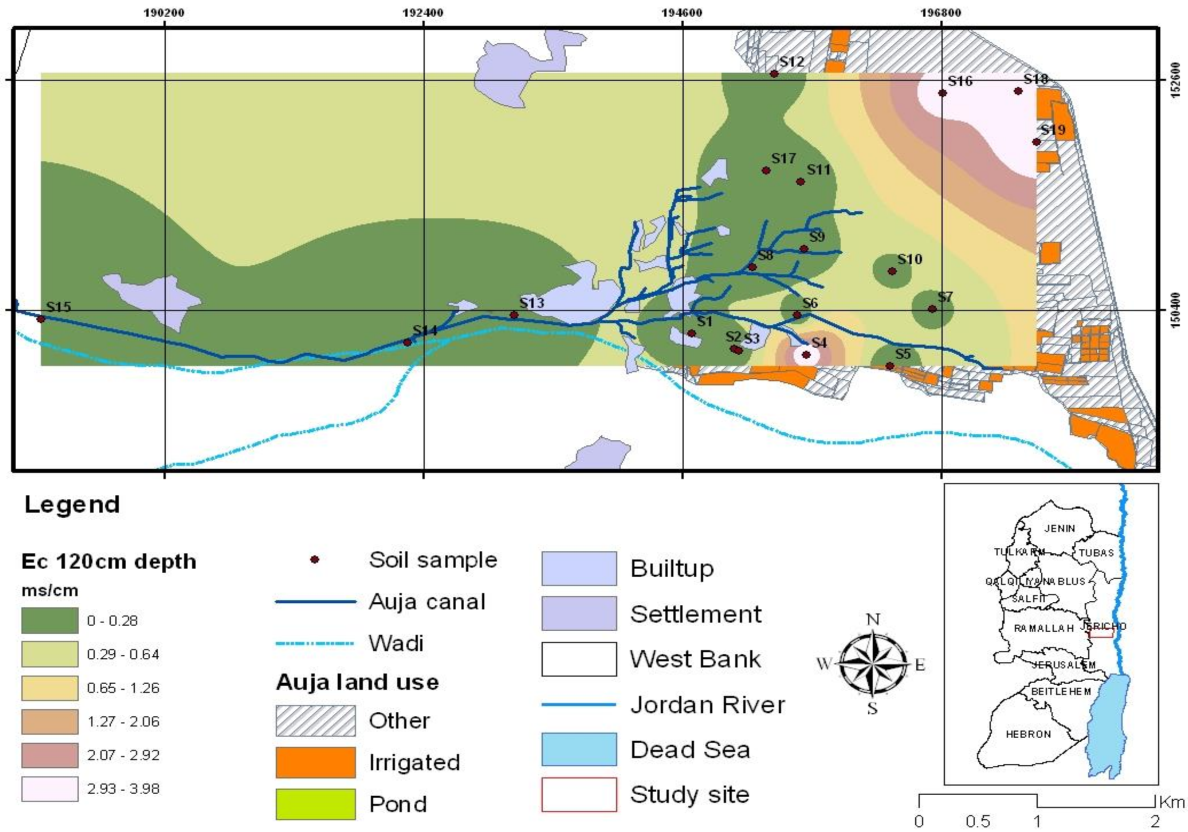

Figure10.29: Electrical conductivity Value of (100-120 cm) depth at the CSA.

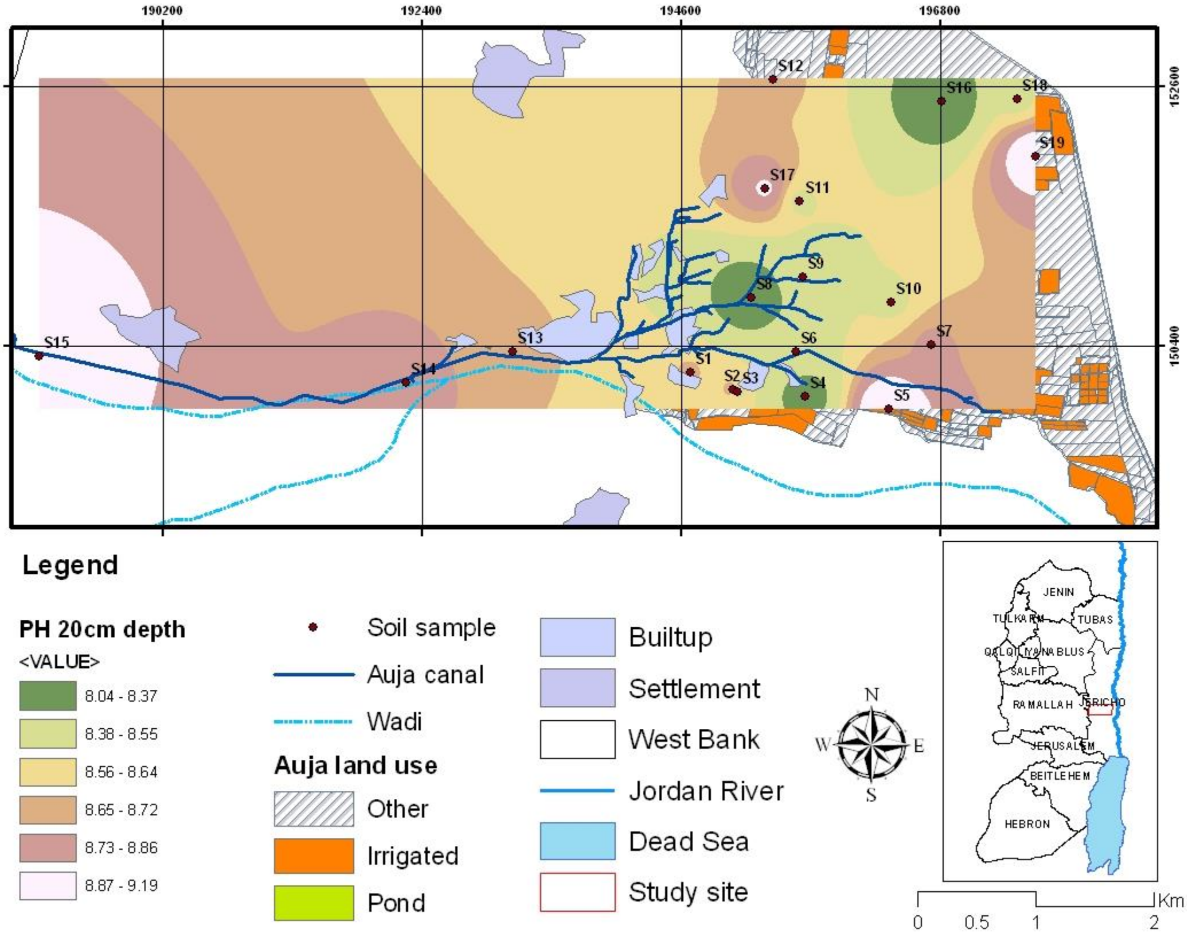

Figure10.30: PH Value of (0-20 cm) depth at the CSA.

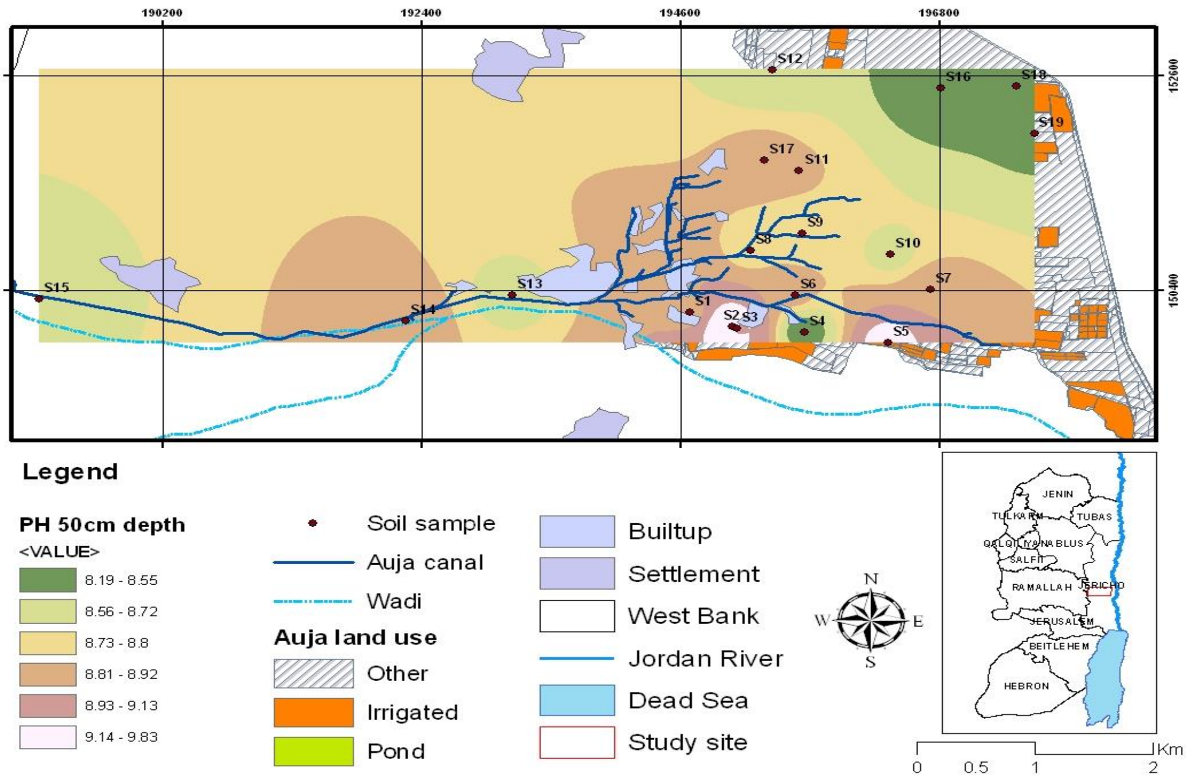

Figure10.31: PH Value of (20-50 cm) depth at the CSA.

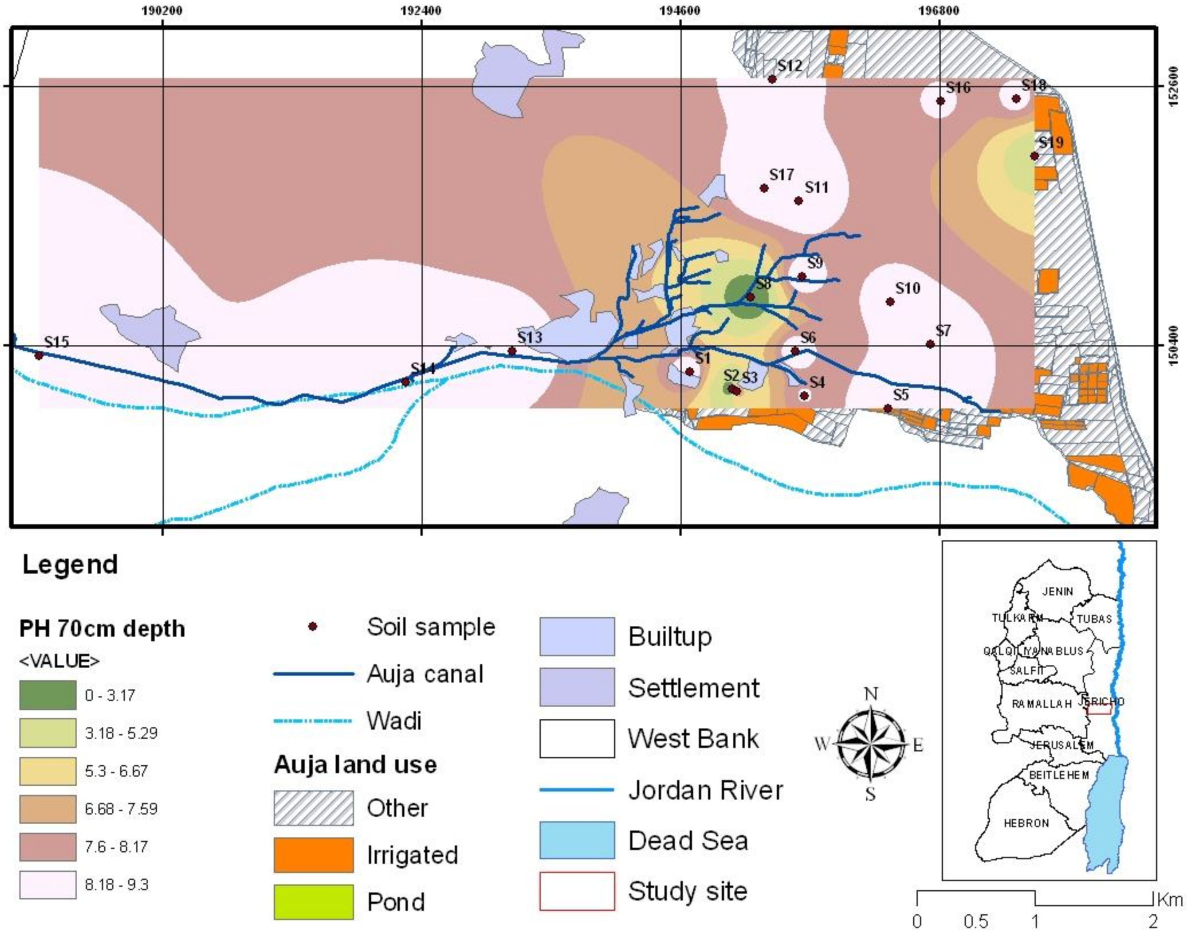

Figure10.32: PH Value of (50-70 cm) depth at the CSA.

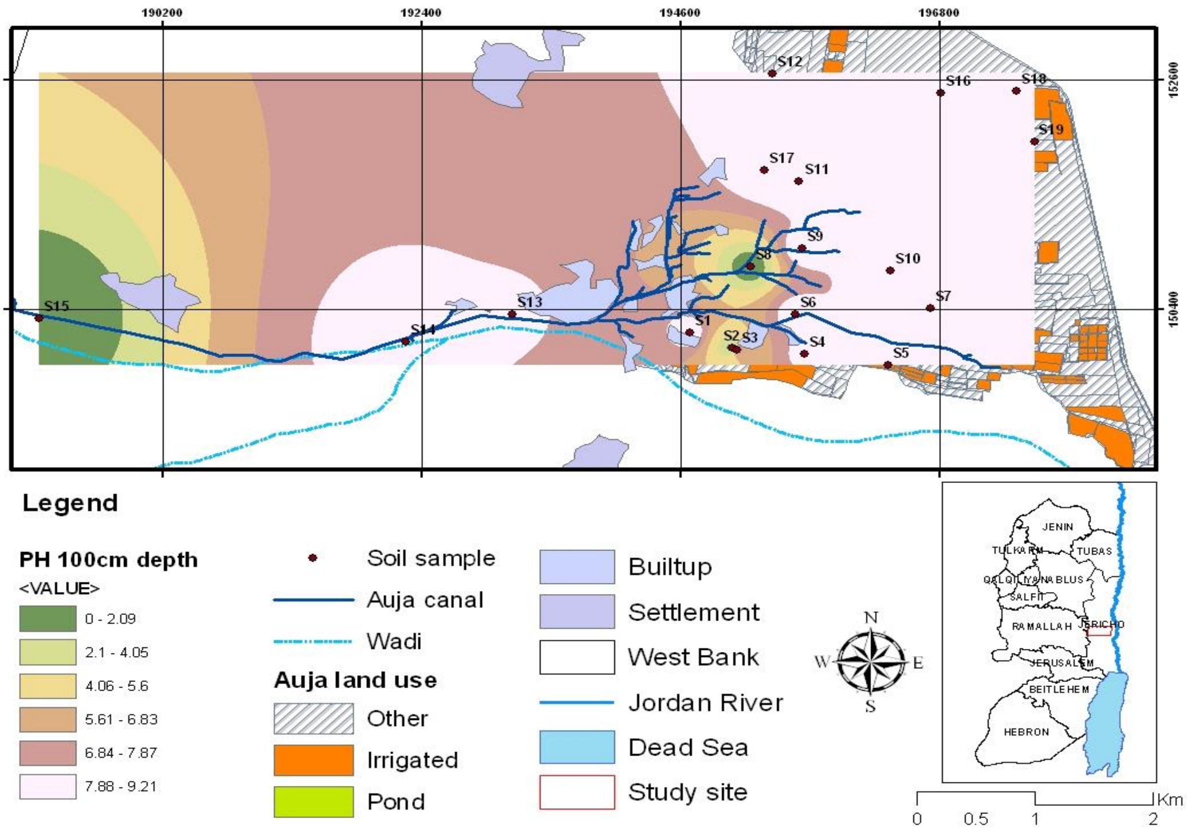

Figure10.33: PH Value of (70-100 cm) depth at the CSA.

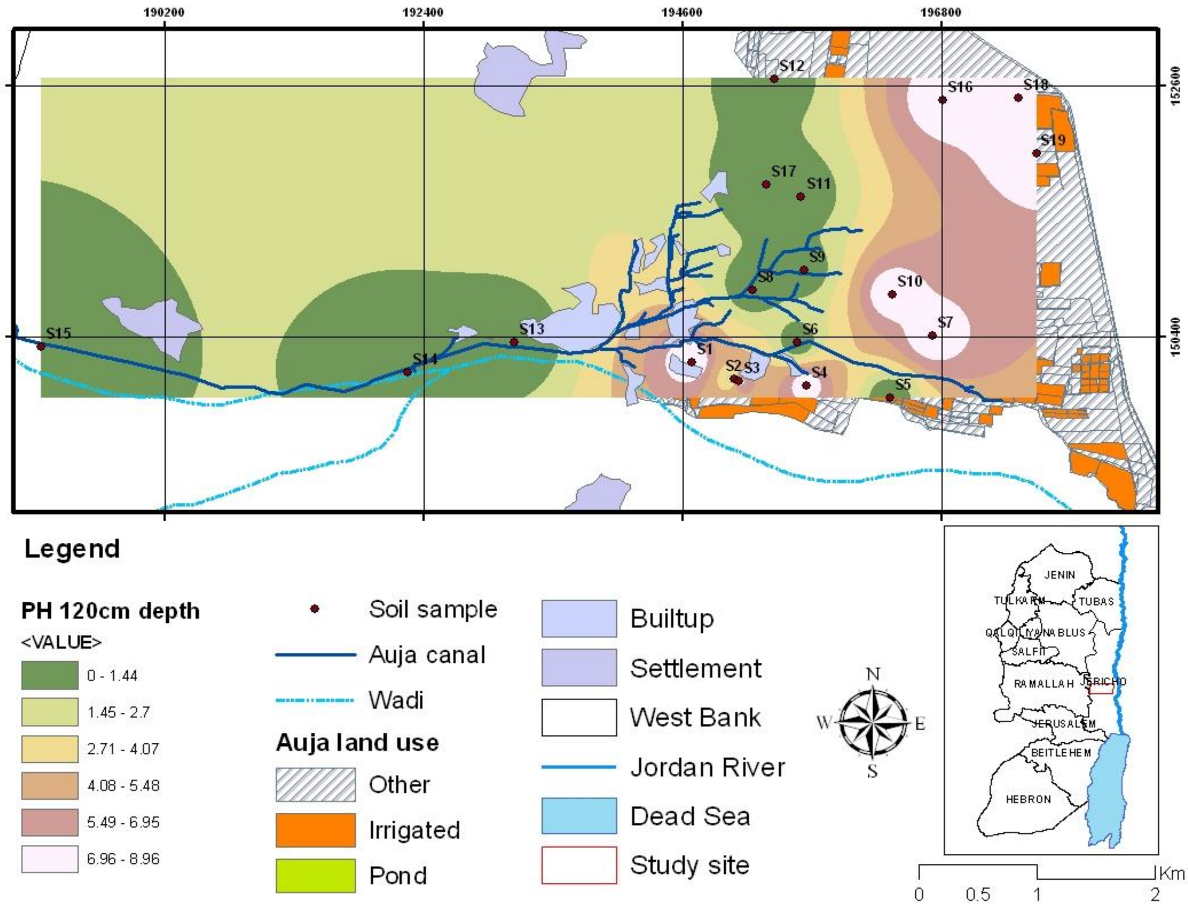

Figure10.34: PH Value of (100-120 cm) depth at the CSA.

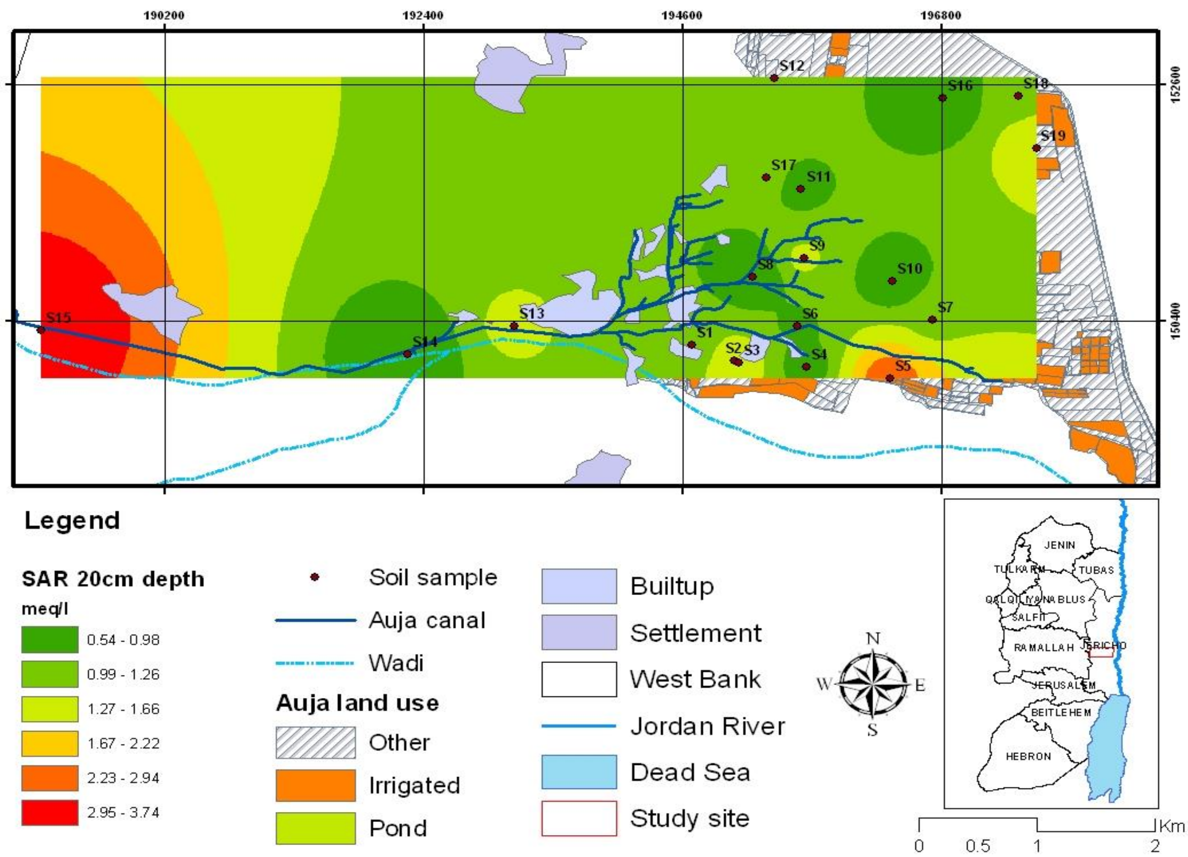

Figure10.35: SAR Value of (0-20 cm) depth at the CSA.

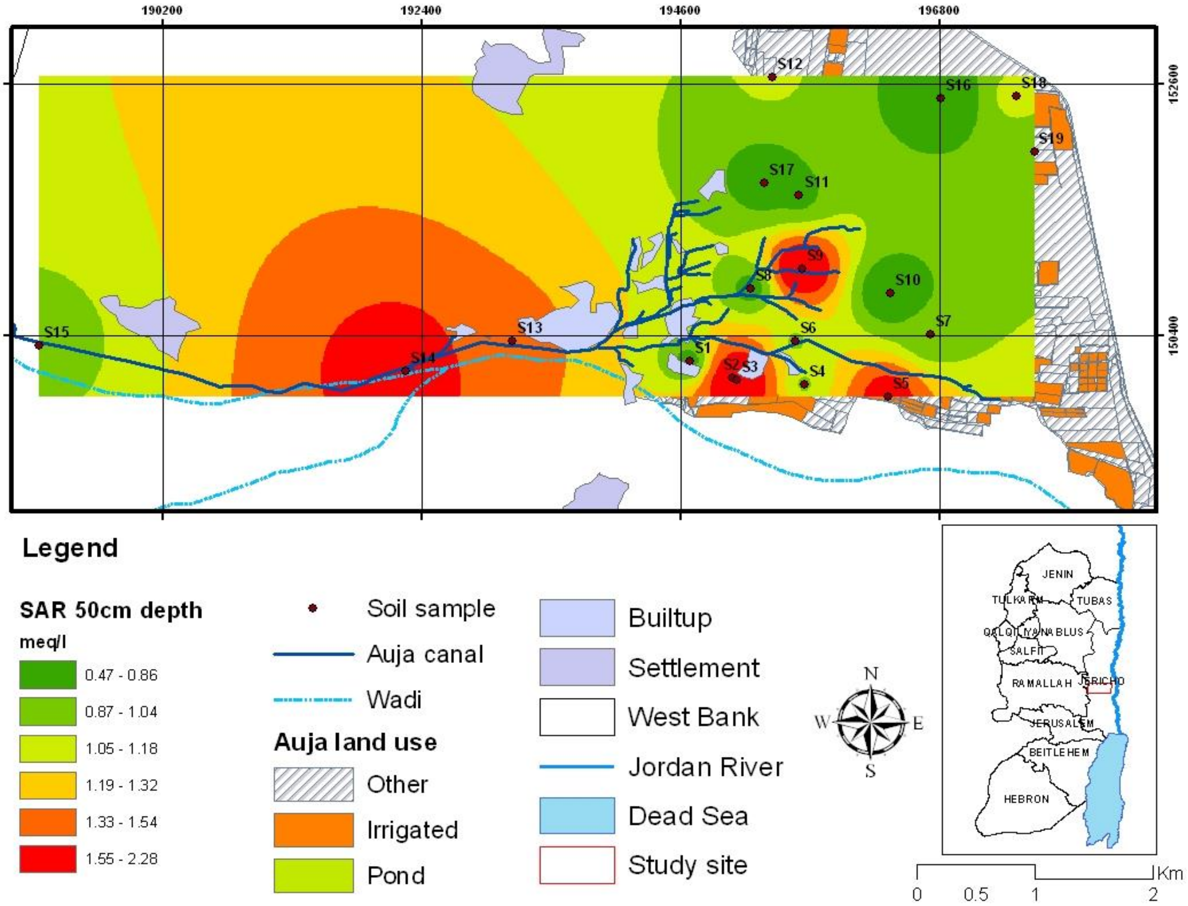

Figure10.36: SAR Value of (20-50 cm) depth at the CSA.

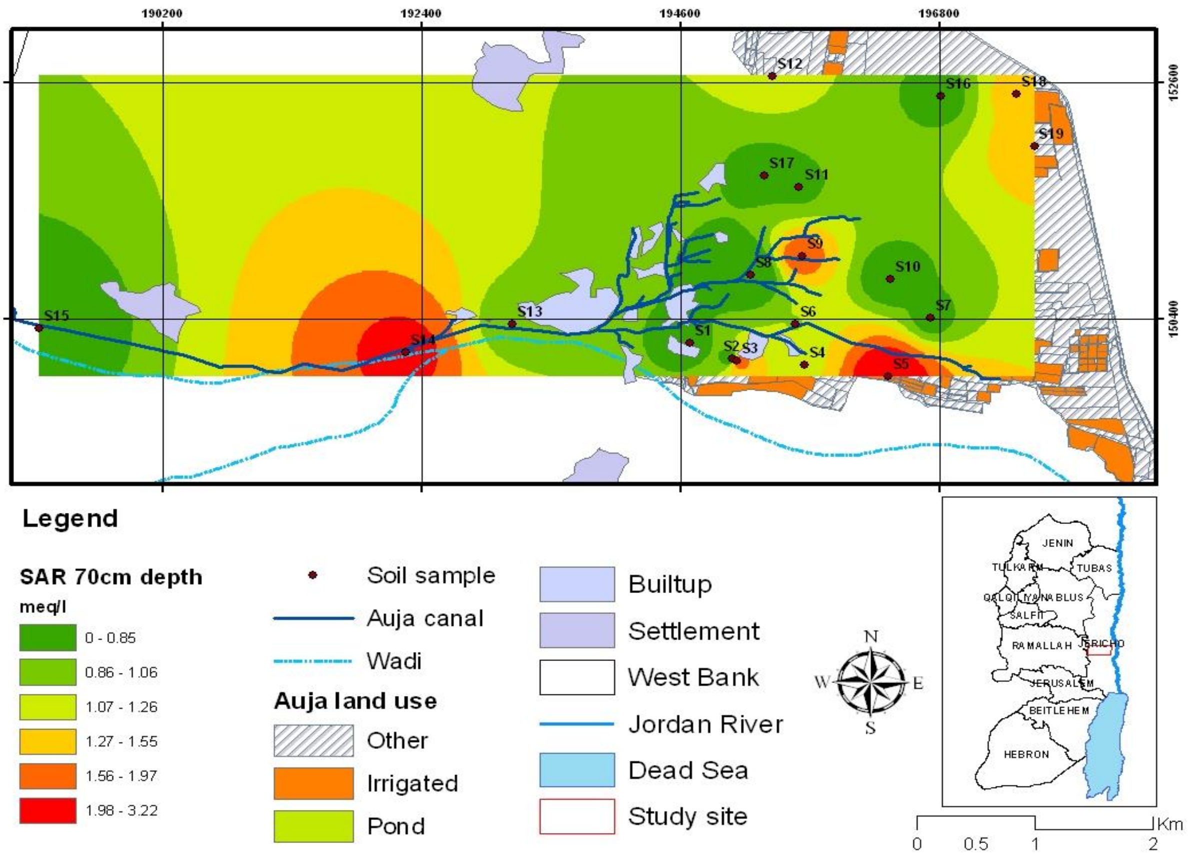

Figure10.37: SAR Value of (50-70 cm) depth at the CSA.

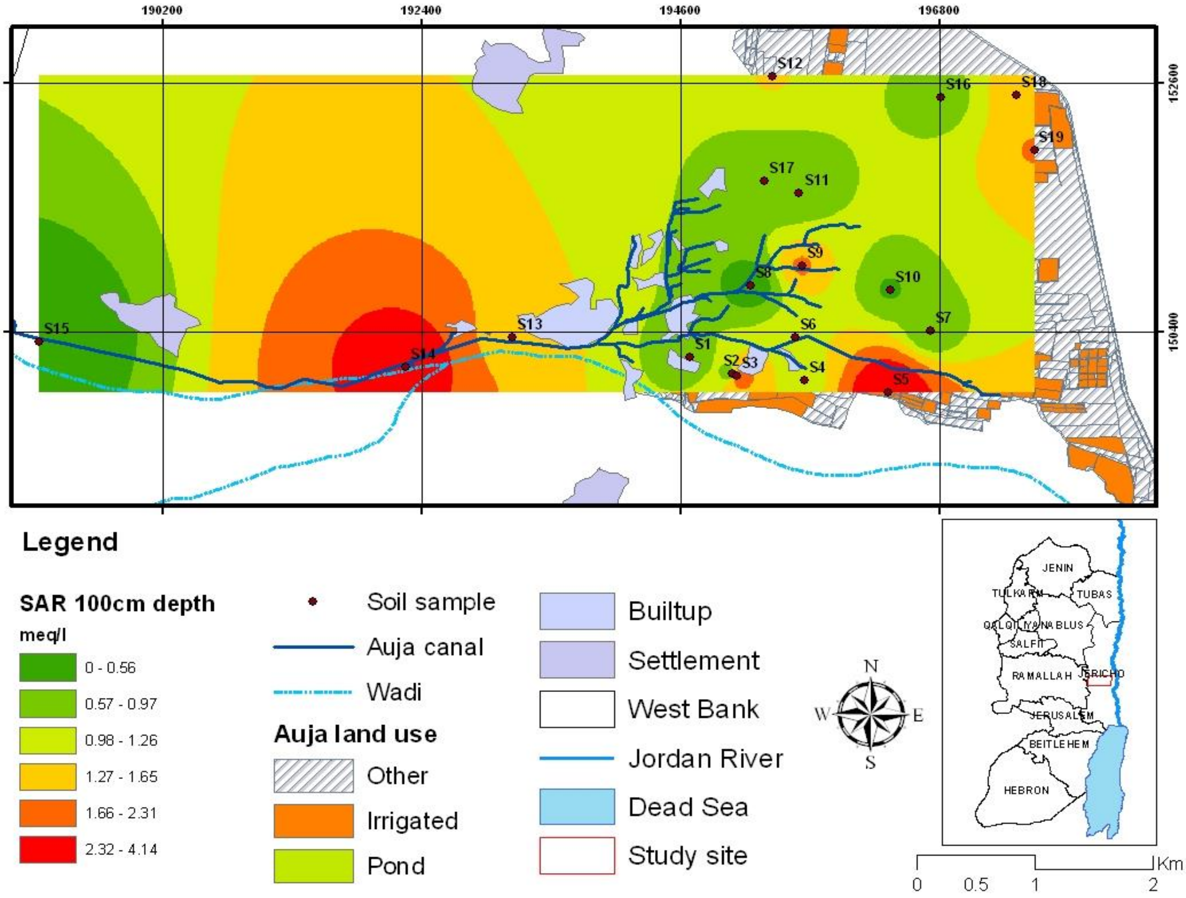

Figure10.38: SAR Value of (70-100 cm) depth at the CSA.

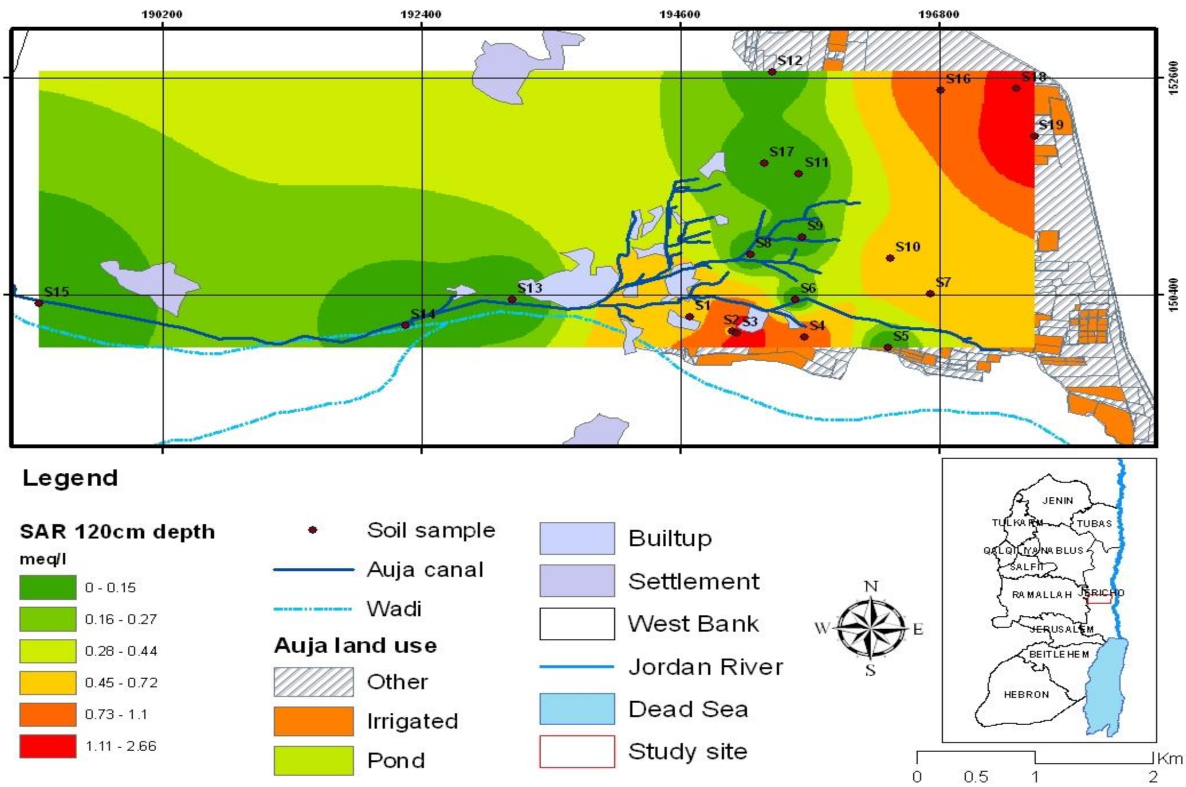

Figure10.39: SAR Value of (100-120 cm) depth at the CSA.

Appendix 10.5

Palestinian Standards of treated waste water quality for irrigation used:

Treated waste water in Palestinian territories was classified into four main grades,(**PS no.743.2003**),they are argument as

(1) Grade A (High Quality) , with maximum BOD 20mglL and 30 mg/L TSS, and larger than 200 F.C/100 ml

(2) Grade (B), the second grade ,it was good quality, it contains 20 mg/L BOD and 30mg/L TSS,F.C (Fecal Coliform) should not to exceed 1000 F.C/100 ml, it is differ from Grade A by concentration of F.C

(3) Grade (C), Medium quality, 40mg/L maximum BOD , and 50 mg/L TSS,F.C should not to exceed 1000 F.C/100 ml.

(4) Grade (D), Low quality,60mg/L max. BOD and 90 mg/L TSS,F.C is 1000F.C/100ml as max. Value.

Article Number 7, in table 10.26, (Palestinian Standards of treated effluent), mentioned the irrigation specification and condition circumstances during usage of this treated waste water. This conditions are mandatory and compulsory, it was classified by positive degrees, this degrees are from 1 to 4, Where each degree reflects the type of action taken in the process of irrigation, the measure description, called the barrier, and therefore, each barrier is expressed in one positive degree or two positive degrees, according to its kind, these kinds of barriers are as following:

(1) The Barriers with one positive Degree are

(a) A distance of not less than 25 cm above the ground between the drippers and the crop, or the fruits of fruit trees

(b) A distance of not less than 50 cm between the level of irrigation sprinklers and fruit, or fruit

(c) Plastic ground cover between water treatment and fruit, or fruit

(d) Sterilization treated waste water.

(e) Sand filter, or a long detention, or 10% treated water.

(f) Crops such as almonds and walnuts (shells are not eaten)

(2) The Barriers with two positive Degrees are

(a) Underground drip irrigation

(b)A distance of not less than 50 cm above the ground between the drippers and the crop, or the fruit of fruit trees.

Table 10.26 Part 1: Kinds of Crops and barriers conditioned during irrigation , PS no.743.2003.

Shells not eaten	**Subsurface Irrigation**	**Plastic ground cover**	**The distance from the**	**Sterilization of treated water**	**Sand filter**	**Crop**	**Grade A**	**Grad B**	**Grade C**	**Grade D**
Weight of each of Barriers with crop							Number of Barriers			
						Top of Form Parks, Play grounds Bottom of Form	0	Prohibited	Prohibited	Prohibited
						Aquifer Recharge (infiltration)	0	0	0	Prohibited
						Discharge into the sea at a distance of 500 meters	0	0	0	Prohibited
						Top of Form Seed production crops Bottom of Form	0	0	0	0
	++	+	++	+	+	Artichoke	0	3	3	4
+	++	+	++	+	+	Corn-to-eat	0	4	3	4
						Green feed	0	3	0	Prohibited
						Dry seeds	0	0	0	0
+			++	+	+	Drip irrigated citrus	0	0	2	3
+			+	+	+	Without drip irrigated citrus	0	2	3	4
+	++		++	+	+	Crops such as almonds (shells are not eaten Pomegranate, pistachios, and pine fruitful,..etc,)	0	3	2	3
	++		++	+	+	Deciduous trees (apples, pears, peaches, Peach, apricot, jujube, cherry)	0	2	2	3
+	++	+	+	+	+	Tropical crops (mango, Avocado, Kaka)	0	2	2	3

Table 10.26 Part 2: Kinds of Crops and barriers conditioned during irrigation , PS no.743.2003.

	++		++	+	+	Grapes with trellis above	0	2	2	3
	++	+	+	+	+	Grapes without trellis above	0	2	2	3
+	++	+	++	+	+	Cacti plants Spoar	0	2	2	3
	++	+	+++	+	+	Palm tree (Mussels)	0	2	2	3
	++	+	++	+	+	Olive trees	0	2	2	3
+	++	+	+	+	+	Flowers plant	0	2	2	3
						Forest trees, not for recreation	0	0	0	0
						Industrial crops and grains	0	0	0	0

In Table10.27,Different kinds of irrigated crops with maximum allowable concentrations of many pollutants in treated waste water were mentioned, the table includes physical properties and chemical concentrations of many elements and compounds, and also microbial concentrations.

Table10.27 Part 1: Microbial and chemical concentrations in treated effluent, PS no.743.2003.

Property (mg/L)	Discharge into the sea at distance of 500 meters	Infiltration in Aquifer	Irrigation (Dry feed)	Irrigation of green feed	Irrigation of parks, play grounds, Public gardens	Irrigation Of industrial Crops and grains	Top of Form Irrigation of forest trees and forests	Top of Form Irrigation of fruit trees
COD	200	150	200	150	150	200	200	150
DO	>1	>1	>0.5	>0.5	>0.5	>0.5	>0.5	>0.5
TDS		1500	1500	1500	1200	1500	1500	1500
PH	(6-9)	(6-9)	(6-9)	(6-9)	(6-9)	(6-9)	(6-9)	(6-9)
Fat Oil and Grease	10	0	5	5	5	5	5	5
Phenol	1	0.002	0.002	0.002	0.002	0.002	0.002	0.002
MBAS	25	5	15	15	15	15	15	15
NO3	25	15	50	50	50	50	50	50
NH4	5	10			50			
O.K.N	10	10	50	50	50	50	50	50
Cl		600	500	500	350	500	500	400
SO4	1000	1000	500	500	500	500	500	500
Na		230	200	200	200	200	200	200
Mg		150	60	60	60	60	60	60
Ca		400	400	400	400	400	400	400
SAR		9	9	9	10	9	9	9
PO4	5	15	30	30	30	30	30	30
AL	5	1	5	5	5	5	5	5
Ar	0.05	0.05	0.1	0.1	0.1	0.1	0.1	0.1
Cu	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Fe	2	2	5	5	5	5	5	5
Mn	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Ni	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0.2
Pb	0.1	0.1	1	1	0.1	1	1	1
Se	0.02	0.02	0.02	0.02	0.02	0.02	0.02	0.02

Table10.27 Part 1: Microbial and chemical concentrations in treated effluent, PS no.743.2003.

Cd	0.01	0.01	0.01	0.01	0.01	0.01	0.01	0.01
Zn	5	5	2	2	2	2	2	2
CN	0.1	0.1	0.1	0.05	0.05	0.05	0.05	0.05
Cr	0.5	0.5	0.001	0.1	0.1	0.1	0.1	0.1
Hg	0.001	0.001	0.05	0.001	0.001	0.001	0.001	0.001
Co	1	0.05	0.7	0.05	0.05	0.05	0.05	0.05
B	2	1	Non	0.7	0.7	0.7	0.7	0.7
Pathogens	Non	Non		Non	Non	Non	Non	Non
Protozoa	Non	Non						
Amoeba $Gardia		<1	<1	<1	<1	<1	<1	<1

Otherwise, actually there are no Palestinian specifications or standards to control the process of the agricultural irrigation water. Palestinians are using the FAO Standards. (MOA, Jan. 2012)

Appendix 10.6 Size and Percentage criteria for the twelve major USDA textural classes.

ACTIVITY 6 - Size and Percentage Criteria for the Twelve Major USDA Textural Classes

Major Textural Classes

The 12 major soil textural classes are based on the relative percentage of sand, silt, and clay in the soil sample or material. The definitive criteria for each of these classes are:

SAND

A. Must contain 85 percent of more of sand, and
B. The percentage of silt plus 1.5 times the percentage of clay shall not exceed 15.

LOAMY SAND

A. Upper limit
 1. Must contain 85 to 90 percent of sand, and
 2. The percentage of silt plus 1.5 times the percentage of clay is not less than 15.
B. Lower limit
 1. Must contain 70 to 85 percent sand, and
 2. The percentage of silt plus twice the percentage of clay does not exceed 30.

SANDY LOAM

A. Contains 20 percent or less clay, and
B. The percentage of silt plus twice the percentage of clay exceeds 30 and has 52 percent or more sand, or
C. Contains less than 7 percent clay, less than 50 percent silt, and between 43 and 52 percent sand.

LOAM

Contains 7 to 27 percent clay, 28 to 50 percent silt, and less than 52 percent sand.

SILT LOAM

A. Contains 50 percent or more silt and 12 to 27 percent clay, or
B. Contains 50 to 80 percent silt and less than 12 percent clay

SILT

Contains 80 percent or more silt and less than 12 percent clay.

SANDY CLAY LOAM

Contains 20 to 35 percent clay, less than 28 percent silt, and 45 percent or more sand.

CLAY LOAM

Contains 27 to 40 percent clay and 20 to 45 percent sand.

SILTY CLAY LOAM

Contains 27 to 40 percent or more clay and less than 20 percent or more sand.

SANDY CLAY

Contains 35 percent or more clay and 45 percent or more sand.

SILTY CLAY

Contains 40 percent or more clay and 40 percent or more silt.

CLAY

Contains 40 percent or more clay, less than 45 percent sand, and less than 40 percent silt.

Short Academic Curriculum Vitae (2019)

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Education:

10/2011-Present day: PhD Program Geoscience
George –August-University Göttingen
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9/2005-May 2010: M.SC. Water and Environmental Science
Al Quads University-Palestine
Title of Thesis: Estimation the physical properties of the Plio-Pleistocene aquifer in Auja area Jericho district, Master theses.

9/1985-5/1991: B.SC. Chemical Engineering
Jordan University of Science &Technology (J.U.S.T), Jordan.
Graduation Project: Industrial &Sewage Water filtration by adding filter aids (Vacuum Rotary Drum-Fine fiber filter design, by using fuller earth (Silicates derivatives), unit operation treatment sewage plant treatment.

9/1984-6/1984: General Secondary School
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Publications:

Auja Area, Poster, Marie A., Shawahna A., Al khayat S., 2010,ISM-AR2007, Abu Dhabi.

Estimating the Physical Properties of the Plio-Pleistocene Aquifer in Development,Article,2016,Polytechnic,Hebron,ICEEP, 2016.

Manage Aquifer Recharge in the lower Jordan valley Article, Climate change Conference in Palestine,International Engineering Association, 2017.Water strategies