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# **SMART – IWRM**

**Deliverable No. 504**

**Title: Delineation of protection  
zones in selected areas to  
demonstrate feasibility**

***Part 1: Western side of the Lower  
Jordan Rift Valley Wadi Al Qilt and  
Jericho sub basin***

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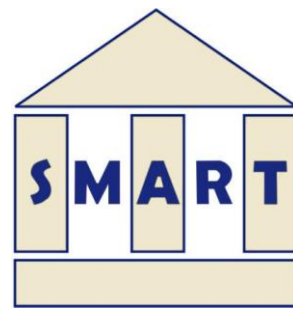
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# Integrated Water Resources Management in the Lower Jordan Rift Valley

## Sustainable Management of Available Water Resources with Innovative Technologies



### 1. INTRODUCTION

Water supply contains many activities in several topics. Among them is the protection on the water quality of the water resources.

Any human activities on the recharge area of a given water resource increase the contamination hazard and the vulnerability of the wells and springs that are feeding from this resources. Polluted surface water infiltrates gradually through the fractures, cracks and joints so the impact of human activities lasts for relatively long periods of time.

This issue becomes more problematic in semi arid and arid zones where the water resources are quite limited and the effect of dilution of the effluents by the rainfall or in the aquifer storage is minimal and rare.

The investigated area is located in a semi arid and arid zone. The urban sector is growing fast and produces effluent that is transferring to the wadis that flows to the Jordan Valley. Due to the large difference of more than 1000 meter between the mountain crest and the Jordan Valley, the wadis are cut steep sides wadis that cut into the permeable rocks in east-west direction (fig.1-1).

Some of the wadis in the area (Wadi Al Qilt, Wadi Auja) receive return flow from springs which discharge along their lengths. Today, the effluents of the main cities wastewater treatment plants are also discharged into these wadis and contaminates the environment and the groundwater.

Additional contaminated source are leakage from some sewage pipelines that transfer the effluences of the major cities located in the high mountain area (Jerusalem, Ramallah and similar) downstream to the Jordan Valley for agricultural purposes. Some of those pipelines are passing nearby some wells. The randomly contamination in Mizpe Jericho 2 is a classic example of occasional failures in the pipeline that pass close to the well. The leakage occur in place where the aquifer is overlain by 100 m' of bituminous chalk that is classified as an aquiclude. In spite of that, the effluence that leak from the pipeline, find some joints in the overlain chalk and reach to the water table that is a depth of about 320 m' from surface.

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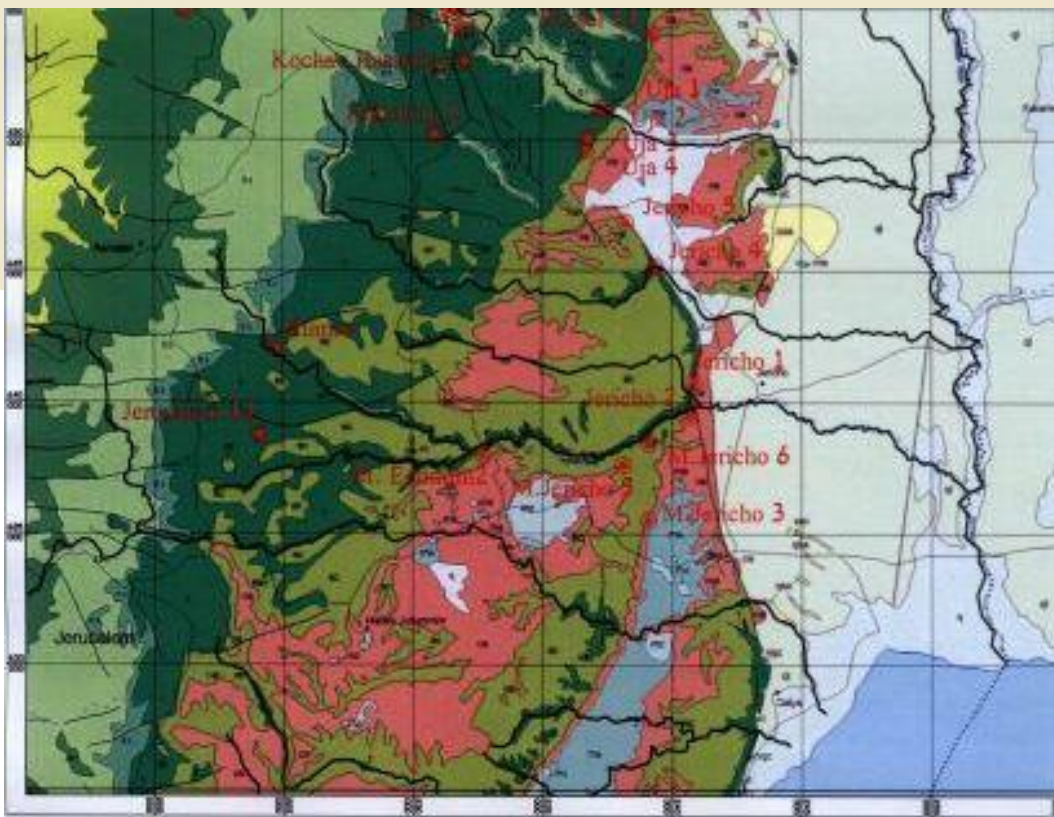


**Fig. 1-1:** Wadis that have evidences on effluent flow on a background of a geological map

### ***Scope of work and the study area***

Ground water in a natural drinking water resource often subjected to severe human impact. Strategies are required to preserve optimum groundwater quality, and so management of this vital natural resource has become worldwide priority. In the last years, the international scientific community has shown great interest on this topic and, thus, many works focused on environmental management for groundwater protection.

Ground water from karst aquifers is among the most important resources of drinking water supply of the worldwide population, in some country karst water contributes 50% to the total drinking water supply, in some regions it is the only available freshwater resource. At the same time karst aquifers are particularly vulnerable to contamination due to thin soil cover, flow concentration in the epikarst, contaminant can easily reach the groundwater, where they may transported rapidly in karst conduits over large distances.

The study area (Fig. 1-2) extends from Jerusalem and Ramallah in the west to the city of Jericho and the village of Auja in the east. The area can be subdivided into three different landscape units: the Higher Hills, the Eastern Slopes and the western Jordan Valley. The Higher Hills are forming the apex of the West Bank and stretch along an approximately N-S axis. Most of the population lives in this region. The Eastern slope region is the area where the slopes descend towards the Jordan Valley. Most of the water resources (springs and wells) that are the target of the current research are located in this region.

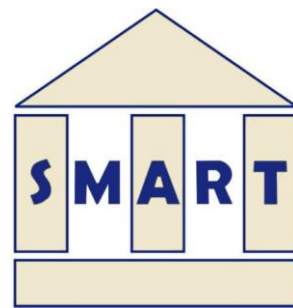
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The western Jordan Valley is the area eastward to the foothill and contains the city of Jericho, Auja village and few Israeli settlements. The major activity in this area is agriculture.

The major scope of the work is to create a protection zone map to the various water sources in the study area. This can be achieved by identifying the water resources and the contamination sources and studying on the hydrogeology of each water resources with a focus on their vulnerability to pollution. It is important to note that for a karstic spring due to its flow characteristic, it is quite difficult to define a precise protection zone area. Even though, we intend to create such a map within the limitations that will be discussed in the chapter that deal with the hydrogeology background.

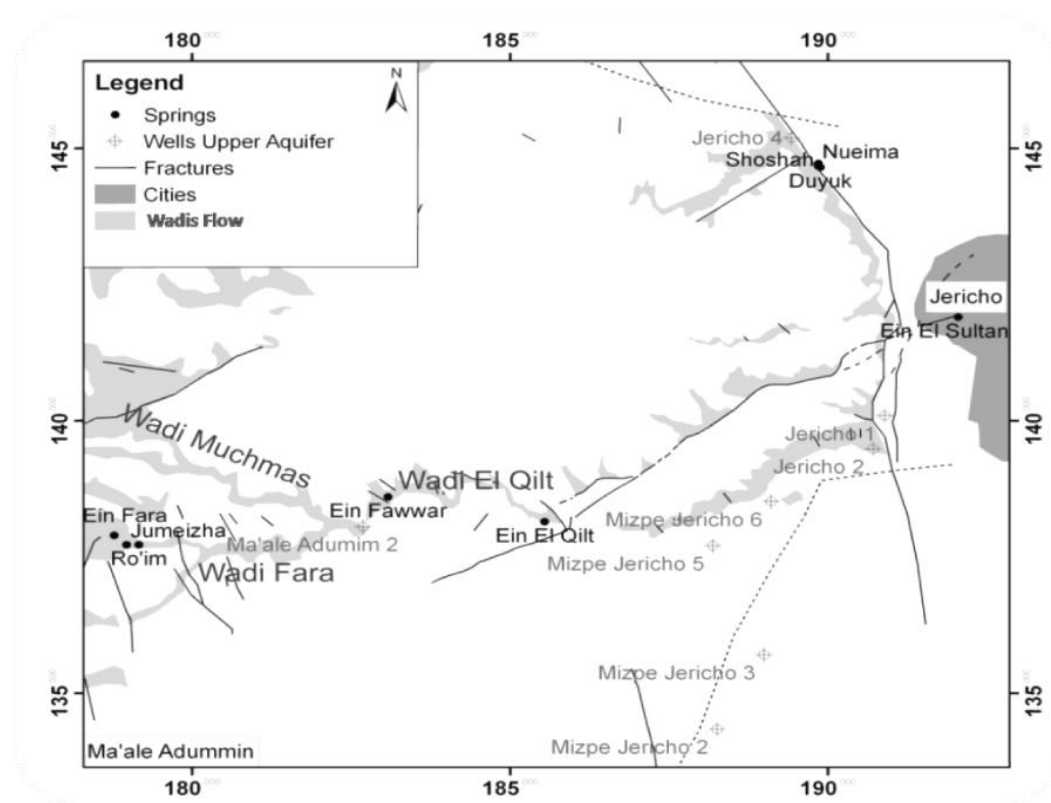


**Fig.1-2.:** Map showing the location of the springs and abstraction wells in the study area.

Additional contamination source are leakage from effluence pipelines that crossing the mountain ridges from west to east (Fig. 1-3). In some places those pipelines are lying on the aquifer outcrops and in other places on younger formation that overlain the aquifer.

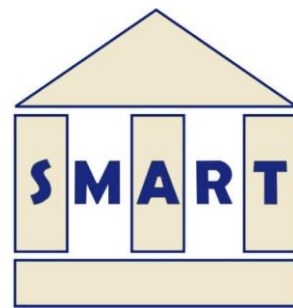
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In places where the pipeline is passing close to wells, leakage from those pipelines nearby wells is acting as a contaminated source that is **much more dangers** than a free flow in the wadis.

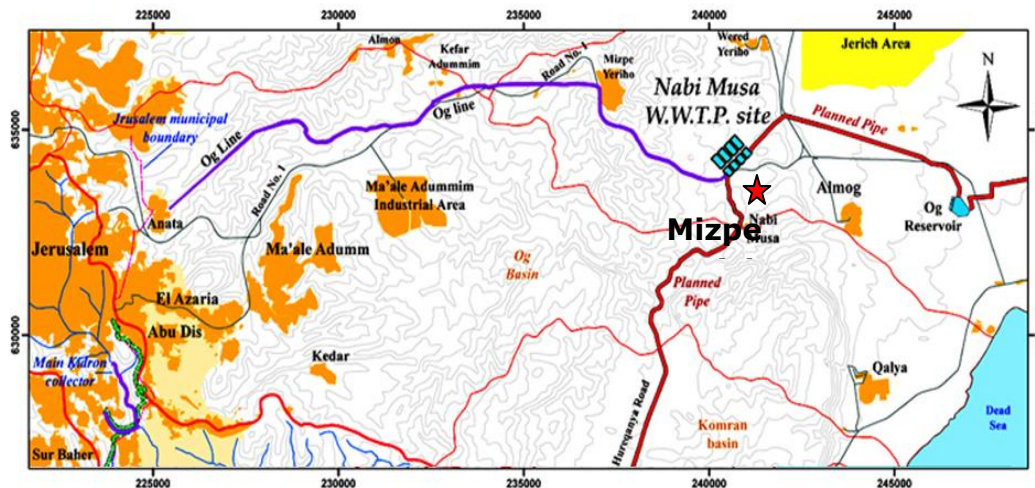


**Fig. 1-3:** Map showing the location of the Og wastewater pipeline.

The climate of the study area is semi-arid. Nevertheless, during high rain event in the mountain area surface-water flows downstream to the Jordan valley. The major wadis in the study area are (from north to south) Wadi Auja, Wadi Nwe'meh, Wadi Qilt, Wadi Og (Muqalek) and Wadi Kidron (Nar). The annual precipitation in the main recharge zone of the aquifer in the Jerusalem-Ramallah Mountains is about 550 - 600 mm /y and decreasing to about 150 – 200 mm /y downstream Jericho City (Fig.2-1). The precipitation in the area is characterized by the short duration and lower amount. Precipitation ranges from 5 to 100 mm in each storm event. According to the Jericho weather station, the mean annual precipitation in the study area is approximately 120- 180 mm/yr, of which approximately 60% falls in the three months of December, January and February. In general, the Jericho district has the lowest rain in the region and short rainy season ranging between 20-25 rainy days per year (ARIJ, 1997;PWA, 2003).

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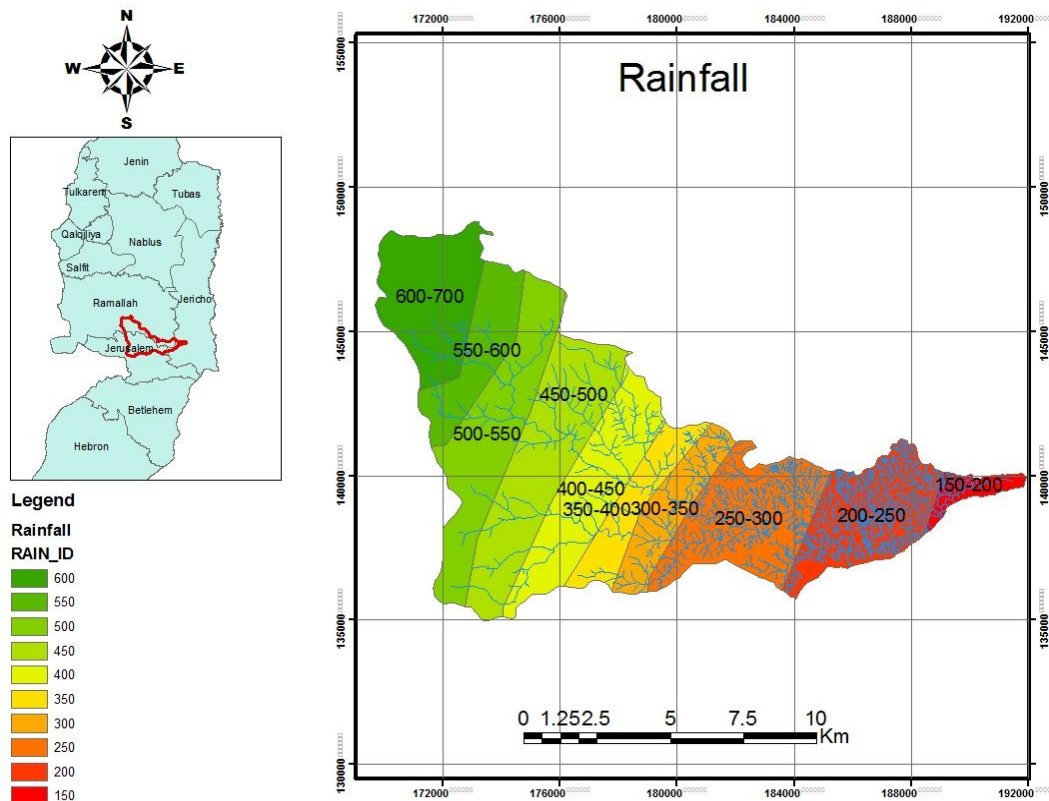


**Fig. 2-1.** Average annual precipitation rate in mm in the Study Area

The Judea Group layers constitute the regional aquifer in the study area. According to well data the total thickness of the Judea Group is about 800-850 m. The aquifer is composed of limestone and dolomite and is interbedded by marls and clays (Guttman, 1998, Hötzl et al. 2008).

In general the Judea Group aquifer is divided into two aquiferial systems. An upper system which outlets are those springs that emerge in Wadi Al-Qilt, Jericho and Wadi Auja (Fig. 2 -2) and a lower system which outlets are the Feshcha Springs in the Northwestern corner of the Dead Sea. The wells within the study area are exploiting water from the lower system.

According to the wells finding, the lower system is divided into two sub-aquifers. An Upper Sub-aquifer in the Upper Cenomanian formations and a Lower Sub-aquifer in the Albion Lower Cenomanian formations. The outlet of these sub-aquifers is common in the Feshcha Springs (Hötzl et. al 2008, Hasan, 2009).

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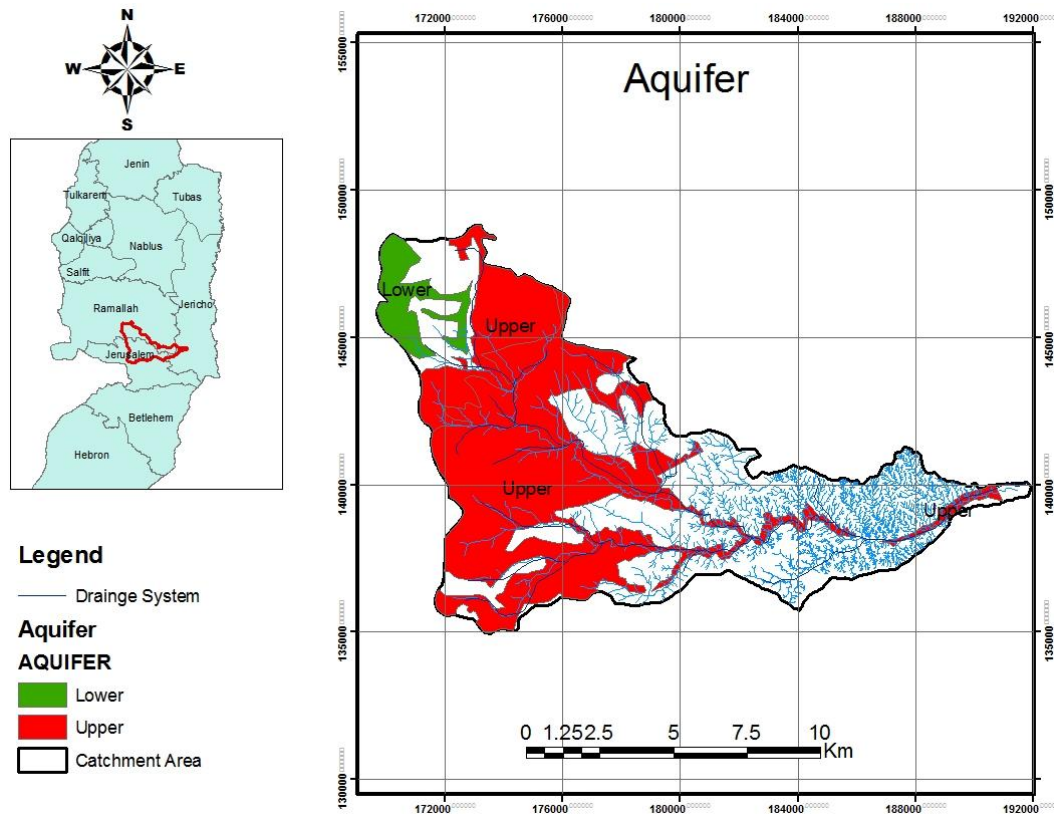
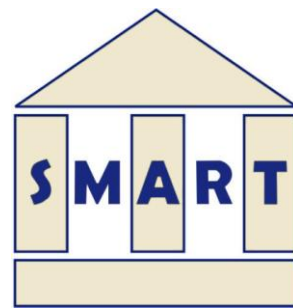


**Fig. 2-2:** The upper aquifer systems were the Qilt springs merge off.

The springs in Wadi Al-Qilt emerge from the limestone layers of the Tournian formations (Fig. 2-3). In order to distinguish between the upper sub-aquifer and the spring system, the spring system calls the Uppermost Aquifer.

The two lower sub-aquifers are regional wide and therefore call the "Regional aquifers", while the Uppermost Aquifer is concentrate to the basin of Wadi Al-Qilt.

There is a large difference in the water levels between the Uppermost Aquifer and the regional aquifers. It means that the two systems are separated in the study area. Near Ein Fawar a well was drilled during the 1980's. In this well (Ma'ale Adumin-2), the water level in the Lower Sub-aquifer is at elevation of about -290 m while the elevation of Ein Fawar is about +85 m. Similar situation was found near Jericho at Ein Duyuk spring area. The well Jericho 4 was drilled nearby the Ein Duyuk spring and is abstracting water from the Lower Sub-aquifer. His water level is around -308 m (Guttman, 1980), while the elevation of the spring is around -110 m. Same figure we can see in Auja spring. There is also a difference of about 200 m between the water level in the wells (that abstract

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from the Lower Sub-aquifer) and the spring that emerge from the Upper Cenomanian layers.

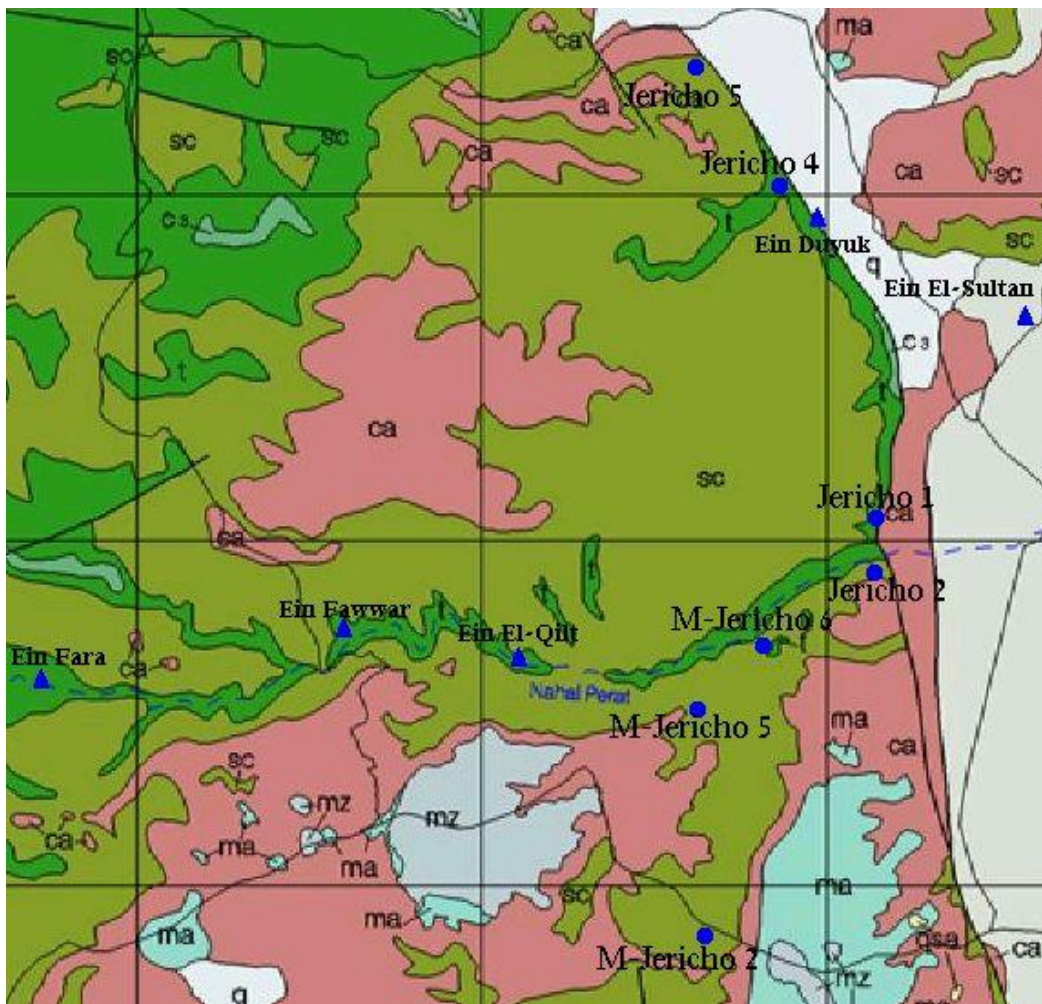


**Fig. 2-3:** The springs and the wells in the study area on a background of a geological map

The recharge of the aquifers in the study area is from rainfall that fall on the limestone-dolomite outcrops in the area between Jerusalem- Ramallah- Yabrud. Most of the outcrops belong to the Upper Cenomanian -Touronian formation. Some of the rainfall on the Touronian formation fed the springs in the Wadi Al-Qilt and Jericho. The rainfall on the Cenomanian formation and part of the Touronian formation fed the regional aquifers that flow eastward to the Feshcha Springs. Because the geohydrology data in the upstream of the study area is quite scarce, it is quite difficult to delineate in accurately the borders of the

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basins of each spring. Nevertheless, for the protection sensitivity map we will delineate the borders of the spring basins according to our knowledge.

The springs Ein Fawar, Ein Fara and Ein Qilt are locating at the upper part of Wadi Al-Qilt and are characterized by quick response to precipitation changes fig 2-4, (such as droughts or very rainy periods). Wadi Qilt is fed from three main springs; Ein Fara, Ein Fawwar, Ein El Qilt.

**1) Ein Fara** is seasonal spring, which emerges upstream at an elevation of 325 m above msl through the floor of the Wadi. Drain from the Quaternary Alluvium Aquifers.

**2) Ein Fawwar**, Considered to be seasonal spring placed 4 Km downstream at elevation of 80 m above msl, estimated average discharge 30,000-100,000 m<sup>3</sup>/d. same as Ein Fara drains from Quaternary Alluvium Aquifers.

**3) Ras Al-Qilt**, is the third spring in row, 2.5 Km downstream of Ein Fawwar. Almost at sea level, 10 m above msl). In general little variation in flow rate in different seasons. The catchments area extends to 176 Km<sup>2</sup> with annual rainfall of 550 mm, in charge for 20 % of groundwater recharges in the Upper Cenomanian Aquifer.

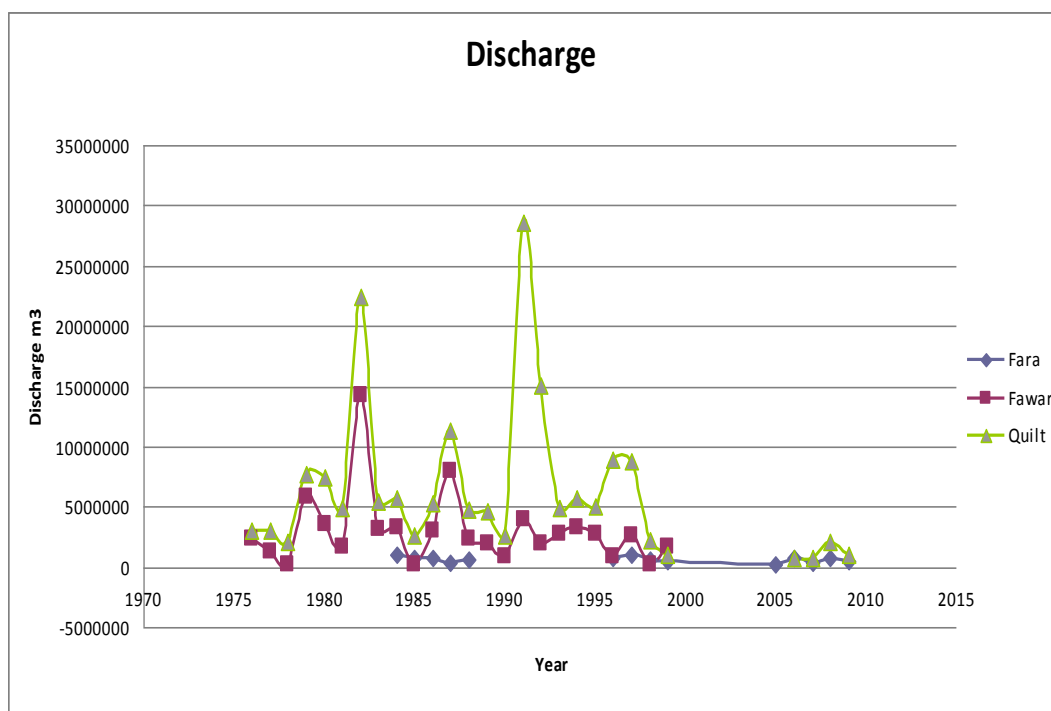
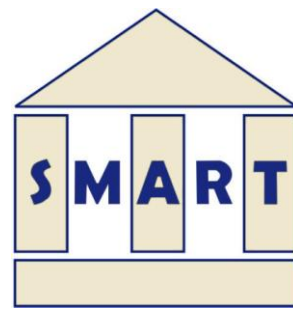


**Fig. 2-4:** Annual spring discharge since 1974. See the drought effect since 1999

Similar behavior was mentioned also in the Auja spring. Auja Spring is an example of a typical karstic spring (Guttman, 2004 and Schmit, 2010).



In these springs the maximum discharge appears shortly after the rainiest days and dies out towards the end of the winter season.

The Jericho springs behave differently. Their discharges are more stable and constant and do not show a high response to precipitation changes like the springs in the upper part of the basin and Auja spring. The reason for this is that the recharge area of these springs is located far away from the springs' outlets and their storage is much greater than the storage of the other springs. Simon (1975) calculated the decay period from the recession curve and got a period of about 41 months. Such long period act as "self-purification" process and the water that reach to the springs are quite clean from E-Coli and other bacteria (there can be randomly contamination from local septic tanks and others outside sources).

Wells located in Wadi Al-Qilt and Wadi Auja region abstracts water from the regional aquifers. Some of them abstract from the Lower Sub-basin (Jericho 4,5 Auja 2,3,4) and others abstract from the Upper Sub-aquifer (Mizpe Jericho 2,5,6 and Jericho 1,2) figure 2-3. As noted previously, the Feshcha springs are the common outlet of the two regional sub-aquifers.

The Marsaba Anticline is the most dominant tectonic element, which acts as the eastern border of the fresh water in the Regional Aquifer. The Marsaba structure is an asymmetric anticline declining in northeast direction. The Mizpe-Jericho wells that are located within this structure are pumping fresh water from the lower part of the Upper Sub-aquifer. The Lower Sub-aquifer contains brines (Hötzl et al. 2008). The Upper Sub-aquifer is unconfined in the Marsaba structure, but the depth to the water level is great (more than 300 m depth). The recharge area is in the high mountain and quite far from the wells.

The storage of the regional aquifer is much bigger than the storage of the springs.

The different in the storage and in the flow rate between the Uppermost Aquifer and the Regional Aquifers can be seen in the radioactive isotopic (Tritium and Carbon-14) that was measured by Kroitoru (1987). He found that the springs in Wadi Al-Qilt and Jericho had young water age and fast flow that indicates the existing of well developed (fossil) karstic system. In contrast, the regional and deep system is characterized by slow flow.

Salinity values in the natural replenishment zones ranged from 30 to 50 mg/l and remained constant throughout the years. The low salinity remained constant also in the springs and in Mizpe Jericho wells.

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Only in Jericho 1 and 2 that are located close to the Jericho fault escarpment, the salinity is high. The salinity source is brines that are located in deep formations within the Rift Valley (Guttman, 1998 Hötzl et. al 2008). Fig. 2-5 shows the salinity in some wells within the study area.

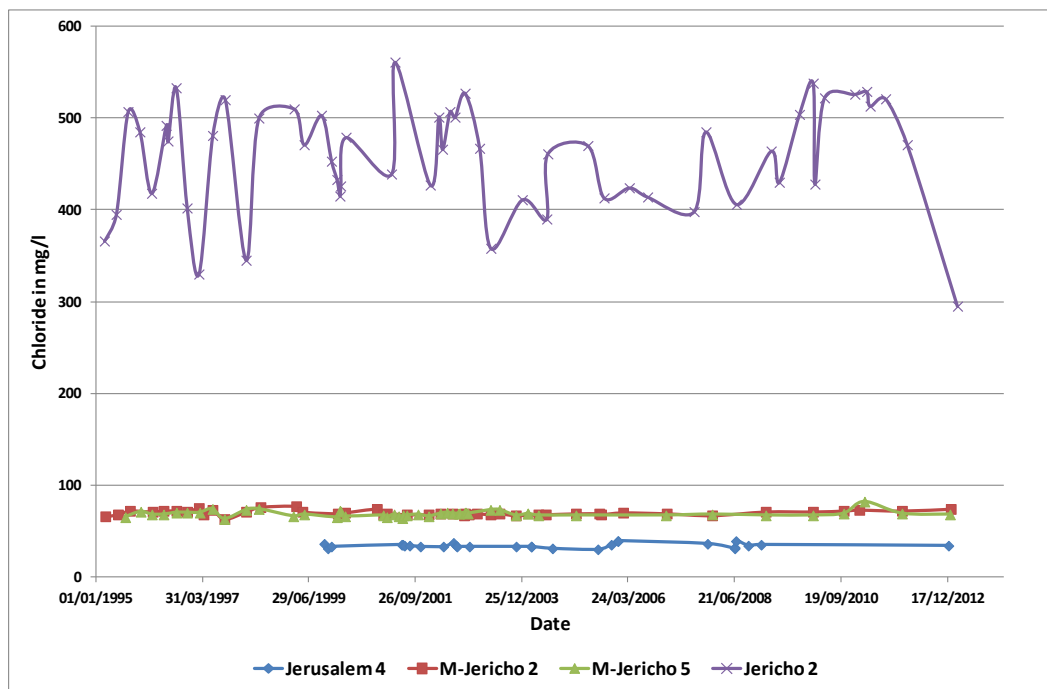


**Fig. 2-5:** The salinity in some wells in the study area.

## 2. RESULTS

In the last 30 years effluents from the Palestinian and Israelis cities and villages are flowing freely in few wadis downstream to the Jordan Valley (see Fig. 1-1). These wadis cut into the permeable rocks in east-west direction. Some of the effluent recharge into the groundwater and reach to the springs and to some wells. The effect of this leakage is reflected in the occurrence of Faecal Coli forms in the spring water (especially in the springs located in the upper part of Wadi Al-Qilt).

Toll et. al described in chapter 3.3.1 in the book "The water of the Jordan Valley" (Hötzl et. al 2008) the potential contaminated sources. They mentioned two major wastewater streams in the study area; in Wadi Mukhmas and in Wadi Muqalek. They also tried to quantify the volume per day of effluent from several sources. Their estimation to a yearly flow of effluent from the treatment plant of

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Al Bireh to Wadi Mukhmas was around 2.62 Mm<sup>3</sup>/yr, most of this quantity disappear in Swaneet / Michmass Wadi. It seems to be that it inters a karstic shaft. Additional untreated water from Northeast Jerusalem into Wadi Muqalek, located East of Jerusalem was estimated around 3.6 Mm<sup>3</sup>/yr. Additional sources are from small Palestinian villages and Israeli settlements that are located close and near the banks of the main wadis and their effluent is reaching also to those wadis (see Fig.3-1). The amount is unknown, but it is a source of contamination especially to the springs in the upper and lower parts of Wadi Al-Qilt. Additional unaccounted amount of effluent is coming from leakages of several pipelines that transfer the effluent from the cities in the mountain area to the agricultural area in the Jordan Valley. The reason (as mentioned in chapter 2) is that the springs in the upper part of the Wadi Al-Qilt are characterize by sharp fluctuations in their discharge in parallel to the intensity of the rainfall. While, the discharge in Jericho springs that are located in the lower part of Wadi Al-Qilt, are much more stable and less effected by changing in the rainfall pattern. The recharge area of Jericho springs are far from their outlet. Therefore, the springs in the Upper part of Wadi Al-Qilt (Ein Fawwar, Ein Fara and Ein Qilt) are much more vulnerable to pollution hazard than the Jericho springs.

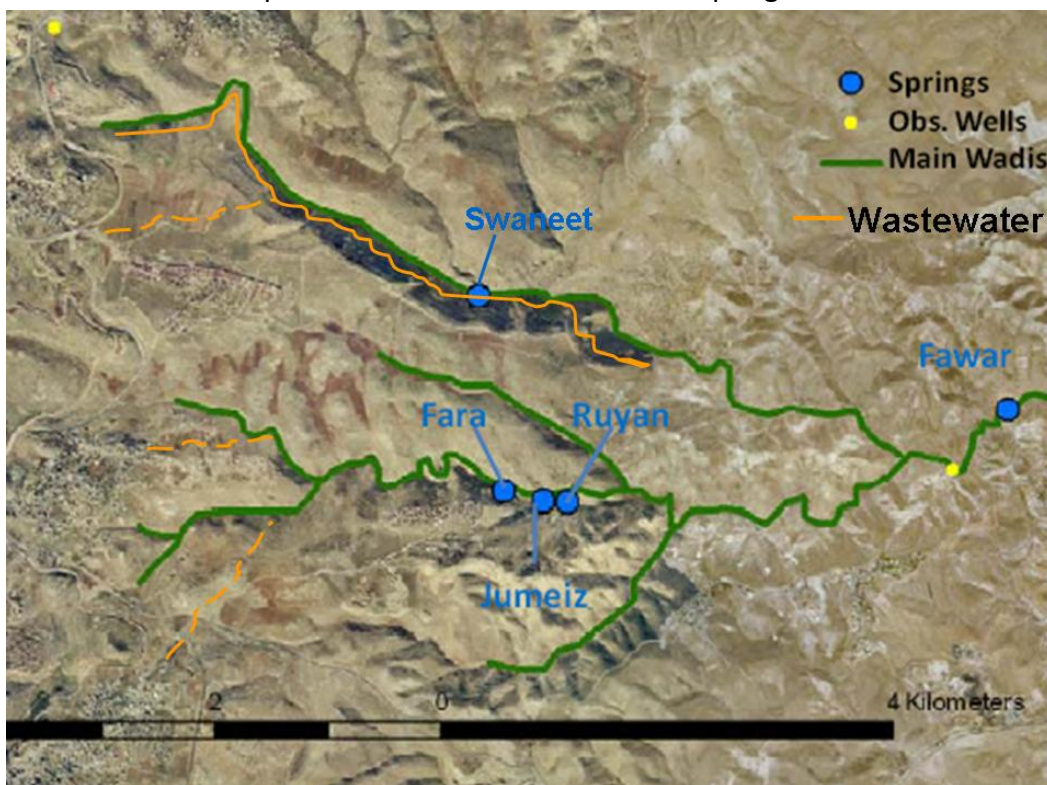


**Fig. 3–1:** Effluent flow in the Wadis in the study area

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In general, the wells that are pumping from the regional aquifers are less sensitive to contamination hazard than the springs. The nitrate content (Fig. 3-2) in the wells is low (around 14-18 mg/l) except in Mizpe Jericho 2. In this well the nitrate concentration is higher, around 40 mg/l. The source of contamination is probably a leakage from the sewage pipeline that passes close to the well. In the past the pipe line was passed very close to the well. Few years ago it was shifted to a distance of about 200 m from the well.

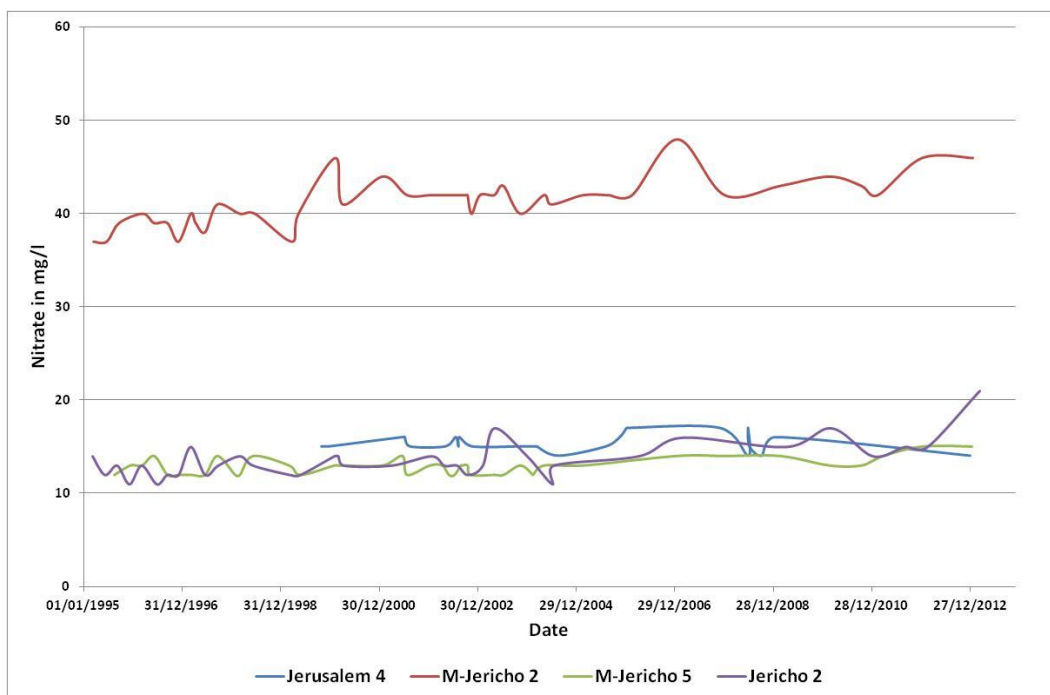


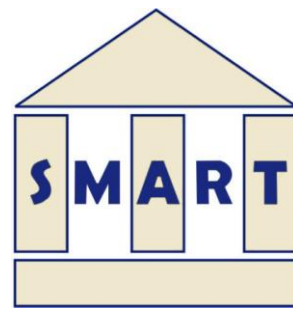
**Fig. 3-2:** The nitrate concentration in the wells

In 2004 the wells Mizpe Jericho 2 and 6 were closed due to rising of the Coliform and higher  $\text{Cl}^-$  demand. The existing of Coliforms pointing that the travel time is short and fast and the contamination sources is close to the wells. The assumption was that the source of contamination in Mizpe Jericho 2 is leakage from the sewage pipeline that is passing near the well. In Mizpe Jericho 6 the assumption was that the source of contamination is leakage of effluent that flow in the Wadi Al-Qilt into the groundwater. In order to identify the contamination sources, Mekorot Water Company invited from the GSI (Geological Survey of Israel) an isotopic study on the water resources in this region. The study (Schilman et. al 2004) included measurement of the  $\delta^{15}\text{N}$  and  $\delta^{18}\text{O}_{\text{NO}_3}$  in Mizpe Jericho, Jericho and Jerusalem wells.

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The samples from Mizpe Jericho 2 and 6 were collected immediately when the pumping was started and 10 min and 2 hours afterward. The results (see Fig. 3-3) show that the isotopic composition change with time from higher values that characterize sewage contamination to relative lower value that characterize unpolluted water. This shifting in the isotopic composition mean that during the pumping, fresh and clean water is entering to the well and the contamination plume is small and limited.

The most contaminated well is Mizpe Jericho 6 that is pumping from the Upper Sub-aquifer and located close to the southern bank of Wadi Al-Qilt. The Wadi Al-Qilt cut into the limestone layers of the Upper Sub-aquifer and effluent that flow in the wadi infiltrate through karst fissures from the wadi floor to the regional aquifer. Because Mizpe Jericho 6 is located close to the wadi bank, the travel time from the leakage point in the wadi to the well is short. The result is randomly contamination in the well. After short pumping the water become clean. Nevertheless, the Israeli Health Ministry close the well for drinking purposes because his sensitivity to recurring contaminations.

Mizpe Jericho 5 is located about 1 km south to Mizpe Jericho 6 and much far from the bank of the Wadi Al-Qilt. According to the Nitrate isotopes, the water in this well was clean. Because the well is located at a larger distance from the wadi (compare to Mizpe Jericho 6) the travel time is much longer that allow to self-purification process.

Between January 4<sup>th</sup> 2013 to January 10<sup>th</sup> 2013, huge amount of rainfall was measured in Jerusalem (fig. 3-4) and in the surrounding area. On January 7<sup>th</sup> 2013, Fecal Coliforms was found in Mizpe Jericho 2 and 5 (no Streptococcus was found and the Total Bacteria was quite low). The juxtaposition of intense rainfall and the contamination in those wells is suspected. A day later (January 8<sup>th</sup>) the water was clean from any contamination. To our understanding, Mizpe Jericho 2 was contaminated by effluent that was leak from the pipeline that passes close to the well. Report that was given to us by the maintenance team, said that not far from the well there is a section in the pipeline that known as a problematic point. We think that during this rain event, the pipeline was full with mixture of rain and effluent that leak into the ground and reach through joints in the bituminous chalk to the aquifer. The volume of the contamination is small and after short pumping it disappears.

The source of contamination that appears in Mizpe Jericho 5 during the rain event is coming from Wadi Al-Qilt. During the rain event there was a huge runoff in the Wadi.

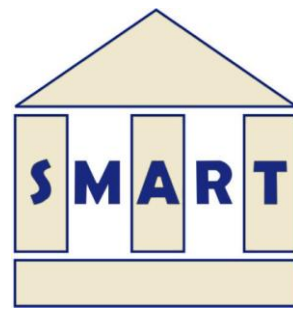
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The runoff that probably contains some percentage of effluent, leak through karst fissures from the wadi floor to the regional aquifer and was pumped by the well. The volume of the contamination is small and after short pumping it disappears.

The results from wells in the recharge area (Jerusalem 4 and Al Azaria 1) indicate that there is also leakage of sewage downward to the aquifer in the recharge area. Because the travel time from the surface to the water level is long, there is a self purification and therefore we do not find any traces of coli or other bacteria in these wells. The same figure can be seen in Jericho 2. This well is located far from the recharge area and the "leak sewage" is reaching to the well after it passes a process of self purification in the aquifer. According to the nitrate isotopes composition, the nitrate in the well is originated from leak sewage but the long travel time improves the water quality and the water is suitable for drinking purposes. Same pattern we found in other well fields that are located along the foothills of the mountain belt like in the Western Galilee and in the Western Judea Mountain.

The picture in the springs is different because of their small storage and the fast flow. Wolfer (1998) sampled the water in the Ein Fara and Ein Fawar springs. He found high concentration of E-coli and F-Coli. He links the high contamination to leakage of effluent in the wadis, especially in Wadi Muchmas. As mentioned in chapter 2, the decay curve of the Jericho springs is quite large, indicating that their recharge area is quite far from the spring outlet. Therefore, the vulnerability to contamination in Jericho springs is smaller than in the springs that are located at the upper part of Wadi Al-Qilt (Ein Fawar, Ein Fara and Ein Qilt).

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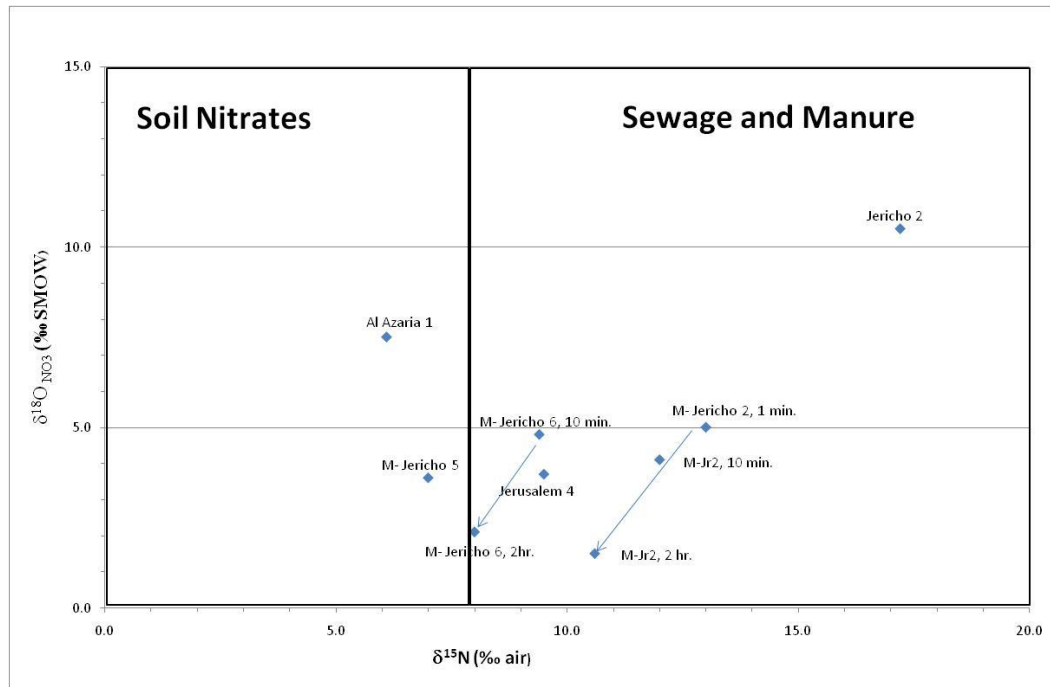


**Fig. 3-3:** The Isotope concentration of the groundwater in the regional aquifer (source GSI 2004)

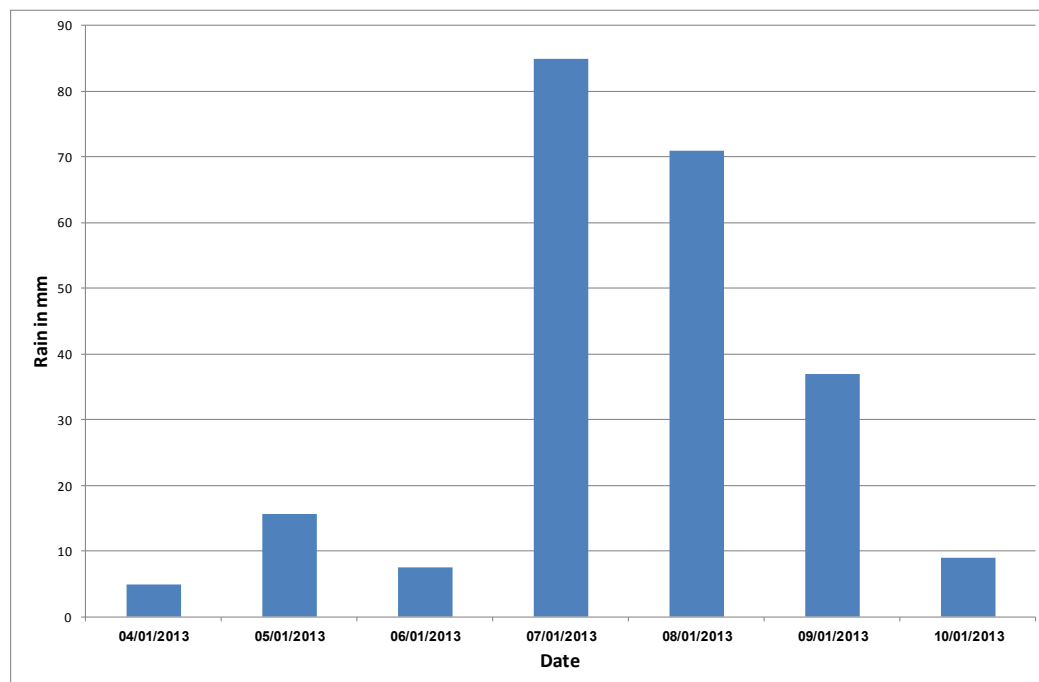
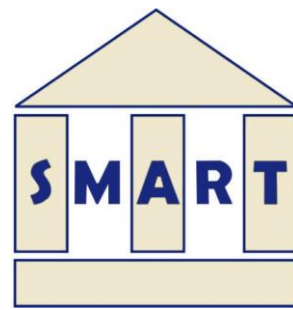


**Fig. 3-4:** Rainfall in Jerusalem during the first part of January 2013

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In general, the difference in the vulnerability between the Uppermost Aquifer (spring system) and the Regional Aquifer (well system), is a result of differences in their storage size and in their flow pattern. The spring system has a smaller storage and fast flow and is much more sensitive to contaminations hazard than the regional aquifer (see next chapter).

Nevertheless, some wells that penetrate and pump water from the regional aquifer are also sensitive to contamination as a result of technical reasons (leakage of nearby effluent pipeline) or hydrogeology reason (locating close to wadi bank that is cut into the aquifer formations).

### 3. DISCUSSION

In the Wadi Al-Qilt and Jericho sub- region there are two aquifer systems. Upper system which its outlets are the springs that emerge in some points along the wadi bank and a lower system that feed the regional aquifer. The deep wells in Jerusalem, Mizpe Jericho and Jericho are pumping from the lower system.

Despite the fact that some deep wells were polluted due to effluent intrusion but still the spring system is the most sensitive to contamination hazard , the risk of contamination of water resources depends on three elements:

- ✓ The **hazard** afforded by a potentially polluting activity.
- ✓ The **vulnerability** of groundwater to contamination.
- ✓ The potential **consequences** of a contamination event.

The springs in the upper part of Wadi al-Qilt (Ein Fawwar, Ein Fara and Ein Qilt) emerge from the limestone layers of the Tournian age. Wadi Al-Qilt and its tributaries cut into the limestone rocks that are part of the outcrops of the springs. The wadi receives effluents of the main cities wastewater treatment plants. This effluent reach through the karst fissures to the springs. Because of their small storage and the fast flow mechanism, the effluent reach to the spring very quickly and in short time that enable the bacteria to exist. The Jericho springs have a larger catchment area and the travel time is much greater. Leakage of effluent in the outcrops leaves enough time for "self purification". To our understanding, contamination events (if occur) in the Jericho Springs are mostly a result of local contamination sources nearby the springs outlets as indicated in the following figures.

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**Fig. 4-1:** Natural and anthropogenic pollution along the Wadi. a: represent the flooding periods, b: animals grazing all over the water stream, c: solid waste disposal and handling across the water stream, d: algal pluming across the water stream.

The wells are pumping from deeper system and are more protected from contamination. Only wells that are pumping from unconfined aquifer and also located close to the wadis bank, may receive small amount of effluent that flow in those wadis and penetrate through karst fissures into the deep aquifer system. The amount is quite small and after very short pumping the "contaminated lens" disappears. Wells that are located far from the wadi bank are not contaminated.

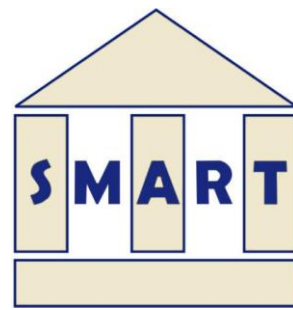
Same figure appear with wells that are pumping from unconfined aquifer with thick overlain chalk layers, but close to their fence pass a sewage pipe line. In case that the pipe line is leaking, the probability that some amount of effluent will reach to the aquifer is high. Again, the amount is small and short pumping will remove this contamination.

Moving the sewage pipe line few hundred meter away from the well fence and proper maintenance, will limited the probability to contaminate the well.

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It was found that wells that are close to wadi bank that its floor is cut into the aquifer formations are quite sensitive to contamination from effluents that flow in the wadi.

In most of the cases the contamination appears randomly. It is impossible to predict when and in which intensity the contamination will appear in the springs and in some wells.

The hydrogeology study and the understanding of the flow pattern at a given region can help us in ranking the water sources according to their vulnerability to contamination and also to map the vulnerable places that might contaminate the springs and/or the wells.

The list below summarized our ranking of the vulnerability of the water sources to contamination in the Wadi Al-Qilt and Jericho sub-region.

The springs in the Upper part of Wadi Al-Qilt (Ein Fawwar, Ein Fara and Ein Qilt).

1. Mizpe Jericho 6 that is located on the Wadi Al-Qilt bank.
2. Jericho springs.
3. Mizpe Jericho 5.
4. Mizpe Jericho 2 (and 7 if will be drilled).
5. Rest of the wells.

The list shows that the primary vulnerable places are inside the Wadi Al-Qilt and the secondary place is in some points along the sewage pipeline that is passing nearby the Jerusalem-Jericho road. Therefore, the vulnerability map will concentrate to the Wadi Al-Qilt and its tributaries cut into the limestone rocks (see Fig. 4.1).

Treating the cities effluents to tertiary level before releasing the effluent to the wadis, is essential action to reduce the contamination hazard of the water sources (springs and wells).

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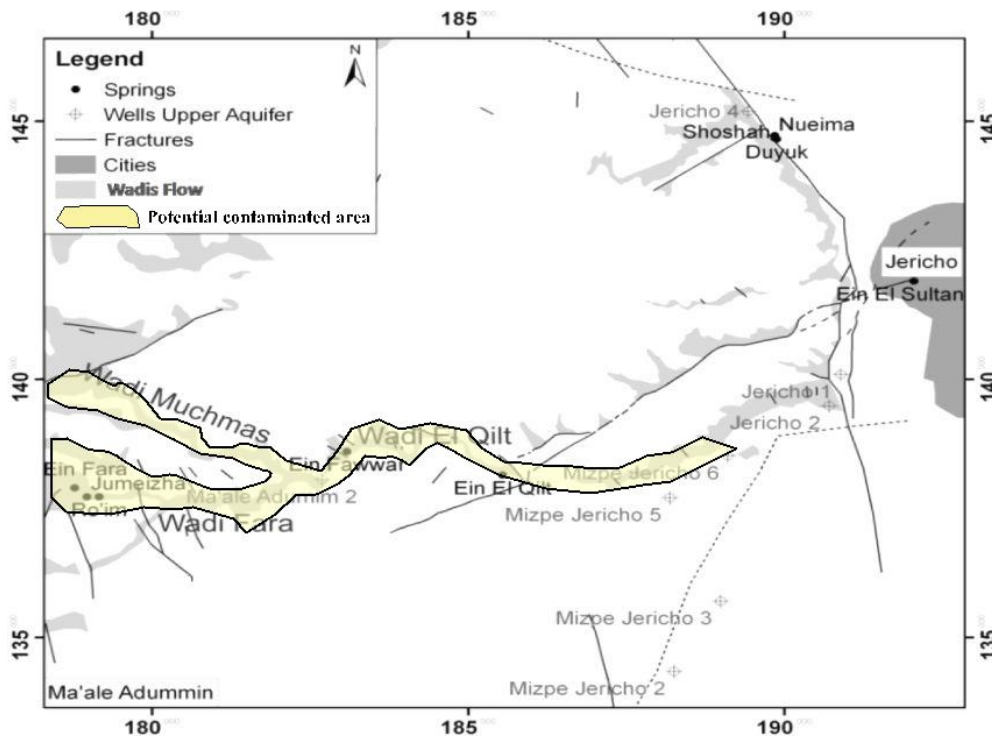


Fig. 4.1: Vulnerability map of the Wadi Al-Qilt and Jericho area

#### 4. SUMMARY

Protection of the water resources is part of the water supply concept. The human activities on the recharge area increase the vulnerability to contamination of the water resources and the wells and springs that are feeding from these resources. This issue becomes more problematic in semi arid and arid zones where the water resources are quite limited and the effect of dilution of the effluents by the rainfall or in the aquifer storage is minimal and rare.

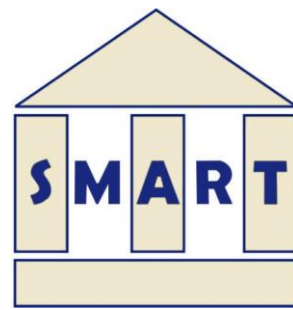
The study area extends from Jerusalem and Ramallah in the west to the city of Jericho and the village of Auja in the east. Most of the population lives in the high mountain area on the outcrops of the limestone-dolomite aquifer. Agricultural activities occur in the eastern part of the study area in the Jericho city and in the nearby Palestinian and Israeli settlements.

The Judea Group layers constitute the regional aquifer in the study area. The aquifer system is divided into two separated systems. The upper system (Spring

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system) that its outlets are the springs that emerge in Wadi Al-Qilt, Jericho and Wadi Auja and a lower system (Regional system) that its outlet are the Feshcha Springs and the wells within the study area are exploring water from the lower system.

The spring system in Wadi Al-Qilt and Jericho had young water age and fast flow that indicates the existing of well developed (fossil) karstic system. In contrast, the regional system is characterized by slow flow. The differences in the flow pattern effect on their vulnerability to contamination.

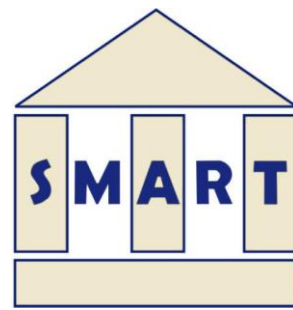
The springs in the upper part of Wadi al-Qilt (Ein Fawwar, Ein Fara and Ein Qilt) emerge from the limestone layers of the Tournian age. Wadi Al-Qilt and its tributaries cut into the Tournian limestone rocks that are part of the outcrops of the springs. The wadi receives effluents of the main cities wastewater treatment plants. This effluent reach through the karst fissures to the springs. Because of their small storage and the fast flow mechanism, the effluent reach to the spring very quickly and in short time that enable the bacteria to survive. The Jericho springs have a larger catchment area and the travel time is much greater. Leakage of effluent in the outcrops leaves enough time for "self purification". Contamination events (if occur) in the Jericho Springs are mostly from a local contamination sources nearby the springs outlets. The spring system is the most sensitive to contamination hazard, during winter time and due to flooding the water turbidity exceeds 1000NTU affecting the water quality, this leads to discharge of the water to the wadi were the lower riparian's downstream need to be compensated of this amount. In summer time the problem is more acute were the needs and demand is in its maximum, organic pollution takes place due to two main facts, increase of tourism between mid of April to end of September the other factor takes place between mid of April to mid of May were framers cut the wool of the sheep's in the canal line. All these activities increase the nutrient content in the water stream leading to algal pluming within the water system.

The wells are pumping from a deeper system and are more protected from contamination. Only wells that are pumping from unconfined aquifer and also seated close to the wadis bank that their floor is cut into the aquifer formations, may receive small amount of effluent that flow in those wadis and penetrate through karst fissures into the deep aquifer system. The amount is quite small and after very short pumping the "contaminated lens" disappears. Wells that are located far from the wadi bank are not contaminated.

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Another source of contamination into the deep aquifer, appear in wells that are pumping from unconfined aquifer and nearby them is passing an effluent pipeline that is leak because of improper maintenance.

Treating the cities effluents to tertiary level before releasing the effluent to the wadis, is essential action to reduce the contamination hazard of the water sources (springs and wells).

It is essential to update the vulnerability map by using some software such as protection distance (PD) method, Wellhead Analytic Element Model (WhAEM2000) and GIS. Those methods can be used to determine the travel time between any sink sources and the contaminated spring or well. It is important to note that we are dealing with karst system and it is quite difficult (even impossible) to identify the karst conduit that may connect between the sink source and the outlet (spring and/or well) and also its permeability. Therefore, our plane is to run several geological scenarios and to compare their results with the hydrogeology conceptual model.

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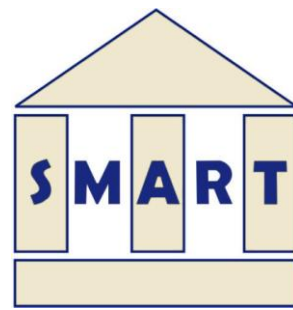
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## **Sustainable Management of Available Water Resources with Innovative Technologies**



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