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Identification of the most suitable areas for the implementation of groundwater artificial recharge (AR) in the LJV

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INTRODUCTION

The artificial recharge to ground water aims at augmentation of ground water reservoir by modifying the natural movement of surface water utilizing suitable civil construction techniques. Artificial recharge techniques normally address to following issues -

(i) To enhance the sustainable yield in areas where over-development has depleted the aquifer.

(ii) Conservation and storage of excess surface water for future requirements, since these requirements often changes within a season or a period.

(iii) To improve the quality of existing ground water through dilution.

(iv) To remove bacteriological and other impurities from sewage and waste water so that water is suitable for re-use.

The basic purpose of artificial recharge of ground water is to restore supplies from aquifers depleted due to excessive ground water development. The sub-surface reservoirs are very attractive and technically feasible alternatives for storing surplus monsoon run off. The sub-surface reservoirs can store substantial quantity of water. Besides suitable lithological condition, other considerations for creating sub-surface storages are favourable geological structures and physiographic units, whose dimensions and shape will allow retention of substantial volume of water in porous and permeable formations. The sub-surface reservoirs, located in suitable hydrogeological situations, are environment friendly and economically viable proposition. The basic requirements for recharging the ground water reservoir are:

a) Availability of non-committed surplus monsoon run off in space and time.

b) Identification of suitable hydrogeological environment and sites for creating subsurface reservoir through cost effective artificial recharge techniques.

The artificial recharge techniques inter relate land integrate the source water to ground water reservoir. Two effects are generated by artificial recharge in ground water reservoir namely - (a) Rise in water level and (b) increment in the total volume of the ground water reservoir.

1. Bani Zaid Wastewater - treatment plant

1.1. Introduction

Water is an essential factor of life and development in arid and semi-arid countries. This is because of rapid population growth, urbanization, and the shortage in water resources accessibility, which is due to the unstable political situation in the region. The Palestinian total per capita water consumption is 139 m^3 while in Israelie is 411m^3. Most domestic sewage is disposed of into unlined cesspits or septic tanks, or directly discharged to the environment without treatment. Sanitation facilities in Palestine are still few in number and most of them are unsustainable. The old existing treatment plants are overloaded and the construction of newly one is severely complicated due to the political situation. In rural areas water and money are not available to provide centralized conventional waste water services. So, the application of decentralized management approach within the water cycle and the use of low cost sewerage are more suited to the socio- cultural and environmental circumstances.

The west bank is predominantly agricultural area with limited water resources**,** and because the agriculture is an important and vital sector in the west bank where it accounts for 25% of the national income and consume approximately 70%of water resources. However the scarcity and fragility of the water resources have constrained the agriculture development in the west bank. About 31 million cubic meters (MCM) of wastewater is collected per year in the West Bank . 75% is discharged directly into the environment without any treatment due to the lack of functional treatment plants. Waste water from 55% of households not connected to a sewer system is discharged to cesspits and percolates into the ground. This put threats on the environment in constructing wastewater treatment plants and motivates considering the reuse of treated wastewater in agriculture.

1.2. Wastewater treatment and reuse in the West Bank

There are five wastewater treatment plants in the West Bank located in Jenin, Tulkarem, Ramallah, Al-Bireh, and Hebron. The treatment plant in Jenin is not functioning. The same applies on that in Hebron. Except for the recently-constructed treatment plant in Al-Bireh, the remainder treatment plants efficiencies are low. The percentage of population in the West Bank connected to sewer networks is 34.6% while almost all the villages do not have sewerage systems and thus use cesspits. This indeed limits the options for the reuse of wastewater. The total collected wastewater in theWest Bank for the year 2006 is approximately 12 million cubic meters (mcm). However, these estimates would increase based on an increase in the per capita water consumption and the sewerage coverage. Wastewater reuse is currently practiced at small scale levels as the case of the experimental wastewater treatment plant of Birzeit University where restricted irrigation is practiced (Chow et al., 2005). Standards for wastewater effluent quality for various uses have been established by the Palestinian Ministry of the Environment, but they are often not enforced (PSI, 2004). The regulations establish four classes of water from Class A (high quality) to Class D (low quality). Multiple barriers (zero to four) are needed depending on the class of effluent water and type of reuse. Many kinds of barriers are listed, including disinfection, distance between irrigation water and crops, and inedible peel/shell on the crop (citrus, nuts, etc.) (Fetter, 1994).

1.3.Bani-Zaid Wastewater Treatment System.

Bani Zaid Waste Water Treatment Plant is located in the town of Western Bani Zaid (Beit Reema and Deir Ghassaneh) 27 km North –West from Ramallah city and is some 10 km far from Salfit/Nablus district. According to the Palestinian Central Bureau of Statistics the total population was estimated at approximately (5500), in 1997. Municipality of Western Bani Zaid recorded that the total number of present population is estimated to be 6000 (4100 at Beit Reema and 1900 at Deir Ghassaneh). The sewer main lines (2.5 km length serving 20% of the population) and a wastewater treatment plant was implemented in 2003, with capacity of treatment that can serve 40% of the area. The treatment plant is based on low-cost technology consisting if anaerobic treatment phase (upflow anaerobic sludge blanket) followed by constructed wetlands and effluent storage tank that can allow gravitational flowing of water to the downhill agricultural area. The idea is to expand the sewer lines to include some other parts of the village (to reach a coverage of 40% of the houses) and to connect the houses on the existing and new proposed lines and thus operating the treatment plant. A demonstration for treated effluent reuse in a site adjacent to the treatment plant could help in raising farmer's awareness with regard to this marginal new source of water. This area provides an appropriate location for the future proposed full- scale wastewater treatment and reuse system. Though the villages are among the first to have tap water, all sewage from the municipal area is currently untreated. The agricultural production methods and the crop production are typical of the West Bank and the high productivity of the local farmers is well known. The existing treatment facilities are located at an elevation of around 390m downwind of the two villages, 600 meters to the nearest house, and three kilometer far away from the nearest water resource. This is for Providing alternative resources other than fresh water for irrigation purposes and Protecting the environment through replacing the cesspits by sewage networks and also protecting the aquifers from pollution.

The wastewater collection system and the treatment plant serve the two villages of Beit Reema and Deir Ghassaneh (municipality of western Bany Zaid) within the boundaries and limits of the municipality. The treatment plant covers the most densely populated areas in Beit Reema and Deir Ghassaneh. The lengths of the existing sewer pipes are around 4500 meters, where 100 houses could be connected to the system. So far one school and 30 households have been connected to the system. The number of beneficiaries connected to the system is estimated to be 200 persons in addition to one school.

1.4 Reuse of treated wastewater through different irrigation methods

The reuse of treated wastewater through sprinkler irrigation are generally more efficient in terms of wastewater reuse since greater uniformity of application can be achieved. However, these overhead irrigation methods may be contaminate ground crops, fruit trees and farm workers. In addition to pathogens, which may contain in aerosolized effluent may be also transported by wind and caused health risk to nearby residents. Sprinkler systems are more affected by water quality than surface and 23 irrigation systems, primarily as result of the clogging of orifices in sprinkler heads and potential leaf burns and phytotoxicity when water is saline and contains excessive toxic elements and sediment accumulation in pipes, valves and distribution systems (FAO, 1992).Wastewater treatment has generally been found to produce an effluent whether suitable or not for distribution through modern irrigation system due to the efficiency and the degree of the treatment, which affects directly the quality of the produced water. The proposed combination of wastewater treatments may lead to suitable quality of reclaimed wastewater provided when the effluent is not too saline. The intermittent sand filter (ISF) or micro strainers will act as further precautionary measures to assure the safe reuse of the treated wastewater in irrigation (Cobham and Johnson, 1988).

The reuse of treated wastewater through drip irrigation: Drip irrigation system considered more safer than any other irrigation system in relation to the contamination risk, however irrigation network components clogging and the consequent none uniformity distribution of the irrigation water which affect significantly the efficiency of the reuse of the reclaimed wastewater in case of inefficient BOD, TSS, N and P removal (Oscar, et al. 1996). Drip irrigation can be also used when soil surface is covered with plastic sheets or straw as mulch, these practices always useful in the arid and semi arid environment prevailing in our region. In these cases, the use of effluent will be more efficient, produce higher crop yield, and reduce salinity as well as provides the greatest degree of health protection for farm workers and consumers of the products (Hellil, 1987).

However, trickle and drip irrigation systems require a high quality of effluent to prevent clogging of the emitters through which water is slowly released into the soil. A successful combination of wastewater treatment units that provides none restrictive on use of effluent in trickle and drip irrigation systems will assure the advantages of the Increase crop growth and yield achieved by optimizing the water nutrients and the High irrigation efficiency as well as the Minimal contact between farm workers and effluent. It can be stated that the ultimate consequence of improving the quality of the effluent produced by the wastewater treatments to suite the irrigation systems will decrease the risk and treats of both soil and plant pollutions. The less TSS, TDS, BOD, N, P, Salt and heavy metals the less soil pollution resulted in due the reuse. Consequently, less soil degradation due to the long-term reuse, plant pollution is also an ultimate result of soil pollution in both short and long term reuse (FAO, 1998). Moreover, the advantages of combining CEPT, UASB and ISF and the precautions requirements to produce suitable quality effluent for safe reuse through proper irrigation system to produce safe agriculture crops and to maintain safe environment at the farm level for both farm workers and consumers could be realized.

1.5 The sewerage network:

Sewage lines were extended in Western Bani Zaid with the length of 4500 meters, this included the lines in both villages to the entrance of the UASB septic tank.

1.6 Problem Justifications:

Water resources are insufficient to meet rising demands due to dramatic increases in population and water consumption and a lack of natural resource planning and inadequate wastewater management in rural areas. The goal of the wastewater improvements is to provide affordable wastewater treatment service to all homes and businesses in the town of Bani Zaid, while minimizing capital investment and operating costs. Most of the houses in that area are lacking of proper wastewater collection and disposal systems. The existing wastewater disposal system in Western Bany Zaid consists mainly of cesspits; some of these cesspits are regularly discharged into the agricultural areas, others allow water to "leach" into the surrounding ground.

The wastewater treatment plant in Bani Zaid is a potential site for Artificial Recharge Test in the western Catchments.

2. WADI AL QILT / Jericho District

2.1 Introduction

Jericho water resources are part of the Eastern Aquifer Basin. Groundwater sources in Jericho district are mainly divided between wells and springs. Regarding surface water, several wadi systems in the area have incised steeply into the mountains west of Jericho. The main system in the area is Wadi Al Qilt system that has a catchment area stretching out from the Jordan River in the east towards Jerusalem and Ramallah in the west. This system is fed from three main springs Ein Fara, Ein Al Fawwar and Ein Al Qilt (Rofe and Rafety, 1965). The system of Wadi Al Qilt springs is the main water source for the **J**ericho **W**ater **T**reatment **P**lant (JWTP). Water is transported from springs to the treatment facility through a 13 km long open transportation canal. This treatment plant is operating only part of the year due to the problems associated with microbiological and other contamination of groundwater. These water quality problems appear regularly during the rainy season. The drainage basin of Wadi Al Qilt was important as there is a lack of data concerning the impact of a WWTP effluent on the self-purification capacity of the season receiving water body (Wadi Al Qilt). Secondly, evidence of pollution from many springs in this basin as well as the sewage flow along the wadi is a potential health hazard for the local inhabitants and users downstream. Achieving sustainable development in Jericho district communities and protection of both public health and water resources for water quality assessment of Wadi Al Qilt. This is to report on the sources and types of potential pollutants and presents water quality data for Wadi Al Qilt drainage basin.

2.2 General features of Wadi Al Qilt drainage basin

Wadi Al Qilt is located in the eastern part of the West Bank. The study area includes part of Ramallah, Al Bireh and Jerusalem (comprises the western part of the study area) and part of Jericho (comprises the eastern part). It represents the major drainage system from the mountain aquifer area between Jerusalem and Ramallah downwards east to the Jordan River with an area of 174.7 km^2. This catchment is a sub-basin of the Jordan River-Dead Sea basin. The drainage basin of Wadi Al Qilt is located in the well-known Dead Sea Rift Valley which has elevations in the range of 200 to 250 m.b.s.l. in the east and the west of the area, in the vicinity of Ramallah and Jerusalem the mountains rise up to elevations over 800 m.a.s.l.

2.2.1 Major wadis

There are two main tributaries in Al Qilt drainage basin in which the result of their discharge combined with the flow from the five springs form the main stream named as Wadi Al Qilt. The first tributary is called Wadi Sweanit which originates from the eastern part of Al Bireh before it combines with the second tributary named as Wadi Fara. Mostly, a WWTP effluent is considered the main source of Wadi Sweanit discharge (Figure 1).

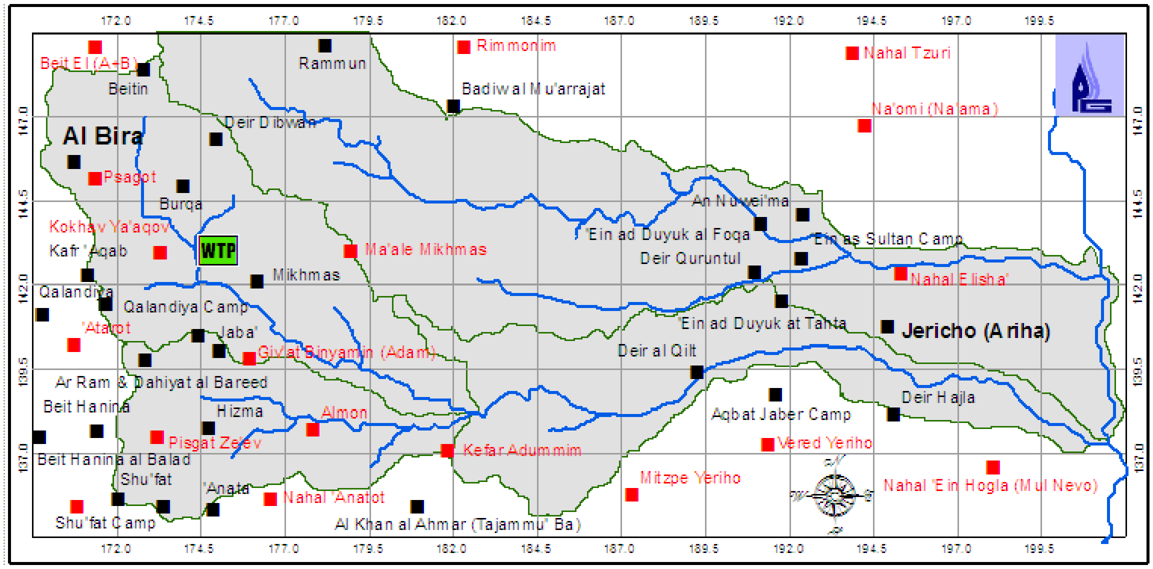

Figure 1: two wadis in Al Qilt Catchment

2.2.2 Spring System

The spring system in Wadi Al Qilt are the followings:

- Ein Fara: a seasonal spring which emerges upstream at an elevation of 325 m.a.s.l. through the floor of the wadi.
- Ein Al Fawwar: a seasonal spring which emerges 4 km downstream of Ein Fara at an elevation of 75 m.a.s.l.
- Ein Al Qilt: It emerges 4.5 km downstream of Ein Al Fawwar at an elevation of 10 m.a.s.l. Its flow has little variation from winter to summer.
- Ein Es Sultan: located to the east of Wadi Al Qilt in the Jericho city. It is related to the Upper Cenomanian – Turonian aquifer.

The average discharge of monthly basis of those springs are shown in Table 1, while 1.27 mcm /y are utilized for domestic purposes.

Table 1: List of average monthly springs discharge for Qalt and adjacent areas

Code	Name	Monthly Spring Discharges (m^3)											
		Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
AS/022B	Al Ru'yan	29740	28412	25773	28528	25446	29887	27586	26104	23055	24990	27531	26351
AS/022A	Al Jummaizah	19019	18046	18781	17436	15183	14618	13266	11361	11528	13394	14857	17298
AS/022	Fara (1999)	39328	34387	36619	67901	58800	60980	50845	46555	41078	38998	36257	40769
AS/021	Al Fawwar (1995)	100178	86791	101219	400539	518813	475579	295768	309741	192427	126086	112630	107346
AS/020	Al Qilt (1999)	138270	127152	127233	209337	179644	188495	173113	170257	156679	152567	143005	138528
AC/061	Al Sultan (1999)	840008	793840	812870	975536	879590	945776	921948	919940	866166	866340	863556	847606
AC/060B	Al Shusah (1999)	42278	41412	38145	49737	46988	52911	48528	43891	40419	40286	40971	38378
AC/060A	Al Nwai'mah (1999)	202054	180779	186321	238666	209486	237846	225860	226043	214917	231806	211191	201594
AC/060	Al Dyuk (1999)	300303	286721	274589	351407	321872	344067	355606	362629	308993	297453	298003	298336

2.3. Population

The Palestinian population was estimated to be 96,935 inhabitants; 38, 192 in Al Bireh, 10,103 in Kafr Oqb, 8,796 in Qalandia camp, 2,238 in Borqa, 3,143 in Jaba, 1,823 in Mikhmas, 24,838 in Al Ram, 5,916 in Hizma, 9,337 in Anata and 1, 345 in Beit Hania (PCBS, 2005). Six israelian settlements are located in the study area and the population is estimated to be 29, 250 inhabitants distributed in the following settlements; 1,333 in Pasagot, 3,922 in Kokhav Yakov, 998 in Maale Mikhmas, 740 in Almon, 1,988 in Giva Binyamin (Adam) and 20,269 in Neveh Yakov, whereas the population of Bisagot Zeev, Allon and Pasgat Omer is still unknown (PCBS, 2005). The catchment is intensively populated in the western part of it, which is considered the recharge area of the aquifer beneath.

2.4 Wadi Al Qilt Drainage System

The main system in the area is Wadi Al Qilt catchmnet area, which is stretching out from the Jordan River in the east towards Jerusalem and Ramallah in the West. This system is fed from three main springs Ein Fara, Ein Al Fawwar and Ein Al Qilt. This system is the main water source for the Jericho water treatment plant, which water is transported from springs to the treatment facility through a 13 km long open transportation canal. This plant is located in Aqbat Jaber refugee camp and serving about 5000 inhabitants. Wadi Al Qilt drainage basin is bounded by Nueima drainage basin from north, Soreq and Al Dilb drainage basins from west, Mukallak and Marar drainge basins from south and Jordan

River from the east. It is located in the Jordan Rift Valley which has elevations in the range of 200m – 250 m.b.s.l. in the east and it rises to 800 m a.s.l. in the west. The catchment is divided into six watersheds; Al Bireh, Dyuk & Sultan, Al Qilt & Fawwar, Al Farah and Jordan watersheds (Fig. 2).

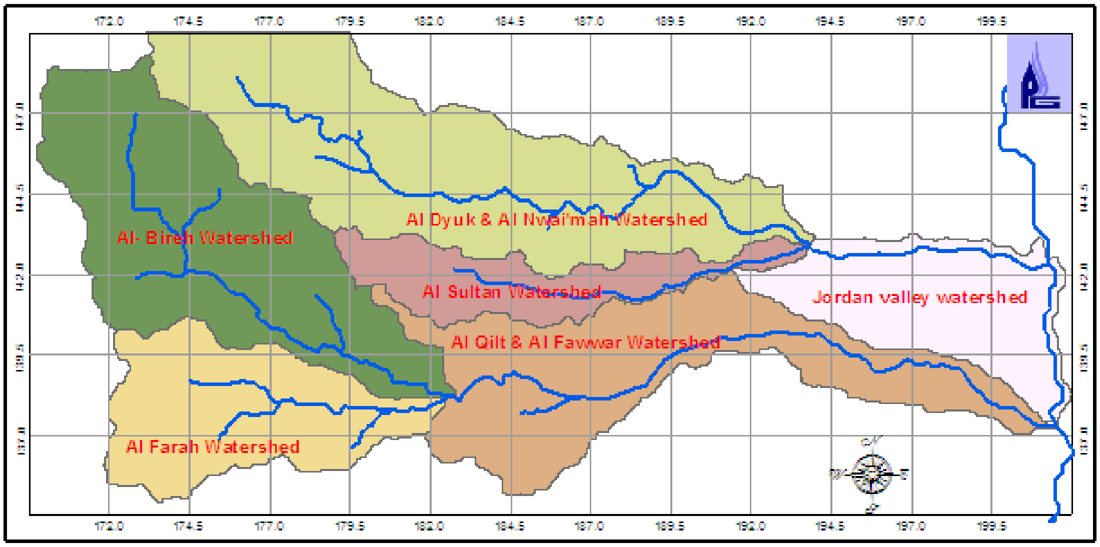

Fig.2: Watershed system of the case study

In the Wadi Qilt area the estimated quantities of the storm water at the outlet of each sub watershed is illustrated in Table 2.The maximum monthly amounts of Runoff is seen in Dec. and Jan. months.

Table 2: Estimated quantities of storm water at the outlet of each sub-watershed

Watershed Name	Area (km^2)	Average Runoff (m3)											
		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Al- Bireh	61.75	1287830	704143	403661	32333	399	0	0	0	0	18458	172699	403661
Al Dyuk & Al Nwai'mah	75.75	877790	479946	275136	22038	272	0	0	0	0	12581	117712	275136
Al Sultan	20.75	162448	88821	50918	4079	50	0	0	0	0	2328	21784	50918
Jordan valley	27.50	9342	5108	2928	235	3	0	0	0	0	134	1253	2928
Al Qilt & Al Fawwar	53.50	158195	86496	49585	3972	49	0	0	0	0	2267	21214	49585
Al Farah	35.25	531639	290683	166638	13348	165	0	0	0	0	7620	71293	166638

2.5 Hydrogeology of Wadi Al Qilt

The catchment area of Al Qilt drainage basin is about 174.7 km^2 with an average annual rainfall over the main recharge area of about 80 km^2 is 500 mm (Fig.3). Nari formation reduces the effective recharge to about 42.5 km^2 (Rofe & Raffety, 1963), which represents about 21.5×10^6 m^3 potentially centering the groundwater system. The average annual discharge from Ein Fara, Ein Al Fawwar, Ein Al Qilt and Ein es Sultan is about 9×10^6 m^3. The springs of Ein Fara, Ein Al Fawwar and Ein Al Quilt emerge form Turonian formations . The aquifer beneath is of Cenomanian-Turonian age, the strata dipping eastwards at $10^o – 15^o$.

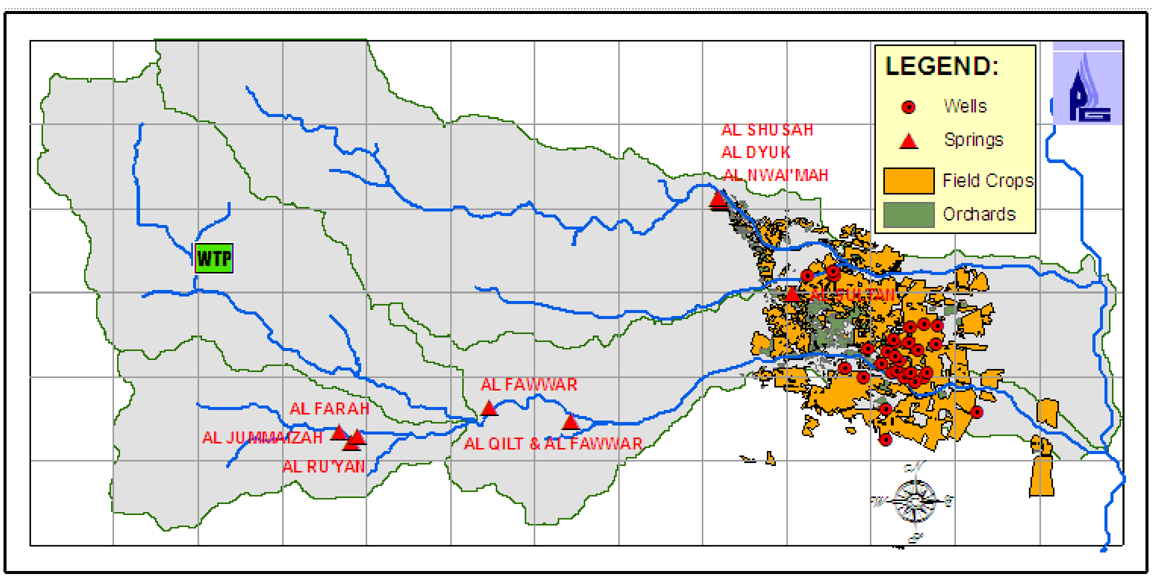

Fig.3: Water resources and land use map of the case study

The geology of the Wadi Al Qilt area is illustrated in Fig. 4 and controlled the recharge mechanism of the formations. Groundwater flow follows the direction of dip, but the water table is at shallower angle, breading the surface were the springs emerge. The Cenomanian formation consists mainly of micritic dolomite which is very hard and virtually nonporous, the void space in the rock occupying only 2.6%. This gives the dolomite an intrinsic permeability of 0.13 millidarcys, i.e., a flow rate of 39.66 mm/yr. however, solution weathering increases the secondary porosity and consequently actual flow increases as joints and bedding planes are widened. The Turonian is a highly fossiliferrous limestone, limestone, with fossil fragments making up 30% of the volume of the rock. The matrix is recrystallized calcite. Primary porosity, therefore, is greater than in the cenomanian, being 8-15% of the rock. The intrinsic permeability is also larger than in the cenomanian, being 135 millidarcys. Groundwater flow in the Turonian is up to 1.5 km/yr, indicating the effect of karstic solution weathering in the system (Abed Rabbo, 1999).

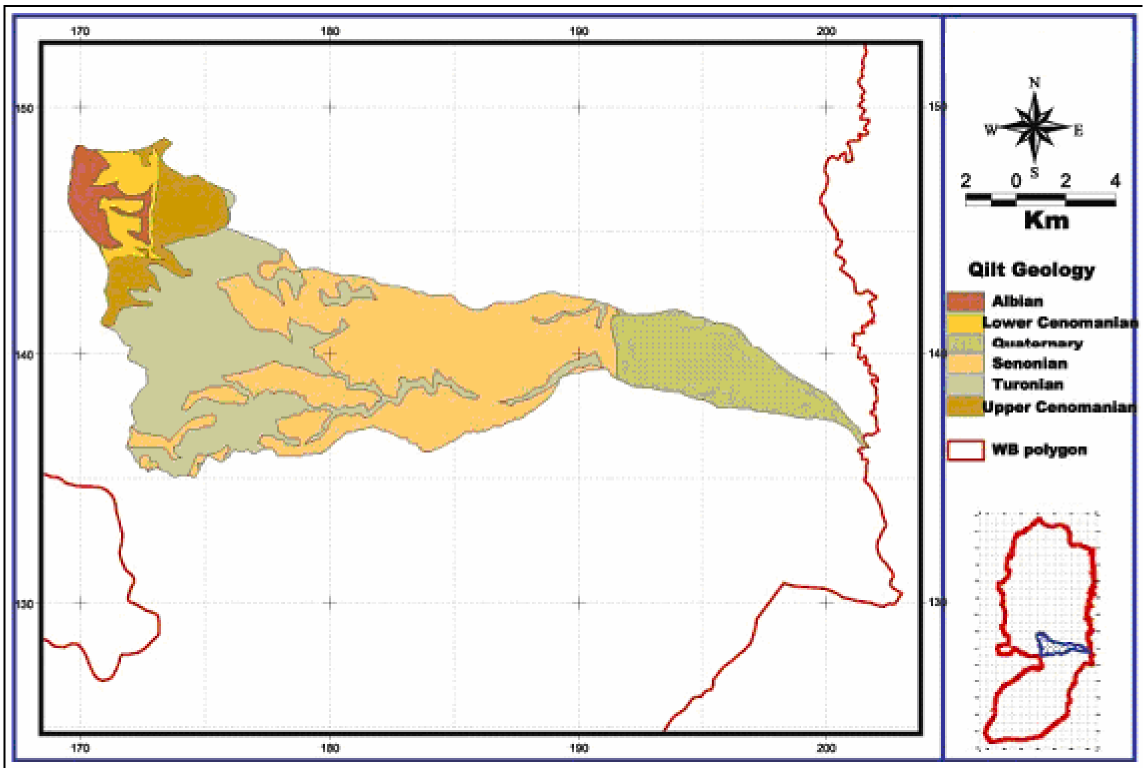

Fig. 4: Geological map of Wadi Al Qilt (Source: PWA, 2005)

There is little variation in the discharge of Ein Al Qilt through out the year. It may therefore be assumed that the water is under pressure and comes from a massive reservoir. The average flow of Ein Fara is 15L/sec or 1500m^3 / day. The combined average discharge rate of Ein Al Fawwar and Ein Al Qilt springs are 100 L/sec. Ein al Fawwar has a large discharge following a heavy rainfall season (Blake and Goldschmidt, 1947). The siphonic spring at Ein Al Fawwar filled the cistern which fed the channel bringing water to Al Qilt and the overflow discharges into the wadi to combine with the flow coming from Wadi Fara and Wadi Sweanit. The pulses from the spring are at 20-minute cycles and used to raise the level of the cistern by as much as 2 m. the karstic nature of the spring is responsible for these pulses. A v-shape cavern is filled before siphonic discharge expels the water in these regular pulses (Abed Rabbo, 1999). The water table under the Jerusalem Hills is at an elevation of about 450 m.a.s.l. The water table passes form the Cenomanian under the Jerusalem Hills into the Turonian as a result of the Fara Monocline (Abed Rabbo, 1999).   Twenty Nine groundwater wells are located within the catchment, with a total abstraction of 6 mcm/year. The August and September months have the maximum abstraction of around 0.6 mcm each. A geological cross section indicates that an interaction between different strata according to the fractured phenomena caused by the formation of the Jordan Rift Valley (Fig. 5).

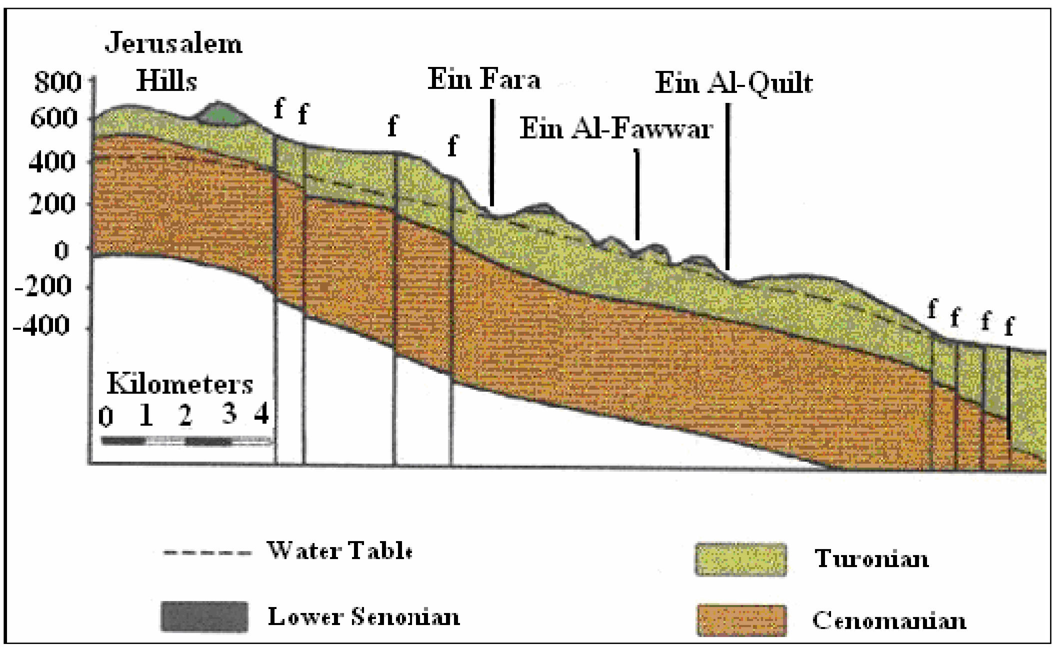

Fig. 5: Geological sketch section along the line of springs in Al Qilt system.

2.6 Sources of pollution

In general, the possible sources of pollution from both, Israeli settlements and Palestinian build up areas in Al Qilt catchment area and can be classified as follows: untreated municipal wastewater, seepage from unsanitary dump sites, untreated industrial waste discharging into municipal sewer system or directly into valleys, seepage and runoff of agrochemicals such as fertilizers and nonbiodegradable pesticides, and stone crushing.In point source pollution, pollutants are discharged from a concentrated and recognizable source while in non-point source pollution, water flows on the surface dissolving and washing away pollutants and soil sediments along its path and finally discharging into receiving waters. In urban environments, the most important point source is the discharge from the wastewater collection system; and where a treatment plant exists, this would be treated effluent from the plant.

2.7 Hydrochemicl Variability along Wadi Al Qilt

Many studies were conducted in Qalt Catchments and many sampling campaigns were carried out along the wadi. As part of the chemical parameters nitrate and chloride are considered as pollution indicators in the evaluation of any water resource. These parameters are generally used for the determination of the level of pollution, type of pollutants and its status. Nitrate is generally an indication of contamination from major nitrogen sources such as a sewage disposal system, animal manure, or nitrogen fertilizers; whereas chloride may originate from dump sites and wastewater containing salt deposits

High values of COD indicate water pollution, which is linked to sewage effluents discharged from urban areas, industry or agricultural practice. The input of anthropogenic contaminants (from point discharges mixing with urban and agricultural runoff) causes distinct, but variable, COD concentration peaks, responsible for increasing the concentrations in nutrients and organic carbon in the fresh surface waters of the flowing water. In general, total coliform (TC) and fecal coliform (FC) are used as indicators for pollution in water analysis. A general trend in the analysis was observed by decreasing the number of fecal coliform colonies going from a WWTP to the open transportation canal. The highest fecal coliform colonies were found for the small stream flowing from the stone crushing station.

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