SUMMARY REPORT - UNIVERSITY OF JORDAN

The research activities in relation to the project objectives carried out during the second period for the WP1 and WP2 are as follows:

- <u>Conceptualization and characterization of the Zarqa River Basin</u>

Climate

A Mediterranean climate type is prevailing at the basin where rainfall precipitates mostly in the winter season (October-May) while the summer season (June-September) is extensively dry. The amount of rainfall in the ZRB decreases towards the east through the basin. The average annual precipitation in the western part of the basin is about 400 mm, while the average annual precipitation in the eastern part is about 150 mm (MWI 2003). The mean monthly air temperature ranges from 6 °C in January up to 22 °C in August, with a mean annual air temperature of 15.0 °C. Climatic changes in the basin resulted in significant drop in annual precipitation for the last 80 years. For example the average rainfall of Amman airport has dropped from 320 mm/year in the 1930s and 1940s to less than 285 mm/year in 1980s and 1990s.

Hydrology and Hydrogeology

The Zarqa Basin drains 4,100 km^2 from the upper northern point to its outlet near King Talal Dam. This area is part of five governorates, namely; Amman, Balqa, Jarash, Mafraq and Zarqa and it hosts three major cities (Amman is the largest). The basin extends from Syria to Amman, and then to the Jordan River. The highest point in the basin is located near the Syrian town of Salkhad in Jebel Al-Arab at an elevation of 1,460 m. The basin discharges its water at the confluence of the Zarqa River with Jordan River at an elevation of -300 m below sea level. Steep bed slopes of the river and its tributaries are in the range of 0.7 to 1.5 percent on average. There are several wadis drain in the Zarqa River Basin, as Wadi Dhuleil, Wadi Jersah, Wadi Zaatari, Wadi Rukban, Wadi Karum, and Wadi Rumeimin.

The basin is the most complex resource system in Jordan. At the lower end of the basin King Talal Dam (KTD) is located with a capacity of 85 MCM. The reservoir of KTD receives runoff from the watershed and wastewater from treatment plants. The reservoir also control water releases to the central part of the Jordan valley where it is mixed with the canal water diverting water from upstream sources. Upstream from the release point to the canal, a water diversion supplies fresh water back to the municipal system in Amman. Figure 1 shows the Zarqa River Basin's boundary and wadis (OPTIMA 2006; Shammout et al. 2013).

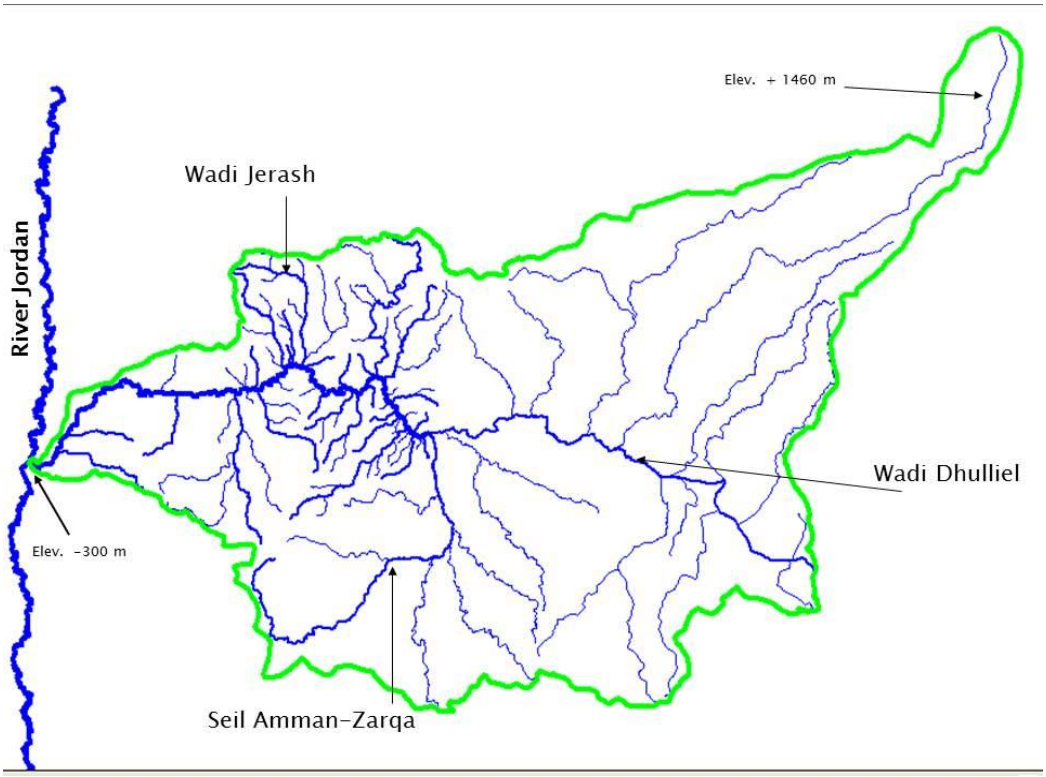

Figure 1 The Zarqa River Basin's bonudary and wadis

The annual effluent of the wastewater treatment plants totals about 60 MCM where most of it flows into KTD while only about 5 MCM are used in the basin and along the river banks for restricted irrigation.

The groundwater in the basin is found in five aquifers, namely; Wadi al Agib, al Hallabat, Baqa, Dhuliel and Amman-Zarqa. The water occurs in the basalt formation locally named B2/A4 and A4. The safe yield of the basin is about 90 MCM while the abstraction rate amounts to about 158 MCM. Part of the deficit in Baqa and Amman-Zarqa aquifers may be compensated from seepage due to leaks in pipe network or excess irrigation. Amman area receives about 40 MCM from the basin groundwater for municipal uses. The industries in the basins pump about 8 MCM. Extraction for irrigation is estimated at 110 MCM.

Geomorphology

In terms of geology, most of Zarqa River Basin belongs to Cenozoic and Mesozoic Era, in addition to Basalt rocks, which are located in the northeast and eastern parts of the basin. The basin is characterized by undulating topography in the west and flat areas in the east and south, with altitude range of 700-1200 m. The southwestern parts, which form small area of ZRB, are located below sea level (OPTIMA 2006). The variations in topography and climate produced a wide range of land regions soil types. The main land regions include the northern Jordan basalt plateau, Jordan highlands plateau, and northern highlands dissected limestone. The soils of the basin differ widely according to rainfall and topography. Arid soils (Calciorthids and Cambiorthidds) with high carbonate and silt contents are found in the eastern parts and more developed soils (mainly xerochrepts) with low salinity and high clay contents are found in the north and west (MoA 1993). Soil depth is function of slope where

deep colluvial soils have been accumulated in the valleys and lower slopes. The upper slopes in the north and northwest are affected by soil erosion and degradation, leaving behind shallow and stony soils. Soil erosion is threatening the storage capacity of King Talal Dam, where colluvial material is washed on steep slopes toward KTD. On the other hand, sheet erosion is more pronounced in the eastern parts and influences water quality of small earth dams. Soil erosion by wind is also dominant in the eastern parts (OPTIMA 2006).

Soil and land use

The soils of Zarqa Basin differ widely according to slope. In the most humid west, reddish to brownish clay and clay loams prevail. Toward the east, the soil become silty loam to loamy in texture, yellowish brown to strong brown with very high carbonate content. Soil erosion on the steeper slope is main cause of alluvial processes where sheet erosion is more pronounced in the eastern part. Land use in Zarqa River Basin has undergone considerable changes. Recently, the expansion of Amman and surrounding towns has been extensive, where before large expanses of grazing land and more fertile agricultural lands could be found between Amman and other towns, it has now developed into a sprawling urban conglomerate. The Basin has regions of natural forests occurring in the mountainous part that are composed of oak, pine, juniper, wild olive and cypress. Agriculture is scattered within the basin comprising rain-fed orchards, olive, and field crops, with irrigated agriculture on the river basin banks. The percentages of the land uses are 0.3% water body, 9.3% forest and orchard, 71% mixture of grass, weeds, and desert shrubs, 7.0% crops, 4.0% urban areas, and 8.4% bare soil (Shammout et al. 2018-in press).

Zarqa River Basin's industries and quality issues

The quality of basin water is influenced significantly by human activities which, in turn affects its uses. Water quality in the basin is affected by many factors; mainly, effluent discharges, poor quality groundwater, return flow, runoff from urban areas and industrial waste discharge.

Since early 1990s, tremendous industrial development took place in the basin. Most of the industrial enterprises were constructed without provisions for adequate treatment of wastewater or safe disposal of waste. Although an environmental law was issued in 2006 after the Ministry of Environment was founded in 2003, environmental regulations are not yet sufficiently implemented. In addition, farm animals in the Zarqa Basin consist of small ruminants (sheep and goats), dairy cattle, poultry farms and few numbers of camels. The majority of these animals are raised in farms (indoors) except for sheep and goat flocks which are extensively raised to utilize the different grazing resources in the basin (e.g. natural vegetation, stubble and wastes and residual of crops). The dairy farms in Wadi Dhuleil contribute significantly to the pollution of water sources in the area.

-<u>Stakeholders and Industries Identification</u>

Jordan has worked on the identification the related stakeholders. These are; Zarqa Chamber of Industry, Greater Zarqa Municipality, Ministry of Water and irrigation, Zarqa Water Directorate, Ministry of Agriculture, Zarqa Agriculture Directorate, The University of Jordan,

Hashemite University, Zarqa National University, Amman Chamber of industry, Ministry of Environment, and the Zarqa Environmental Directorate.

At this stage of the project, there is a direct contact with Ministry of Environment-Zarqa Environment Directorate, and the Ministry of Water and Irrigation. They are very supportive to this project. Moreover, several surveys and visits have been conducted along Zarqa River and the related industries by their support. The information related to industries and heavy metals have been compiled from the related stakeholders.

In this project; Jordan has compiled a list of the industries in the Zarqa River Basin. Where, the main industrial activities in the basin are: Al-Hussein Thermal Power Plant, Petroleum Refinery, Electroplating, Textile, Clothing, Paper and Carton Processing, Painting Industry, Plastic Industry, Leather Production, Food Industries, Dairy Farms, Poultry Farms, Distillery and Food Industries, Pharmaceutical Industry and Chemical Industries, Aluminum Industry, Intermediate Petro-Chemicals, Engineering Industries, and Mining Industries, mainly phosphate.

- <u>Characteristics of water quality of the Zarqa River</u>

Jordan has started to implement the water sampling and analysis based on the protocol document that developed by the NKUA team. Field surveys and visits are conducted along Zarqa River, industries, related ministries, and authorities to identify the sampling locations. Samples are collected from different locations; Abu Nseir Wastewater Treatment Plant (WWTP); **JO01AN**, Berein; **JO02B**, Khirbet es-Samra Wastewater Treatment Plant; **JO03KS**, Al-Qneih Bridge; **JO04QB** Jerash Bridge; **JO05JB**. Figure 2 shows the sampling locations along the Zarqa River. Table 1 shows the analysis of water in the Zarqa River.

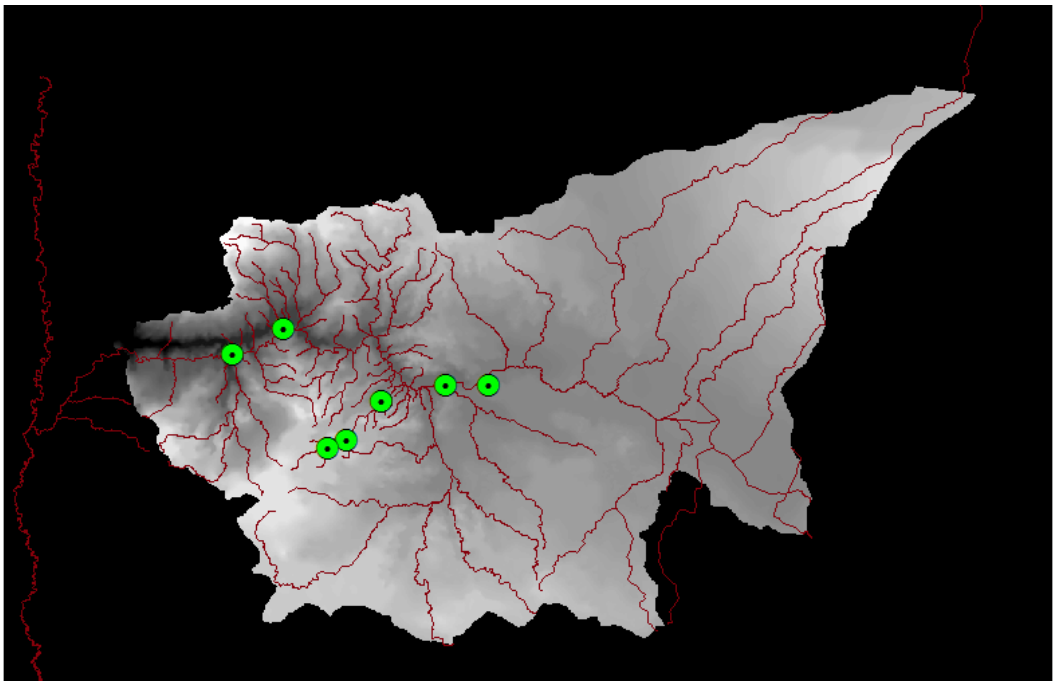

Figure 2 The sampling locations along the Zarqa River

Table 1 Analysis of water along Zarqa River (first stage).

Location/ Summer First stage 2017	Longitude UTM	Latitude UTM	PH Field	EC Field uS/cm	TDS Field mg/l	EH Field mV	DO Field mg/l	DOC mg/l
JO01AN	776352.16	3553396.57	7.74	1750	1064	4.4	4.64	11.82
JO02B	778569.69	3554534.45	7.93	1710	1052	4.6	5.36	11.71
JO03KS	795947.41	3561137.83	7.43	1700	1050	46.9	4.95	13.23
JO04QB	790682.72	3561081.33	8.23	1700	1019	-21.2	5.6	13.62
JO05JB	770878.38	3567955.56	8.57	1850	1101	-1.8	6.48	7.46

Location/ Summer First stage 2017	K mg/l	Na mg/l	Ca mg/l	Mg mg/l	HCO3 mg/l	NO3 mg/l	PO4 mg/l	Cl mg/l	SO4 mg/l	Si mg/l
JO01AN	18.48	227	82.9	35.6	470	27	30	244.8	125	1.8
JO02B	17.43	248	70.84	27.8	338	57	17	288	119.4	1.1
JO03KS	18	260	70	22	330	70	20	309	119	1.4
JO04QB	25	250	70	25	244	81	21	330	113	1.5
JO05JB	30	260	86	28	249	75	22	374	153	1.6

Location/ First stage 2017	Cr ug/l	CrVI ug/l	Ni ug/l	Fe ug/l	Mn ug/l	Co ug/l	Pb ug/l	Zn ug/l	Cu ug/l	As ug/l
JO01AN	20	20	30	40	80	20	80	100	190	220
JO02B	20	20	30	80	80	30	120	100	50	710
JO03KS	20	20	30	60	50	30	160	100	80	660
JO04QB	30	30	30	40	128	30	190	100	85	710
JO05JB	20	20	30	40	20	30	180	70	110	420

Location/ Summer First stage 2017	Al ug/l	B ug/l	V ug/l
JO01AN	700	309	100
JO02B	730	300	100
JO03KS	710	347	70
JO04QB	730	351	100
JO05JB	710	300	100

- **Analysis of existing water uses and demand: sources and uses**

In this task of Work package 2 (WP2); the Geological Survey Department- Ministry of Agriculture Natural Resources and Environment, Cyprus, addresses all CrITERIA participating countries to identify the water sources, uses and demand. This includes water demands (crop evapotranspiration), and net irrigation requirements (NIR) of the main crops cultivated in the studied areas. Jordan has compiled the required information for the Zarqa River Basin:

1- Water sources of Zarqa River Basin

Rainfall:

Rainfall provides the main source of water to the Zarqa Basin. The annual average volume of rainfall based on long term (1937 – 1998) average is estimated at 926 MCM, with a mean

annual rainfall of 217 mm to 248 mm (MWI and JICA, Jordan Master Plan 2000). Most of these amounts are lost by evaporation, while a small part is recharging groundwater. Hydrological studies and MWI reports show that only 7.8% of rainfall is recharging groundwater, while 90 % is evaporated.

Surface Water:

Due to the heavy utilization of groundwater in Amman-Zarqa, the base flow of Zarqa River decreased from 5m3/s to less than 1m3/s. The flow of the river now consists mainly of effluent discharge from three treatment plants. The average annual surface runoff in the Zarqa River as measured at new Jarash bridge is around 68 MCM (43 and 25 MCM for base flow and flood flow, respectively) for the period (1969–1999). The surface water originated from the basin as flood flow mixed with treated water are used partly for irrigation along the river and the rest are stored in King Talal Dam (KTD), which has a designed capacity of 75 MCM. The water in KTD is released for irrigation downstream and in the Jordan valley.

Groundwater:

Groundwater resources of the Zarqa River Basin are very important in terms of supply and use. The main source for irrigational water in Zarqa basin is the ground water. The records of MWI for year 2013 show that there were 885 wells in the basin. Agricultural wells constitute 67% of these operational wells. The annual safe yield of groundwater is estimated at 87.5 MCM. In 2002, there were 710 wells distributed throughout the Zarqa River Basin. These wells are utilized for agricultural and domestic purposes. An obvious increase in water withdrawal was observed during the 1992-2002 period.

Non-conventional water sources:

Treated wastewater is a very important non-conventional water source for ZRB. The main source is the effluent from As-Samra, with a total annual amount of 100 MCM (Year 2016). Other WWTP that provide this source of water include Baqaa with 4.7 MCM, Abu Nsair with less than 1.0 MCM and Al-Mi'rad and Jarash with less than 1.0 MCM. The other non-conventional water source is the desalinized water of Abu Al-Zaigan which is pumped for drinking water use with a total of 12 MCM.

Supply from Inter-Basin Transfer:

The basin used to have water supply for drinking coming from the basins of Azraq, Wala, Lajoun, Swaqa and Jordan Valley, with a total annual amounts of 92.4 MCM (Shammout et al. 2013; Shatanawi and Shammout 2011). The Disi project is currently providing an additional annual amount of 62 MCM of water for Amman.

2- Water uses

In 2002, there were 710 wells distributed throughout the Zarqa River Basin. And, in 2013 there were 885 wells. These wells are utilized for agricultural and domestic purposes. Over-abstraction was evident in the Zarqa basin where the safe yields have been exceeded by more than 100 percent in some years. The irrigated agriculture consumes about 104 MCM of

groundwater resources; much more than the safe yield. As a result, water levels in the main aquifers are declining due to the over-exploitation with some aquifers showing considerable deterioration of their water quality due to salinity. A summary of water consumption (use) by the different sectors in the basin is shown in Table 2.

Table 2 The Summary of groundwater consumption by different sectors in Zarqa River Basin.

Water use	Annual consumption (MCM) by MWI
Drinking	85.0
Industrial	7.4
Agricultural*	63.9
Safe yield	87.5
Total	156.3
Consumption/safe yield	(87.9/156.3)= 179%

The water demands (crop evapotranspiration), and the net irrigation requirements (NIR) of the main crops cultivated in the Zarqa River Basin have identified. By multiplying the total ETc or NIR values of a crop by the cultivated area of the crop in the study site we can calculate the total water demands or irrigation requirements of the specific crop. The respective sums of all cultivated crops in a study site represent the total volume of agricultural water needed. Table 3 that shows the summary of irrigated crops in Zarqa Basin and their annual net crop water requirements (NCWR), Table 4 shows the irrigated requirements for vegetables (lettuce, celery, carrot, radish, green onion) in Zarqa Basin, as an example.

Table 3 Summary of irrigated crops in Zarqa Basin and their annual net crop water requirements (NCWR),

Crop	Area (dunum)	Proportion (%	Average ETc (mm)	NCWR (MCM)
Olives	49,859	27.5	726	36.2
Fruit Trees	41,179	22.7	765	31.5
Forage	6,384	3.5	1206	7.7
Mixed crops	4,393	2.4	888	3.9
Vegetables	77,368	42.7	**500**	38.7
Protected agriculture & nursery plantations	2,100	1.2	810	1.7
Total	181,282	100		~120*

Table 4 Irrigated requirements for vegetables (lettuce, celery, carrot, radish, green onion) in the Zarqa Basin (Planing date: 01/05 and Harvest: 03/08), as an example.

Month	Decade	Stage	Kc	ETc	ETc	Eff rain	Irr. Req.
			coeff	mm/day	mm/dec	mm/dec	mm/dec
May	1	Init	0.7	3.3	33	1.2	31.7
May	2	Init	0.7	3.56	35.6	1	34.6
May	3	Deve	0.77	4.16	45.7	0.7	45.1
Jun	1	Deve	0.89	5.1	51	0.1	50.9
Jun	2	Mid	1.01	6.08	60.8	0	60.8
Jun	3	Mid	1.05	6.37	63.7	0	63.7
Jul	1	Mid	1.05	6.42	64.2	0	64.2
Jul	2	Late	1.05	6.45	64.5	0	64.5
Jul	3	Late	1.01	5.95	65.5	0	65.5
Aug	1	Late	0.96	5.47	16.4	0	16.4
					500.3	3	497.3

- The water analysis along the Zarqa River Basin, Table 1, shows that there is No toxicity with Chromium or CrVI at first stage of the sampling, where it is within the ideal detection limits. Thus, we did more sampling from other locations dated in winter (second sampling). The outreach results for the second sampling have not yet been finished.

- Obviously, Table 2 shows that the safe ground water yield can only supply the drinking water requirements of the population. But, the consumption/safe yield = 179%. This resulted in a decline of groundwater levels as well as the Zarqa River base-flow.

- It can be seen from the Tables 3 and 4 that the total area of irrigated crops in the Zarqa River Basin is about 181,282 dunum, and their total annual net crop water requirements is about 120 MCM. Moreover, the water uses accounting shows a gap between supply and demand as a result of water sectors conflict. This means that the intensive irrigated agriculture taking place in the Zarqa River Basin, as well as inappropriate cropping pattern which includes cultivation of olives and fruit trees.