Water Resources Protection Plan for Zara – Ma`een – Mujib Project Watershed

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1) Introduction

Surface water resources are increasingly important for domestic water supply in Jordan. In order to protect the water resources in Zara- Ma`een- Mujib project watershed, WAJ with cooperation with USA-CDM Co. implement a project concerning surface and ground water resources protections in this watershed.

Zara – Ma`een – Mujib (ZMM) Watershed is located in the central part of Jordan, including the majority of Madaba Governorate, and limited southern parts of Amman Governorate.

In ZMM Watershed, the base flow and the flood flows are used to supply the Zara Maieen Water treatment plant with raw water that is treated and then pumped to the Capital Amman. This supply is done through The Mujib dam and the Walla dam. Other sources that includes the Wadi Zarqa Maieen springs, the hot springs and the Wadi Abu Khusheibah.

Water Resources Protection Plan for Zara-Ma`een-Mujib Project Watershed is a technical definition used to explain the restrictions (prohibitions, limitations and measures) on urban, industrial, touristic and agricultural development. For each protection zone special restrictions are developed and defined, and presents the concept of water resources protection zones and the implemented methodology for delineating the water protection zones for the Zara – Ma'een – Mujib Watershed.

2) Objective of the project

The objectives of the Project are as follows

1. Developing Water Resources Protection Zones for the Zara – Ma`een – Mujib Watershed:
    a. Water protection Zone-1,2 and 3 for the dams, wadis and springs.
    b. water protections Zone1,2 and 3 for the major wadis in the watershed.
2. Land use Practices and Its Possible Pollution Impacts Within the Zara – Ma`een – Mujib Watershed
3. Providing technical support to the WAJ in developing Watershed Management Plans for Wadi Es-sir and Mujib Zara Ma`een Watersheds;

3) Project area descriptions

3.1 Location

The Zara – Ma`een – Mujib (ZMM) Watershed is located in the central part of Jordan including the majority of Madaba Governorate, and some southern parts of Amman Governorate (Figure 3-1). The area of the ZMM Watershed covers about 1019 Km^2 merging between the Jordan valley (central zone) morphology and the eastern escarpment morphology.

3.2 Climate

The northern and Eastern parts of the ZMM watershed characterized by a Mediterranean climate as the rest of Jordan's highland, with a wet winter season (October – April) and a dry winter summer season (April – September). While the

western parts of the watershed characterize by a sub-tropical climate, mild winters and very hot summers.

Annual average temperatures vary around mid twenties degree and can exceed the 40 C in summer. While during the winter night's, temperature might decrease below 10 C.

The winter precipitation tends to fall in short and intense events. According the records of the 5 rainfall stations located in the watershed, the yearly average rainfall within the different parts of the watershed varies 214 mm in Dhiban station to 314 mm in Mushaqqar station. Yearly rainfall data (Years 1998-2008) for the 5 rainfall stations of the watershed are presented in table 3-1 and illustrated in Figure 3-2.

Table 3-1: Yearly rainfall data (Years 1998-2008) for the rainfall stations in the ZMM watershed

Year	Madaba	Maieen	Mushaqqar	Wadi Wala	Dhiban
1998	188.6	228.1	221.8	NA	117.5
1999	167	113.6	154.7	NA	113.5
2000	288.7	296	336	273.1	304
2001	232	234.5	248.1	252	292.3
2002	438	362.2	468.5	409.9	364
2003	288.9	300	337.9	176.5	230.2
2004	343.9	252	416.3	256.5	259.6
2005	321.1	245.6	367.9	180.2	175.6
2006	300.5	228.3	344.9	199.7	204
2007	322.8	263.1	351.2	207.9	200.7
2008	166.2	151	208.2	114.3	93.5
Yearly Average	277.97	243.13	314.14	230.01	214.08

Figure 3-1: Location Map Of The Zara Main Mujib (ZMM) Watershed

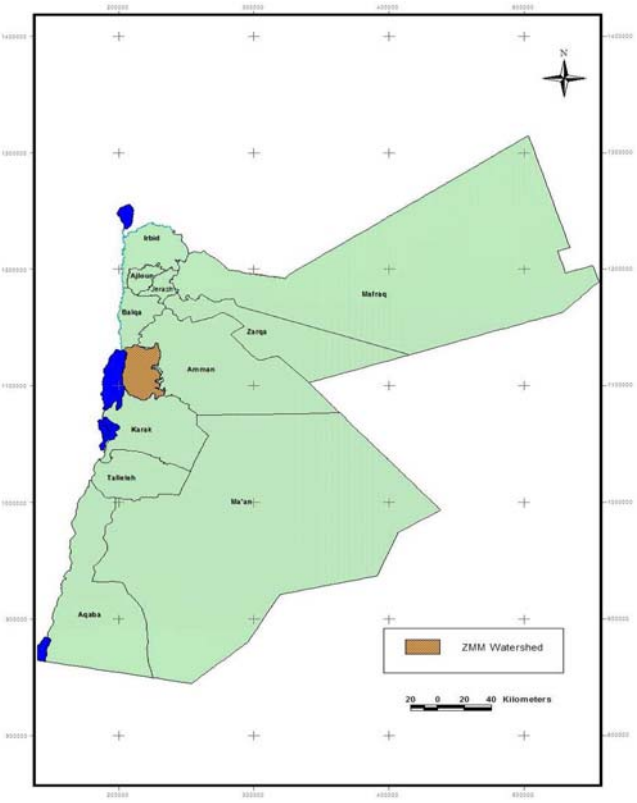


Figure 3-2: Yearly rainfall data (Years 1998-2008) for the rainfall stations in the ZMM watershed

3.3 Topographic, Geologic and Structural Setting

The Variation in topography within the "ZMMW" is wide, where the elevation varies between 900 m ASL and 1000 m ASL in the northeast and the south of the watershed to -400 m BSL on the shores of the Dead Sea. The major topographical feature within the study area is the Dead Sea. It is landlocked and fed by the Jordan River and run-off from side wadis. The Dead Sea is located about 418 meters below sea level-the lowest elevation and the lowest body of water on the surface of the Earth. The total surface area of the Dead Sea catchment is approximately 40,700 km^2.

Also, the ZMM watershed includes several major wadis (from the south to the North) such as: Wadi Mujib, Wadi Wala & Hedan, Wadi Abu Khusheibah and Wadi Zarqa – Ma`een.

Geological Description

Due to the tectonic activities that formulated the Jordan rift valley and continue to occur over millions of years, in association of the erosion activities especially during the recent geological period, major portion of Jordan's geological strata are outcropping and can be identified along the Jordan valley.

Cambrian, Triassic and Cretaceous System are outcrops mainly distributed through the foothills, the escarpment along the valley. While the Tertiary and Quaternary deposits cover most of the area, igneous rocks are of limited occurrence and concentrated in the southern parts of the valley within Wadi Araba and Aqaba areas. The major geological

units (formations) exposed along and in the vicinity of the understudy area are listed in Table 3-3, and presented through the geological map of the project area (Figure 3-3).

The Triassic – Jurassic/Lower Cretaceous Sedimentary Rocks.

This system consist of a thick sequence of sandstone with intercalated beds of carbonate rocks, and include two major geological groups, these are The Kurnub Sandstone "K"), and the older Zarqa Group (Z).

Zarqa Group

The Zarqa Group is exposed at very limited areas mainly in the eastern Jordan Valley escarpment as a narrow belt and its locally out crops in the study area near Ghor Kabid. It is mainly composed of alternating calcareous sandstones, oolitic marls, blue-gray shales, gray and yellow limestones, crystalline limestones, marly limestones and partly dolomitic limestones with sandy limestone and sandy marls beds.

Kurnub Group

Kurnub Group consists mainly of white, multi-coloured and grey sandstone, mostly medium- to coarse-grained, with thin beds of grey and brownish siltstone. In northern Jordan, very fine- to coarse-grained, partly carbonaceous sandstone with intercalations of sandy dolomite, dolomitic limestone, siltstone and shale are common.

Table 3-3: Description of Outcropping Formation

Period	Epoch	Group	Formation	Symbol	Lithology
Quaternary	Holocene (recent)		Fan, talus, terrace, river		Sand, clay, gravel
	Pleistocene	Jordan valley	Lisan	J	Marl, clay, gypsum, sand, gravel
Tertiary	Pliocene		Basalt Undifferentiated	B	Basalt Dolerite
	Miocene				
	Oligocene				
	Eocene	Balqa	Rijam	B4	Chert limestone
	Paleocene				
Upper cretaceous	Maestrichtion		Muwaqqar	B3	Chalk marl
	Companion		Amman	B2	Silicified limestone, chert
	Santonian		Wadi Ghudran	B1	Chalk, chalky marl
	Turonian	Ajlun	Wadi Sir	A7	Limestone
	Cenomanian		Shuaib	A5-6	Marly limestone
			Hummar	A4	Limestone
			Fuheis	A3	Marl
			Naur	A1-2	Marl, limestone
Lower cretaceous	Albian	Kurnub		K	White sandstone with dolomite and shale; varicolored sandstone with limestone, shale, dolomite and marl
	Aptain				
	Neocomian				
Jusrassic		Zarqa	Azab	Z2	Limestone, marl, dolomite, sandstone, shale
Traissic			Main	Z1	Sandstone, calcareous sandstone, limestone, shale, gypsum
Cambrian		Ram	Umm Ishrin		Sandstone, siltstone
			Burj		
			salib		
Precambrian		Aqaba & Araba		G+Sr.	Igneous, metamorphic,

Period	Epoch	Group	Formation	Symbol	Lithology
		complexes			Conglomerate

"Upper cretaceous – Lower Tertiary" System.

This system consists of a thick sequence of carbonate rocks and represented by two geological groups, these are the Balqa and Ajloun Groups. The Belqa Group overlies with conformity the Ajloun group, and consists of thick beds of chalky limestone overlain by thick beds of limestone, which considered as an important aquifer, while Ajloun group consist of seven formations (A1-7).

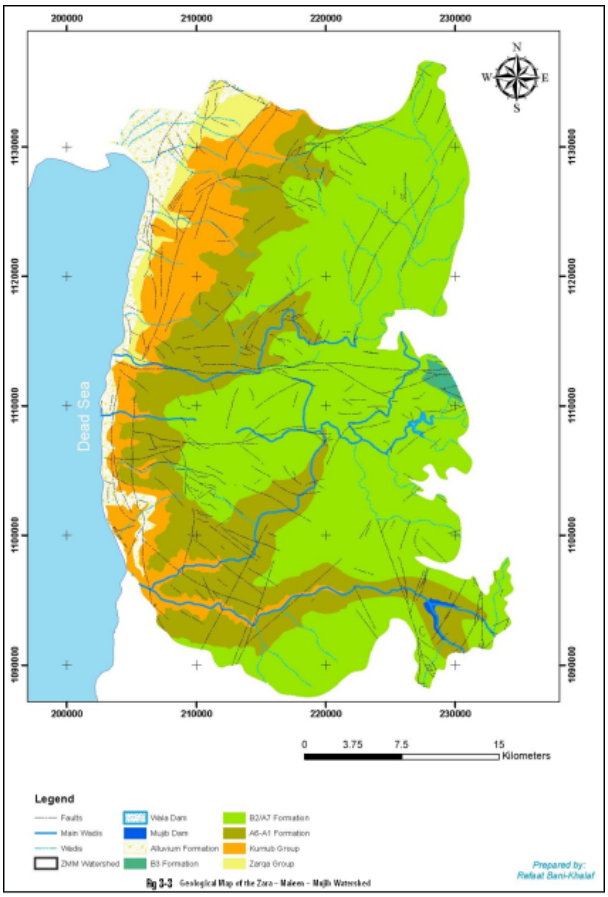


Fig 3-3 Geological Map of the Zara – Maleen – Mujib Watershed

The Lower Ajloun Group

The Lower Ajloun Group overlies disconformably the Kurnub Group. It comprises a Late Cretaceous sequence dominated by marl, limestone, dolomite, and shale. The system is characterized by large variations in lithology and thickness. It is mainly outcrops on the slopes of the rift escarpment and the side wadis. The lower Ajloun group include the following formations: the Na'ur Formation (A1/2); the Fuheis Formation (A3); : The Hummar Formation (A4) and the Shuayb Formation (A5/6).

The Balqa Group

This group consist of a thick sequence of carbonate rocks consists mainly of limestone and dolomitic limestone, and were divided into the following formations:

Wadi Umm Ghudran Formation (B1): Amman Silicified Formation (B2a) ; Al-Hisa Phosphorite Formation (B2b); Muaqqar Chalk - Marl Formation (B3); Umm Rijam Chert-Limestone Formation (B4), and Wadi Shallalh (B5) formation:

Quaternary & Recent Deposits

The Lisan Formation of Jordan Valley Group of Quaternary Period and Pleistocene Epoch. This formation consists predominantly of millimeter-to-centimeter-laminated, very weak, friable, low density, white, calcareous mudstone with alternating white marl, greenish brown clay and evaporate. This formation was formed in brackish water of the Lisan Lake which occupied the Dead Sea basin during the Late Pleistocene.

In the vicinity of the main wadis, sand, silt and clay size materials with gravel and cobbles were deposited. Depending on the distance from the main wadis, these deposits become finer or coarser. They were accumulated through the processes of weathering, erosion and sedimentation during the recent time. At the mouths of wadis near the foot

of scarps and at the rims of the Jordan Valley Depression, alluvial fans of unsorted wadi sediments have frequently developed.

3.4 Water Resources

3.4.1 Surface Water Resources

The ZMM Watershed extends between the Mujib surface water basin and the Dead Sea rift side wadis surface water basin. The surface water resources in the ZMM watershed are represented by the base flow and the flood flow of both of the "Dead Sea Rift Side Wadis" and the Mujib surface water basin. Table 3-4-1 presents the Annual Flow Volumes in MCM/year for those two basins

Table 3-4-1: Annual Flow Volumes for the Wadi Mujib and Dead Sea Rift Side Wadis Basins[1]

Basin	Catchment area (Km^2)	Average Annual Rainfall (mm/year)	Flood flow (MCM/Year)				Base flow (MCM/Year)
			Dry Year	Median	Wet Year	Average	Average
Dead Sea Rift Side Wadis	1508	240	6.6	15.1	34.0	21.7	22.6
Wadi Mujib	6727	180	10.6	30.7	115.2	70.9	35.0

Surface water drains westwards to the Dead Sea via Wadi Mujib, Wadi Walla & Hedan, Wadi Abu Khusheibah and Wadi Zarqa – Maieen and their numerous tributaries. The base flow in those wadis /tributaries is derived from a number of springs and seepages. The average yearly base flow from those two sub-basins is about 57.6 MCM.

The total average flood flow for those surface water basins is about 92 MCM/year[2]. These volumes are very important for the hydrogeological cycle where it participate in recharging the water springs; the local aquifers and increase the storage of the dams.

In the ZMM Watershed the base flow and the flood flows are used to supply the Sweimeh water treatment plant with raw water that is treated and then pumped to the Capital Amman. This supply is done through the following sources

- The Mujib and Walla dams: According to JVA data base, the Sweimeh water treatment plant was supplied from this source by 22.2 MCM/y and 25.3 MCM/y during the years 2007 and 2008 respectively[3]. All of these quantities are flood water.
- Other sources that includes the Wadi Zarqa Ma`een springs, the hot springs and the Wadi Abu Khuseiba. The Zara Ma`een Water treatment plant was supplied from these sources by a total of 17.4 MCM/y and 17.9 MCM/Y during the years 2007 and 2008 respectively[4].

[1] MWI Data Base,2008
[2] MWI data base, 2007
[3] JVA data base, 2008
[4] JVA data base, 2008

3.4.2 Groundwater Resources

The ZMM watershed is located within the Dead Sea groundwater basin, where the sedimentary sequence forms the primary aquifers of the watershed. The aquifers which are occurring within the escarpment are being drained by deeply incised wadis in a westerly direction towards the Dead Sea. Over exploitation of the available groundwater resources during the last decade, has resulted in water level declines and ceasing off some of spring and base flows, particularly in Mujib basin. The groundwater level depletion ranges 5m to 25m.

3.4.2.1 Major Aquifer System

Due to the tectonic activities that formulated the Jordan rift valley and continue to occur over millions of years in association of the erosion activities especially during the recent geological period, the three major aquifer system dominated the hydrogeology of Jordan can be identified within the ZMM Watershed.

Going micro scale , the local hydrogeology of the ZMM watershed is represented by two major aquifer system , the Upper aquifer (B2/A7) and the lower aquifer (the Sandstone of the Kurnub and older ages), and one major aquitard (A1-6) which separates those two major aquifers. The Tertiary, Neogene and younger aquifer systems are of limited importance.

The sandstone hydraulic system,

Within the watershed, this system includes the Ram aquifer, the Zarqa aquifer (Z) and the Kurnub aquifer (K). The major springs (including the Zara Springs) in the ZMM watershed are discharging from the kurnub aquifer. In addition to several springs discharging from the Zarqa Aquifer[5].

The Cretaceous hydraulic system

The A1/A6 Aquifer

The lower Ajlun group overly the sandstone aquifer system. The most important unit within this group is the Hummar aquifer (A4) in central and north Jordan. However the whole A1/6 group is considered an aquitard on a regional scale, except in the south and southeast of the country where the group becomes lithologically arenaceous. . Many springs are emanating from the A1/A6 aquifer system and are of local importance for the water supply, especially north-western highlands. The A1/A6 is to a large extent exploited by wells throughout northern and central Jordan.

The hydraulic conductivity of the A1-6 Aquifer varies between $2.0E^{-5}$ m/s (as for the A4 formation) to 1.0 E^{-9} m/s (as for A3 and A 5-6 formations) with an average of 7.0 E^{-6} m/s.

The "Amman-Wadi Sir Aquifer", coded as A7/B2.

[5] MWI Data Base, 2008

This aquifer crops out on the highland east of the Rift zone and in most areas dips gently eastwards. The overlying Muwaqqar Formation (B3) is an aquitard which confines the A7/B2 aquifer.

The A7/B2 is the most important aquifer system in Jordan. It has a wide and continuous extent, a relatively high permeability (Hydraulic Conductivity: 2.0 E^{-5} m/s) and receives the largest amount of modern recharge. In the northern and central part of the country it is found at moderate depths and therefore easy to exploit. The system is a principal source of fresh water for domestic supply, irrigated agriculture in the highlands, and industrial uses in the western part of the country. But it is largely overexploited and the quality of its water is deteriorating due to human activities.

The Tertiary, Neogene and younger aquifer systems

In the watershed this system includes the Jordan Valley alluvial aquifer system, and alluvial deposits at the eastern shore of the Dead Sea. This system characterized by total heterogeneity of its hydraulic properties

The eastern part of the Jordan Valley lies between the Jordan River in the west and the eastern escarpment of the rift in the east. The alluvial aquifer extends from the northern shore of the Dead Sea in the south to the downstream part of the Yarmouk River in the north. The total length from north to south is about 100 km. The average width varies between 4.5 km to a maximum of 13 km, with an average width of 8 km. The western and southern boundaries of the system are the discharge zone of the Jordan River and the Dead Sea. The eastern boundary is mainly the contact of the alluvium with older rocks of mainly Upper Cretaceous age (Ajloun and Balqa series). The lower boundary of the system consists of different bedrock types of the Kurnub, Zarqa, Ajloun, and different Belqa Formations.

The eastern shore of the Dead Sea is generally very close to a steep cliff formed from north to south of Triassic Zarqa group, Cambrian-Kurnub sandstone and Saramuj conglomerates. The alluvium is generally narrow and comprises Lisan formation and Holocene gravel and boulders. On the other hand the alluvium becomes wider and thicker in the southern part and receives indirect recharge from stream runoff, lateral flows of the adjacent aquifers of the escarpment and from vertical leakage of underlying bedrock aquifers.

3.4.2.2 Groundwater Wells

According to MWI data base system, the ZMMW include 33 active groundwater[6] wells. These wells are used for domestic, agricultural, tourstic and industrial demands. Number of wells and the total consumption rate (for the period of 2004-2007) for each category are presented in table 3-4-2.

Table 3-4-2: Annual Groundwater Consumption/ sector from the Active Groundwater Wells in the ZMM Watershed for the Years 2004 - 2007

[6] MWI records, 2007

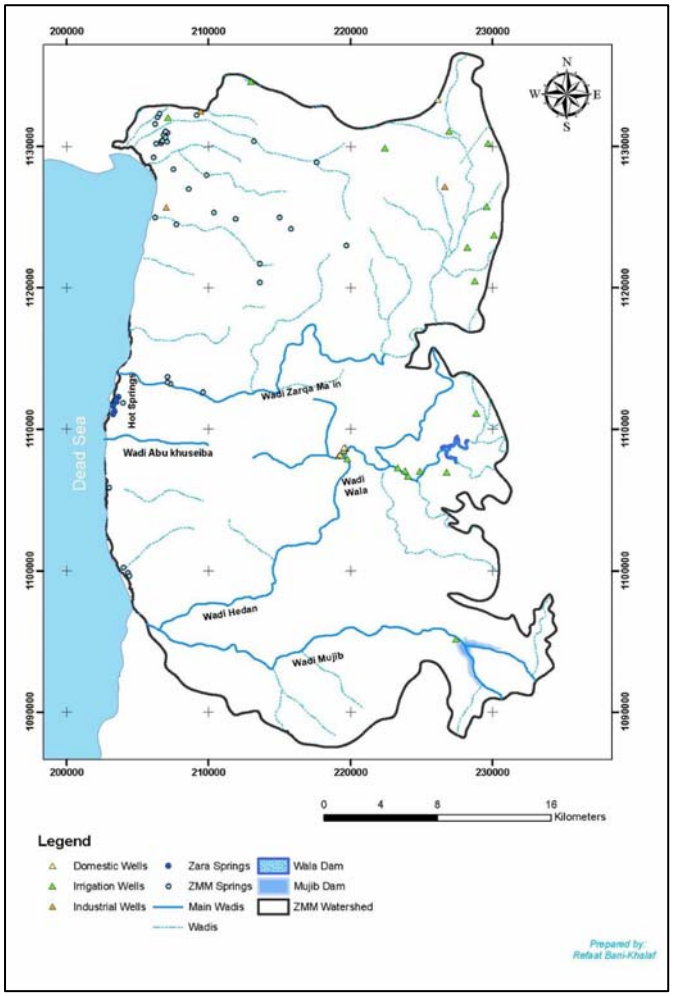
Category	No. of Wells	Yearly Consumption Rate (MCM) 2004	2005	2006	2007	Average	%
Domestic	10	9.43	9.43	9.13	9.92	9.48	75.24
Agricultural Demands	19	3.94	2.86	2.61	1.48	2.72	21.59
Industrial & Tourstic	4	0.32	0.38	0.47	0.44	0.40	3.17
Total	**33**	**13.69**	**12.67**	**12.21**	**11.84**	**12.6**	

3.4.2.3 Water Springs

The ZMM Watershed is rich with water springs. According to MWI data base, 49 springs are recorded in the ZMMW. Details of these springs including location, aquifer and its annual discharge rate (for the period of Year 1999 – 2007) are presented in Table 3-6. In the year 2006/2007, the discharge rate for 36 springs was measured by MWI monitoring directorate. The total recorded yearly discharge rate was 30.8 MCM. This volume of water was discharged through the following groups of springs:

- The Zara springs produced about 7.8 MCM
- The Wadi Zarqa' Ma`een springs produced about 14.9 MCM
- The rest of the springs produced about 8.1 MCM

The Major springs within the watershed are discharging from the Kurnub Sandstone aquifer. In addition to that, several springs within the ZMM Watershed are discharging from the Alluvium Aquifer, B2



3.5 Water Quality

This section of the report presents and discusses the water quality characteristics of the four major water resources providing the Sweimeh water treatment plant with its demands of raw water. Water quality data presented hereinafter were provided by the data base unit of the WAJ central labs.

3.5.1 Wadi Abu Kshebah

Available water quality data for this source is limited and represented by two samples that were collected and analyzed during the year 2007 (Table 3-5-1). Analyses results indicated:

- The water is brackish were the EC value varies between 2000 to 2200 mmohs/cm, where the HCO3 is the dominant cation while the Cl is the dominant anion.
- Nitrate is low and varies between 1 to 2 mg/l.
- Turbidity is high and varies between 9.5 NTU to 10.5 NTU. This is normal for surface water samples, especially when it is collected during the winter period.

Table 3-5-1: Water Quality Data for Wadi Abu Kshebah Raw Water[7]

Sampling Date	11/01/2007	23/04/2007
Electrical Conductivity	2000	2220
pH	8.09	8.11
Bicarbonate	172.63	168.97
Calcium	154.3	161.92
Potassium	24.1	28.93
Magnesium	26.2	29.91
Chloride	448.01	517.24
Sodium	211	234.6
Sulfate	245.28	296.16
Hardness	465	527
Nitrate	2.01	1.59
Silica	34.15	31.04
Turbidity (NTU)	10.48	9.51

3.5.2 Zara Springs

Available water quality data for the Zara springs goes back to the years 2003 and 2004 . According to the subject data, the water of these springs is brackish where the average EC value is 2238, and HCO3 is the dominant cation and the Cl is the dominant anion.

Furthermore, the NO3 value of these springs water is low and varies between 3 mg/l to 8 mg/l.

3.5.3 Wadi Zarqa – Ma`een

Available water quality data for this source covers the period between the 2003 to the year 2008. Also available data for the same source include the TDS, NO3, NH4 and Turbidity values collected from the area below the treatment plant of the Ma`een Resort. The general characteristics of this source water are summarized as the following:

- The water is brackish, where the EC values vary between 2800 and 3100, where HCO3 is the dominant cation and Cl is the dominant anion.
- The NO3 concentration is low and usually below 10 mg/l.
- According to the available data, recorded turbidity values vary between 34 NTU and 451 NTU.

[7] Water Authority of Jordan Central Labs - 2009

While, water quality data for water samples collected below the Ma`een Resort treatment plant indicated no impact of the treated wastewater on the water of this source, as indicated by:

- The total dissolved solids vary between 1460 mg/l and 1740 mg/l.
- The low NO3 value, that varies between 0.2 mg/l and 2.88 mg/l
- The Ammonium concentration is mainly below 0.5 mg/l.

3.5.4 Wadi Mujib Water

Wadi Al-Mujib is the major source for providing the Sweimeh treatment plant with water. Based on the available water quality data that covers the period of 2003 – 2008, following is the general water quality characteristics for this water source:

- Wadi Mujib effluents are brackish where the Ec values range between 800 to 5349 mmhos/cm with an average value of 2326 mmhos/cm. Furthermore, HCO3 is the dominant cation and Cl is the dominant anion
- The NO3 concentration varies between 0.2 mg/l to 84 mg/l with an average value of 12.4 mg/l.
- The average Turbidity value is 1.74 NTU for this source of water according to the available limited measurements.
- The Escherichia Coli measurements vary between <2 to 16000.

4. Land use Practices and Its Possible Pollution Impacts Within the Zara – Ma`een – Mujib Watershed

The ZMM Watershed is located within the area of the Madaba Governorate. Total population within the ZMM Watershed is about 129,7928. Within this wide watershed many land use pattern occurs (Figure-4). In this section of the report the major land use practices within the ZMMW are presented.

4.1 Residential Usage

The residential usages within the ZMM Watershed are classified into the following categories:

- Major cities: this sub-category is represented by Madaba city which is located in the northeastern parts of the watershed.
- Towns: such as Theban town which is considered the major town in Madaba Governorate.

[8] Department of Statistics,2008

- Villages and settlements: several small villages and settlements are scatted all over the watershed.

4.2 Agricultural Usage

The agricultural land usage represents about 6.5% of the total ZMM Watershed. This type of usage can be divided into the following main categories:

- Vegetable farming (IRRIGATED LAND): It represents about 0.6% of the watershed area. Farmed vegetables include
- Field crops: usually such crops are farmed in flat and semi-flat wadis and depend on rain for irrigation
- Olive and orchard farming: it represents about 4.75% of the watershed, and include olive, citrus, Grape, Guava, Peach and Fig trees.
- Green Houses: it is used for producing vegetables (Figure 4).
- Chicken farms: more than 90 chicken farms were defined within the watershed .

4.3 Touristic Usage

This type of usage is concentrated in the northwestern parts of the watershed within the northern parts of the Dead Sea shore. Under this category of land use, the following can be listed:

- 5 stars hotels such as the Marriott and the Zara – Ma`een hotels
- 3 stars hotels such as the dead sea hotel
- Several tourstic suites were built within the tourstic zone of the Dead Sea area. These buildings consist of small apartments (about 50m2 in average) that can be used during the week ends.
- Public beaches

The resulted fluid wastes the hotels in the watershed in managed by small wastewater treatment plants located in the vicinity of each hotel. The reclaimed water is used for irrigating the green spots of each hotel. Only the residential/tourstic suites (constructed & under construction) are considering the septic tanks to mange fluid wastes.

4.4 Mining

No major industrial activities are going on within the ZMM Watershed. The only major industrial activity conducted within the watershed is Gypsum Mining . Such activity is practiced is several parts of the watershed.

Such activities are concentrated in the following three major spots within the watershed: (i) In the western parts of the watershed close to the upstream part of the Wadi Mujib; (ii) In the central parts of the watershed close to the upstream portion of the Wadi Zarqa Ma`een; and (iii) Within the northern parts of the watershed to the West of Madaba city.

In general, most of the mining activities are conducted in very "rigid /steep" slope areas. Thus, site preparations is required, and done through using huge quantities loss materials. The resulted sand and gravel from the mining activities are accumulated and placed on the Cliffs looking to the major Wadis . As a result, and during the winter season, the rain events and the resulted flows works on transporting part of these sediments to the Wadi courses and finally to the Zara – Ma`een WTP, resulted in an elevated turbidity levels causing the treatment plant's shutdown.

Furthermore, it was noticed that the resulted fluid wastes from the conducted maintenance operation for the mining machines and vehicles are stored in an inadequate way close to the Wadi slopes, leading for a possible contamination for the surface water resources that are collected and then pumped to the Zara – Ma`een WTP.

4.5 Services Usage

This type includes general stores, supermarkets, gas stations, vehicles maintenance stations and olive pressing stations (Figure 3-9). Such type of usage is concentrated in the northeast part of the watershed being associated with the concentration of population.

Most of the olive pressing stations are using cesspits for managing the resulted fluid wastes from the pressing operations. Furthermore, major part of the fuel stations is old, thus, it is possible that, the fuel tanks in these stations are leaking.

4.6 Natural Reserves

The ZMM Watershed included the Mujib Nature Reserve. This reserve was established in 1987 over an area of 212 Km2 and managed by the Royal Society for the Conservation of Nature. Bordering the Dead Sea at 416 m bsl , the Mujib Nature Reserve surrounds Wadi Mujib. Seasonal and permanent streams flow through many of the wadis, supporting luxurious aquatic plants in the river-beds. It is also one of the major sources that compensate the high evaporation rate of the Dead Sea

Surveys indicate that the reserve contains over 300 species of plants, 10 species of carnivores, and numerous species of resident and migratory birds. The richest vegetation is found in the wadi beds where there are Palm trees, in addition to Wild Fig, Tamarix trees and Oleander shrubs, in addition to the Reed bed along the wadi.

The steep mountain slopes support several highly adapted mammals, including the Rock Hyrax, the Eurasian Badger and, most importantly, the Nubian Ibex, a large mountain goat. Today, only a small number of Ibex remain in the wild due to widespread illegal hunting.

Many carnivores inhabit the various vegetation zones in Mujib. The Caracal, a medium sized cat with black and white ear-tufts, lives in rocky wadis. It is a powerful and agile hunter with great jumping power, known to catch flying birds in its paws. Mujib is also an internationally important passage way for migratory birds. Huge numbers of White

Storks passed through every year starting from August, Black Storks, Buzzards, Honey Buzzards, Levant Sparrow Hawks, and much more. The globally threatened Lesser Kestrel breeds in the reserve every spring. The breeding population reaches some times 0.1 % of the globally estimated population. At least nine species of birds of prey are known to breed in the reserve, significantly Bonelli's eagle, Short-toad Eagle, Long-legged Buzzard, and Barbary Falcon

4.7 Infrastructure

The ZMM Watershed is served by two main highways, the desert highway that connects the capital Amman with Aqaba and the Dead Sea – Aqaba highway. In addition to that, all the residential spots within the watershed are served by internal asphalted road system.

Furthermore, the Madaba wastewater treatment plant serves the major residential spots in the Watershed. This treatment plant is located in the northern parts of the watershed with an average daily treatment capacity of 5000 m^3/day, where its treatment efficiency not less than 98%.

Furthermore, another wastewater treatment plant is located in the middle parts of the watershed, serving the Ma`een touristic resort. The capacity of the subject treatment plant is about 150m^3/day, while the volume of the treated wastewater varies between 80 m^3/day to 100 m^3/day. The treated water is used in restricted irrigations after mixing it with fresh water.

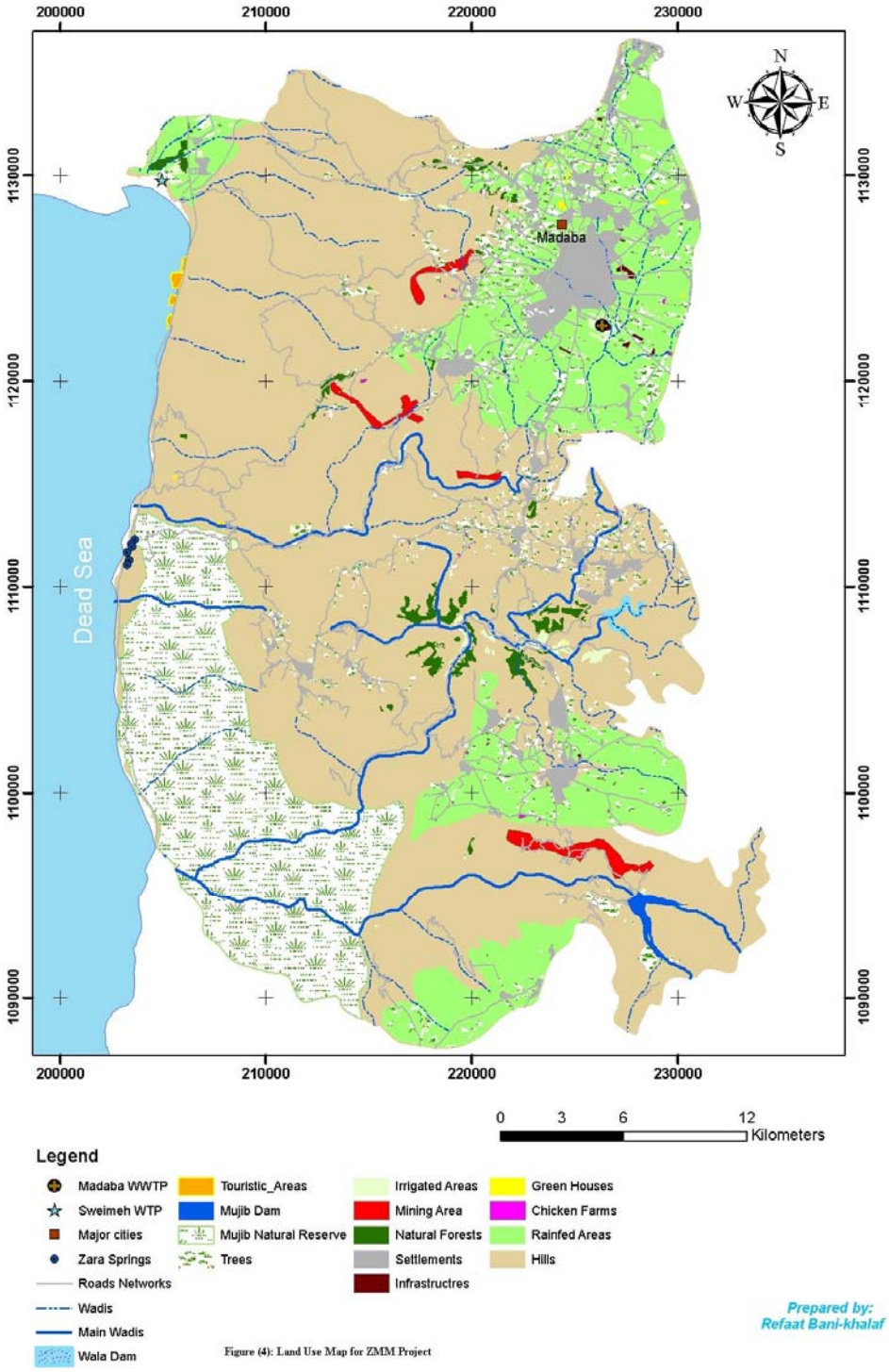


Figure (4): Land Use Map for ZMM Project

5. Water Resources Protection Plan for the Zara – Ma`een – Mujib Watershed

"Water resources protection zones" is a technical definition used to explain the restrictions (prohibitions, limitations and measures) on urban, industrial, tourstic and agricultural development. For each protection zone special restrictions are developed and defined.

This section presents and discusses the concept of water resources protection zones and the implemented methodology for delineating the water protection zones for the Zara – Ma`een – Mujib Watershed.

5.1 Implemented Methodology (Regulation and Judgment)

The "Instructions for protecting water resources used for drinking purposes" issued by the Water authority of Jordan *(Instructions for protecting water resources used for drinking purposes – IPWR - June, 2006*[9]) are used to define the water protection zones in the ZMM Watershed.

5.2 Developing Water Resources Protection Zones for the Zara – Ma`een – Mujib Watershed

5.2.1 Dams

A. Mujib Dam

Zone -1 Protection for the Mujib dam is already well protected by JVA by acquisition for constructing and operating the dam as listed on JVA (Figure-5,5-A).

Zone -2 Protection for this dam extends for 2.5 Km on both sides of the dam body and upstream of the dam lack as shown in figure-5. In this zone it is very important to have the following restriction on the ongoing human practices:

- The ongoing agricultural practices upstream of the dam body should reduce the usage of chemical pesticides and fertilizers and replace it with the concept of organic farming.
- The households should use septic tanks for disposing the resulted fluid wastes. Such tanks should be emptied on regular bases and transported the nearest treatment plant.

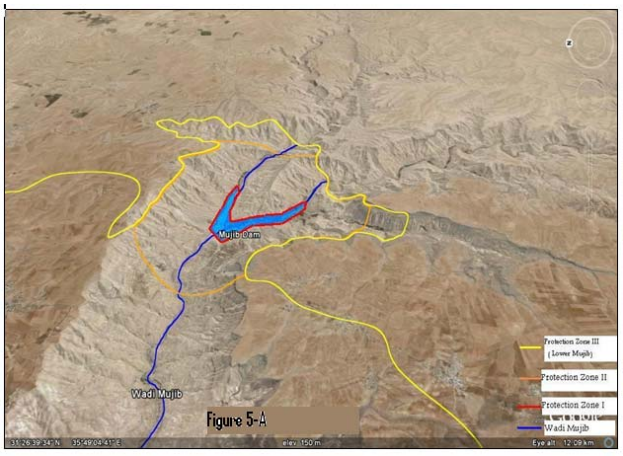


Figure 5-A

[9] "Instructions for protecting water resources used for drinking purposes"-June,2006

- Gypsum mining is the most important activity which ongoing within zone 2 of this dam. Such activities need restriction to avoid the cuttings and the soil to reach the water body and increase the water turbidity and silicate component. Accordingly, such activites needs to be prohibited in this zone of the Mujib dam.

B. The Walla Dam Area (Wala Dam, Wadi Wala and Wadi Hiddan)

Walla dam Zone-1 protection is already well protected by JVA by acquisition for constructing and operating the dam as listed on JVA maps (Figure-5,5-B).
Zone -2 Protection for this dam extends for 2.5 Km on both sides of the dam body and upstream of the dam lack (Figure-5). No major activities are going on within Zone-2 protection area of the Wala dam. Only small spots of agricultural activities are presented within the far upstream portion of Zone-2 protection area of the Wala dam. Irrigating such spots depend totally on rainwater and seasonal water resources in the area.

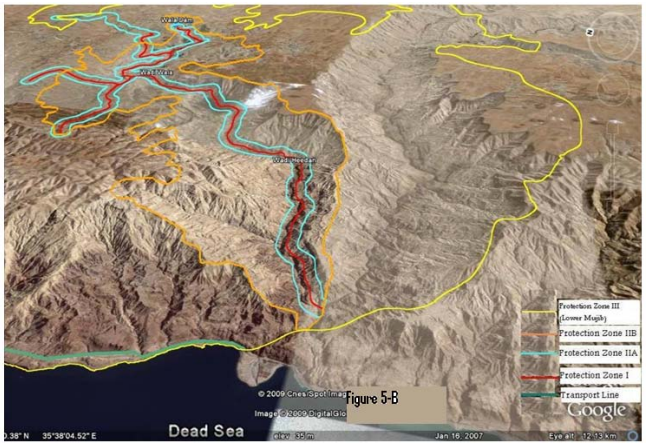


Figure 5-B

While for Wadi Wala and Wadi Hiddan, zone -2 protection for this wadi was divided into two parts, A and B . Zone -2 A protection is delineated with a line of 350m from the wadi edges and along the Wadi course. While Zone -2 B is delineated to cover to direct topographical sub catchment for Wala and Hiddan Wadis including the contour line area of 700 m ASL

5.2.2 Wadis

A. Mujib Reserve Intake: (Wadi Al –Mujib)

This station is located in the downstream portion of Wadi Mujib, opposite to the Mujib Reserve visitor's center. Zone-1 protection for Wadi Mujib including the pumping station and the pumping line (Figure-5,5C) is already reserved and in good conditions. It is very important to control the human activities that may be conducted in this zone within the area between the Mujib dam and the upper boundaries of the Mujib reserve.
Furthermore, is very important to conduct a flood management plan to avoid any destruction on the plant and the conveying line during the high and intensive floods

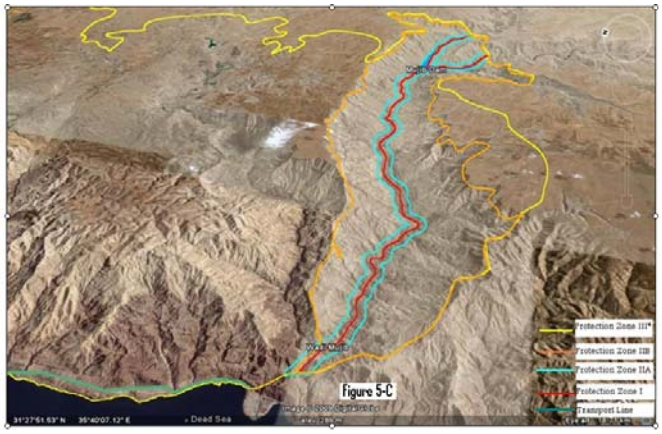


Figure 5-C

Major part of Zone -2 Protection for Wadi Mujib is located within the boundaries of the Mujib natural reserve. Being the major source for Sweimeh treatment plant, the maximum protection for the Wadi Mujib's water was considered when delineating the Zone -2 protection along the wadi course to the intake/pumping station. Thus, zone -2 protection for this wadi was divided into two parts, A and B (Figure-5). Zone -2 A protection is delineated

with a line of 350m from the wadi edges and along the Wadi course. While Zone -2 B is delineated to cover to direct topographical sub catchment for Wadi Mujib including the contour line area of 700 m ASL. Accordingly, the following are recommended:

- Mining activities should be prohibited below the contour line 700 m ASL.
- The ongoing agricultural practices in the area between the Mujib dam and the boundaries of the Mujib natural reserve should reduce the usage of chemical pesticides and fertilizers and replace it with the concept of organic farming.

B. Wadi Abu Khshaibeh

Wadi Abu Khshaibeh is located within the western portion of the middle part of the ZMM Watershed. Zone -1 protection for this wadi including the direct wadi course and Wadi Abu Khshaibeh collection/ conveying station (located in the down stream portion of the subject Wadi) is well conserved and protected by the JVA and WAJ. No human activities were recognized within this zone (Figure-5,5-D).
No activities are going on within Zone-2 protection area for the Wadi. This condition is related to the rigid topography of Zone-2 protection area and the limited population density in the watershed.

Zone -2 protection for this wadi was divided into two parts, A and B (Figure-5). Zone -2 A protection is delineated with a line of 350m from the wadi edges and along the Wadi course. While Zone -2 B is delineated to cover to direct topographical sub catchment of the wadi. The reasons behind such detailed delineation are the following:

- To protect the springs located within the wadi course and/or on the wadi edges.
- To protect the upstream portion of the wadi that includes the aquifers outcrops that is the source for the spring's water in the Wadi.

Accordingly, it is very important to restrict the land use within zone 2 to organic farming only. Furthermore, it is very important to have a flood management plan to avoid destroying the current facilities (collection & conveying station) located in the downstream portion of the wadi.

C. Wadi Zarqa Ma`een

The Zarqa Ma`een springs are located along both sides of Wadi Zarqa Ma`een that is extended within the middle part of the ZMM Watershed. Water from these springs is collected through an intake connected to a pumping station that pumps the collected water to the Zara – Ma`een Water Treatment Plant.

Zone-1 for this source including the collection/pumping station well reserved, but the intake area is not well protected as indicated by the presence of solid wastes inside the intake pool (Figure-5).

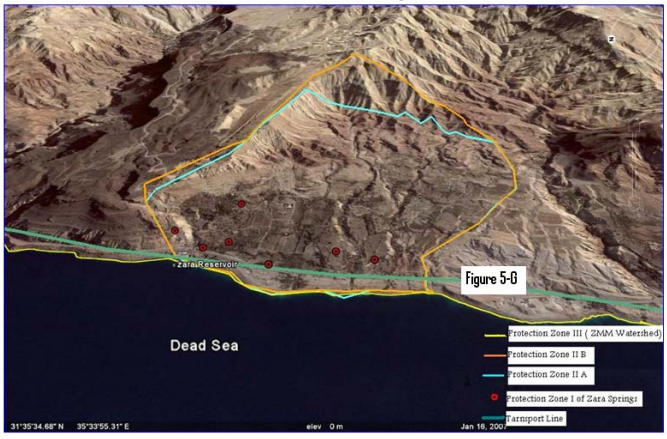
Zone -2 protection for this wadi was divided into two parts, A and B (Figure-5,5-F). Zone -2 A protection is delineated with a line of 350m from the wadi edges and along the Wadi course. While Zone -2 B is delineated to cover to direct topographical sub catchment of the wadi. This detailed delineation was implemented to protect and conserve springs located along the wadi course, in addition to the aquifers outcrops that is the source for the spring's water.

The only major activity located within zone -2 protections for this source is the Ma`een resort. The resulted wastewater from this treatment plant is treated in a wastewater treatment plant located within the resort site. The reclaimed water is used for irrigation purposes within the direct vicinity of the resort area. Thus, the treatment plant has no impact on the water quality of this source. This conclusion was supported by the analyses results for several water quality samples collected from the area below the wastewater treatment plan. Nevertheless, it is important to have continues monitoring program from the treatment efficiency of this treatment plant. Furthermore, the agricultural spots located within zone-2 should implement the concept of organic farming.

5.2.3 Springs and Wells

i. Zara Hot Springs

Zara hot springs are located far eastern portion of the ZMM Watershed's middle area. The spring's area includes an intake and a pumping station. Even though WAJ and JVA reserved the springs area with a fence, but the overall, Zone one for this springs close to the intake and the pumping stations is in a very bad condition, where the fence's door is broken allowing people to enter to the fenced zone area for recreational purposes especially in the weekends (Figure 5). As a result zone-1 protection for those springs is filled with different types of solid wastes. Thus, it is highly recommended to clean zone -1 for these springs and repair the broken door to stop the people from entering into this zone.



No. major activities are going on within Zone -2 protections for these springs, except for some scattered agricultural spots. Zone -2 protection for these springs was divided into two parts, A and B (Figure 5). Zone -2 A protection is delineated with a line of 2.5 Km upstream of these springs area. While Zone

-2 B is delineated to cover to direct topographical sub catchment of these springs. This detailed delineation was implemented to protect and conserve these springs and the aquifers outcrops that is the source for the spring's water. It is important to have a periodical monitoring plan for the upstream part of the hot springs are that includes the aquifers outcrops that is the source for the spring's water. Also the monitoring program should cover the agriculture activates that are located upstream of these springs within this zone.

6. Conclusion & Recommendation

6.1 Conclusions

1. Water Quality Status

Mainly, the quality of the four water resources supplying the Sweimeh treatment plant is within the Jordanian Standards for drinking water. The following limited exceedances were noticed (based on the limited available data)

- Increase in turbidity values during the winter season.
- Increase in NO_3 values

2. Land use Practices and Major Environmental Issues of Concern

Following are the major findings regarding the land use practices within the ZMM Watershed

- The population density is concentrated within the northeastern corner of the watershed. No populated spots are located close to any of the four water sources that provide the Sweimeh water treatment plant with water.
- Agricultural activities are the major land use practice in the watershed. Such activities are concentrated in northeastern, northwestern and southern parts of the watershed. It includes vegetable farming, trees farming and managing chicken farms. This sector is facing the following two issues of concern
    - The wide usage of chemical fertilizers and pesticides, especially by the vegetable farmers.
    - The difficulty in managing the resulted solid wastes from the chicken farms
- Mining is conducted in four major spots (north, central and southeastern parts) within the watershed, close to the Wadi Zarqa Ma`een and Wadi Mujib. The resulted solid wastes from the mining sites are managed in an inappropriate way, leading such wastes to be a potential source for increasing the turbidity of the water of Wadi Zarqa Ma`een and Wadi Mujib..
- Major part of the fuel stations in the watershed is old. The essential issue of concern for such stations is the possible fuel leakage from the station's underground fuel tanks.

- The northwestern part of the watershed faces a rapid development in the touristic sector, where new hotels and suites are "constructed/under construction". Such development will add new pressures on:
    - The limited water resources in the watershed.
    - The infrastructure represented by managing the resulted fluid and solid wastes.

6.2 Recommendations

1. Implementing the ZMM Watershed Water Protection Zoning

In spite of being far away from any major human activities that may impact its quality, the current water sources supplies the Sweimeh treatment plant needs to be protected and conserved through implementing the Water Protection Zones Concept (Figure 6-1). Reasons for such protection are the following:

- The watershed area is facing a rapid development in different aspects that may have on the long run impacts on the quality of the local water resources. Such development aspects include:
    - Rapid tourstic development within the Dead Sea area of the watershed, which include the construction of new hotels and suites.
    - Rapid urban development within the northeastern portion of the watershed, represented by the construction of residential households and establishing big and medium size agricultural farms.
- Sweimeh treatment plant is a major supplier to the capital Amman with water. Any shutdown for this plant will affect the water availability for major part of the capital residencies.

2. Protecting the Wadi Mujib

It is essential to protect the whole length (26 Km) of Wadi Mujib. Currently Wadi Mujib area (Area-1) that is extending for 15 km from the downstream portion of the Mujib Dam till the upstream of Mujib Reserve is not protected. While, the last 11 km of the wadi (Area-2), that extends from the upstream end of the natural reserve till the Mujib collection and conveying station is protected through the established Mujib Nature Reserve.

Thus, the area-1 requires protection from the following ongoing human activities:

- Agricultural activities very close to the main Wadi Mujib course.
- Mining activities within the hilly area overlooking Wadi Mujib.

3. Implement an Agricultural Technical Support Program

It is important to implement an agricultural technical support program for the farmers within the ZMM Watershed. The overall objective of this program is to minimize the usage of chemical fertilizers and pesticides in the watershed's agricultural lands.

To achieve that target, the subject program should focus on introduce and train the local farmers on the following two concepts:

- The concept of organic farming.
- The concept of Integrated Pest Management (IPM).

4. Conduct a site investigation For The Fuel Stations

It is highly essential to conduct a site inspection for the fuel tanks in the old fuel stations within the watershed. The purpose of this inspection is to examine the physical condition of these tanks, and accordingly, evaluate the possibility of any fuel leakage form it. Such inspection should be supported by water quality sampling the nearby water resources to test for oil contaminations.

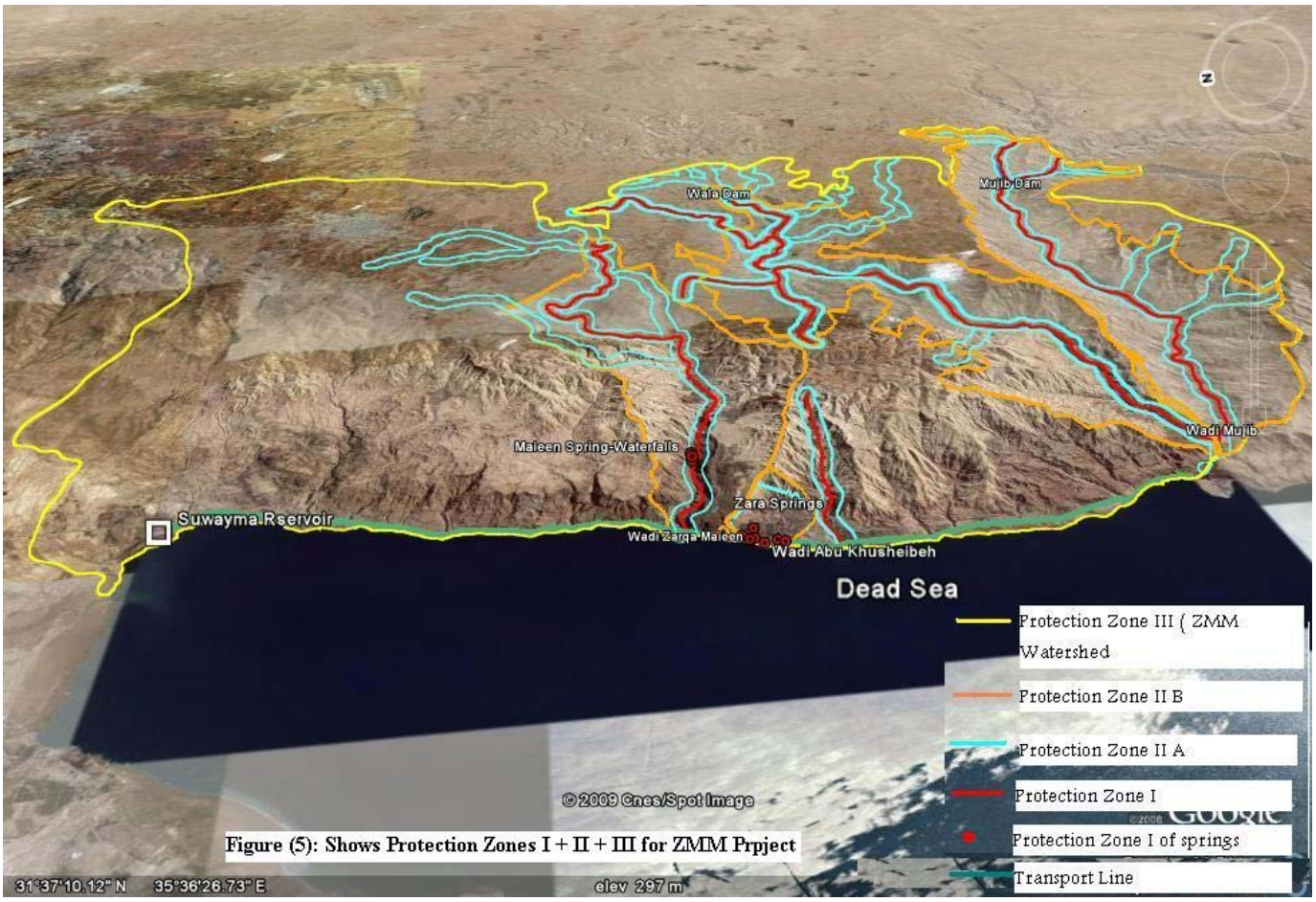


Figure (5): Shows Protection Zones I + II + III for ZMM Prpject