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DAMS IN JORDAN CURRENT AND FUTURE PERSPECTIVE

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ABSTRACT

Without concrete action Jordan will face a water series problem in the near future. Jordan is a naturally water scarce country. Its climate ranges from semi-arid in the northwestern part of the country to arid desert in its eastern and southern reaches. Jordan is subjected to periodic droughts; water supply from surface sources has declined substantially over the past years. The difficulty to solve water shortage is significant, but not insurmountable. In this study, this issue will be continued without taking real solutions from the government. This paper examines how construction of new dams may reduce the gap between the sources and water demands. Some important information is presented about the dams. Currently existing dams and those that will be constructed in the country in the future perspective plan may resolve the problem of the water shortage. Rainfall harvesting, ponds, and construction new dams in the near future will assist in the reduction gap between water sources and demand.

Keywords: Dams, water resources, watershed, supply, demands.

INTRODUCTION

Currently, Jordan is the 4th country in the world that is suffering from freshwater storage. Jordan's water demand is 900 MCM/yr, as well as 75 percent of it arises in the Jordan River Basin. Total dams capacity in Jordan is estimated at 350 MCM, including the desert dams. There are seven dams that are constructed in the north and middle Jordan valley with a total storage capacity of 270 MCM. These dams include Arab, Ziglab, King Talal, Karameh, Shueib, Kafrein and Al Wehdah Dam. Moreover there are three dams Wala, Mujib and Tannur that are constructed in the southern Ghors with a total live storage of 30 MCM. Stored water from these dams is used for livestock and groundwater recharge (Ministry of Water and Irrigation, Jordan Valley Authority, 2006)

Jordan is a relatively small country with limited natural resources. Jordan is categorized between the arid and semi arid countries. As shown in figure 1 the average annual rainfall in Jordan Valley is (50-300 mm) and the area is (5.7%) of the total area of Jordan, and in High Land the average rainfall is between (400 – 580 mm) and the area is (2.9%), while in the desert Area (Badia) the average rain fall (50 – 200 mm) and the area is (91.4%) of Jordan area.

Annual quantities of rainfall in (MCM): in Wet Years 11000 and Dry years 5800 and the Annual average 8300 (MCM): from these quantities is used as surface and ground water is 8% (Hamdy and Lacirignola, 1999). Jordan can be considered one of the most four water stressed countries in the world, with less than 150 m^3 annual per capita of water resources, while the world water poverty line is 1000 m^3 the water available per capita in1946 was 3600 m^3 and the prediction in 2025 will be 104 m^3 as shown in figure 2. To meet the increased demand on water resources, the Ministry of Water & irrigation in Jordan is working hard for additional water resources for efficient management of water recourses (El-Naser, 1999).

The current state of water infrastructure, institutions, and policies seems to indicate that stabilization or improvement in the water security situation for the Jordanian people will come gradually. Fundamental factors of increasing energy costs and difficulties in financing capital expenditures and operating costs and covering subsidies will slow capital investments, especially as traditional donors reduce their spending (UNU, 1995).

The lack of consistent and accurate data makes long-term planning and management extremely difficult. One specific case that came to the attention of the review team was the 2030 Water Resources Group (WRG) determination that total water supply in 2009 was 866 MCM compared to the official record of 936 MCM, a difference of 70 MCM (Don Humpal *et al*., 2012).

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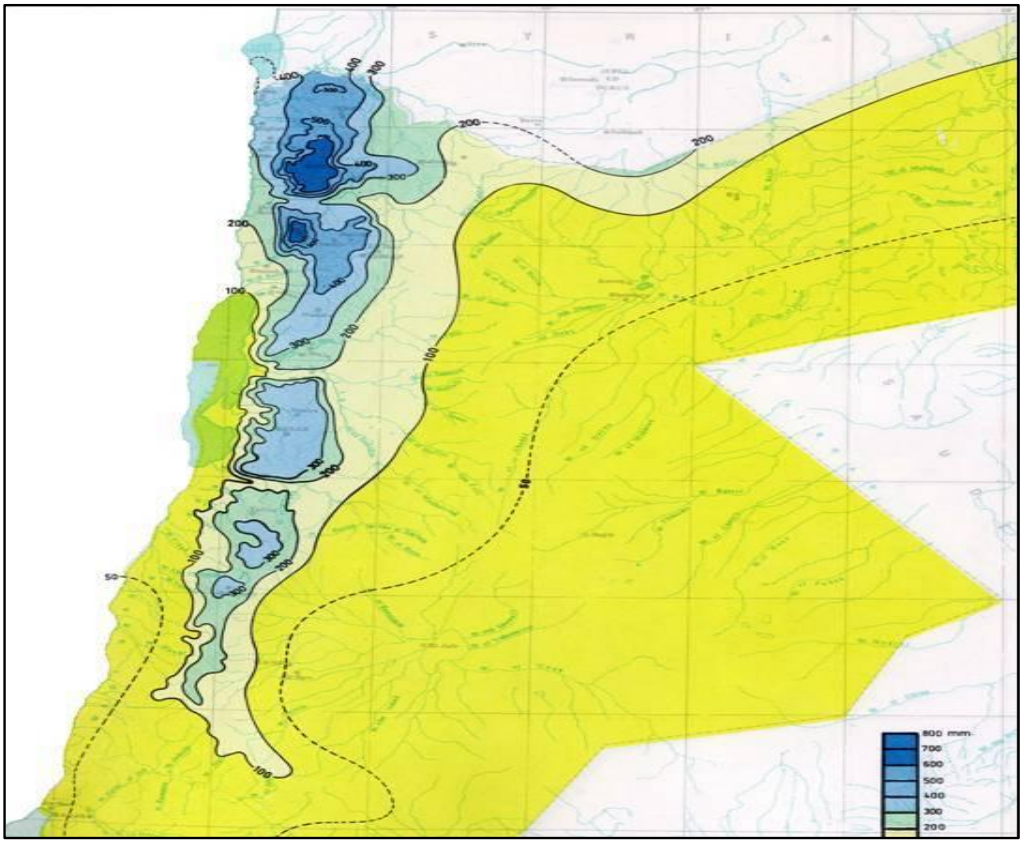

Fig. 1. The average annual rainfall in Jordan.

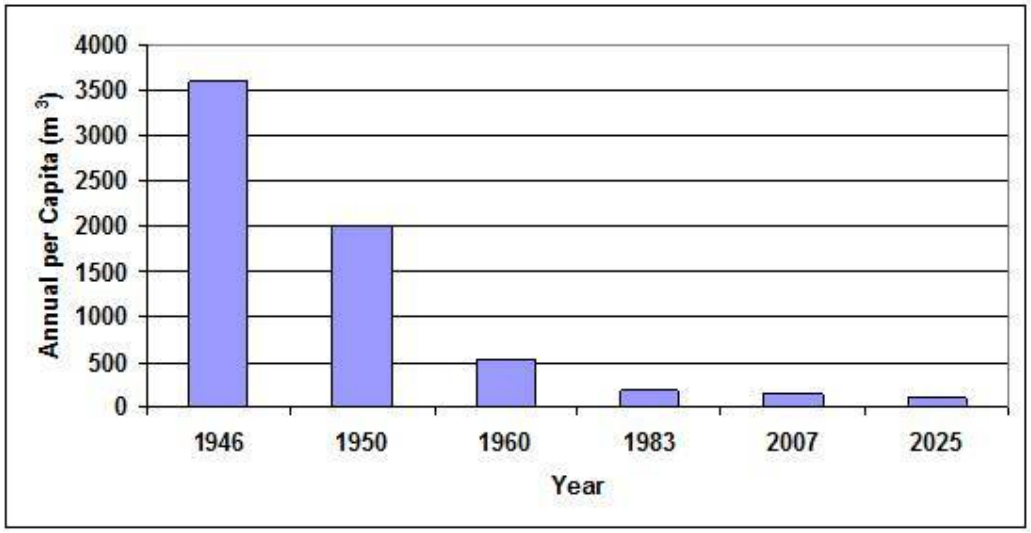

Fig. 2. Annual water available per capita in Jordan.

Surface water resources in Jordan are distributed among 15 major basins, as shown in table 1. Surface water flows in the country's basins vary greatly between seasons and years. The safe yield of the twelve major aquifers in Jordan is shown in table 2. The location of the major watersheds and the flow directions within the basins are shown in figure 3 (a) and 3 (b). The annual amount of surface internal water resources is about 680 MCM (Earth Trends, 2006). The long term average of surface water flows for 15 major basins is shown in table 3.

The major surface water resources is the Jordan River, Yarmouk basin is the largest source of external surface water and it accounts for 40% of the surface water

resources of Jordan, however, the flows of the Yarmouk have significantly decreased primarily due to Syrian dam construction upstream and decreased precipitation over the past 30 years (FAO, 2007).

Table 1. Surface water drainage of Jordan.

	Basin	Annual Discharge MCM
1	Yarmouk	166
2	Zarqa	84
3	Northern Side wadis	58
4	Southern Side Wadis	58
5	Jordan Valley	8
6	Mujib & Wala	102
7	Dead Sea Side Wadis	43
8	Hasa	43
9	Azraq	41
10	Hammad	24
11	Sarhan	18
12	Jafr	13
13	Southern Desert	1
14	Wadi Araba - North	46
15	Wadi Araba - South	8

Table 2. Major aquifers in Jordan.

	Aquifer	Safe Yield MCM/yr
1	Amman-zarqa	60-70
2	Azraq	30-35
3	Yarmouk	30-35
4	Jordan River Side Wadis	28-32
5	Jordan River	15-20
6	Dead Sea	40-50
7	Hammad	11-12
8	Sarhan	7-10
9	Jafr	7-10
10	Disi / Mdawara	2-3
11	Wadi Araba / North	5-7
12	Wadi Araba / South	4-6
	Total	240-294

Water Related Issues

The main water issues in Jordan are: limited Water Supply, water Quality deterioration, and water distribution losses. An integrated Sustainable Water Management Approach is needed for better management of all water resources to cope with increasing demand while preserving the environment (Hadadin *et al*., 2010).

The Major users of water in Jordan (as per year 2007) are:

- Agriculture (63%) = 590.6 MCM/Year
- Domestic (32%) = 301.5 MCM/Year
- Industry (5%) = 48 MCM/Year
- Total = 940.1 MCM
- Dam‘s Supply /2007 = 158.7 MCM, 16.8%

The Average Water Consumption in Jordan over the last decade was over 850 MCM/yr. The demand was increased to about 1600 MCM in the year 2010. The possible sources of needed water are: safe abstraction of groundwater, recycling waste water, surface runoff water, and desalination. The available surface runoff is around 710 MCM/yr. Dams, lagoons, and ponds are viable means of collecting and utilizing surface runoff water, which otherwise would be lost.

Strategy for Dams in Jordan

In order to give a well planned scheme for the future, Jordan has adopted a National Water Strategy. The strategy is a comprehensive set of guidelines employing a dual approach of water demand management and water supply management. It places particular emphasis on the needs for improved water resource management, stressing the sustainability of present and future uses. Special care will be given to protect the water supply against pollution, quality degradation and the depletion of resources. Furthermore, resource management will be improved by increasing the efficiency of conveyance and distribution systems, while the applications and uses of water will be more selectively determined (Tutundjian, 2001).

Ten dams have been constructed in the last five decades with a total capacity of around 275 MCM. The main dam is the King Talal Dam on the Zarqa River, with a total capacity of 80 MCM. The Unity Dam (Al Wihdeh) on the Yarmouk River shared between Jordan and the Syrian have a total reservoir capacity of 110 MCM. All the dams, except the Karamah Dam on Wadi Mallaha, are built on the Side Wadis with their outlets to Jordan river valley (JRV) and are used to store floods and base flows, regulate water and release it for irrigation (Directorate of Planning and Water Resources, 2005).

- Jordan Valley Authority (JVA) is striving to maximize the use of the available surface runoff in order to relieve the dependency on excessive use of groundwater.
- JVA realizes the need for more conservation and collection of various water sources.
- JVA finds in Dams Construction a big potential to provide water for Municipal, Industrial, Irrigation and Livestock.
- JVA also finds in Dams a good potential for recharging the groundwater resources and reducing the over abstraction

Existing Major Dams

The flow in River Jordan has dropped drastically. The water of most of the rivers and wadis draining water

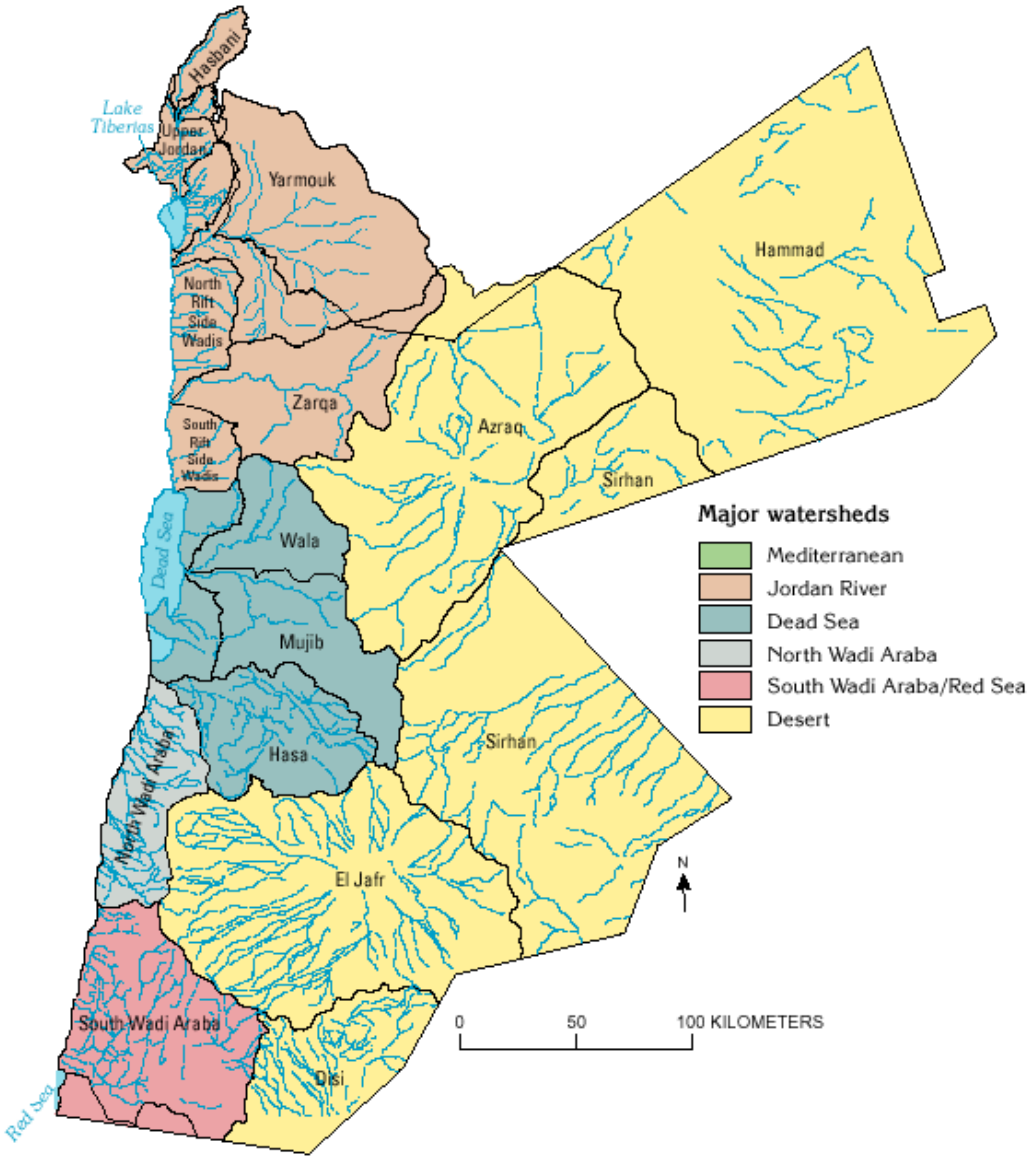

Fig. 3 (a). Major watersheds in Jordan.

towards the Dead Sea basin are being utilized or stored by some nine reservoirs with a total capacity of 221 MCM. The major reservoirs are King Talal Reservoir (KTR), Wadi Al-Arab and Tanour dams, the Unity Dam and others. Al-Wihdeh Dam on the Yarmouk River which is 96-metres-high dam can hold up to 110 MCM of water. Al Wihdeh Dam was completed and became operational in 2007; the water storage behind the dam had reached only 7.5 MCM, which means that only 6.8% of the capacity was used.

Eighteen small dams with capacity of about 30 MCM are located in the desert and the stored water is mainly used for animal uses and artificial groundwater recharge. In addition, many water harvesting projects storing the rainfall in large and small reservoirs.

Location of existing dams in Jordan is shown in figure 4, and the catchment for each dam and its type are shown in table 4, and the dimensions of each dam and its capacity is illustrated in table 5

Desert Dams

Desert covers about 8 090 000 ha or 90 percent of Jordan. It is characterized by a very sparse vegetation cover and an annual rainfall of less than 200 mm. In the past it was only used for grazing. In the last two decades, however, 20 000 ha have been irrigated; using underground water

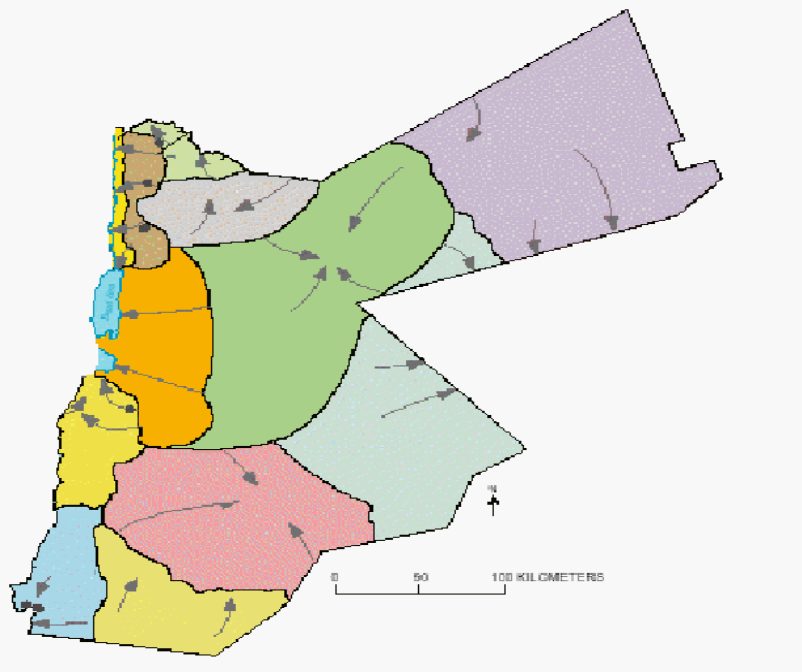

Fig. 3 (b). Flow direction in the major watersheds in Jordan.

Table 3. Long term average of surface water flows.

Basin	Base Fow MCM/year	Flood Flow MCM/yr	Total Flow MCM/yr
Yarmouk	105	155	260
Jordan Valley	19.3	2.4	21.7
North Rift Side Wadis	36.1	13.93	50
South Rift Side Wadis	24.8	7.7	32.5
Zarqa River	33.5	25.7	59.2
Dead Sea Side Wadis	54	7.2	61.2
Mujib	38.1	45.5	83.6
Hasa	27.4	9	36.4
Wadi Araba North	15.6	2.6	18.2
Wadi Araba South	2.4	3.2	5.6
Southern Desert	0	2.2	2.2
Azraq	0.6	26.8	27.4
Sirhan	0	10	10
Hammad	0	13	13
Jafer	1.9	10	11.9
Total	358.7	334.2	692.9

(Source: MWI Water Budget Report, 2011).

and ponds. Desert dams will be established in Badia (semi desert) to provide local population with permanent water resources. The desert dams and artesian wells can be used for agricultural purposes and for watering livestock. In addition, water from the wells may be desalinated and treated for drinking purposes (ESCWA/FAO, 1993).

There are many desert dams in Jordan, their locations are shown if figure 5. Their total capacity is about 32 MCM, the distributions of desert dams in Jordan and their water capacity are shown in tables 6 and 7.

In addition to 0.50 MCM of 14 small dams built by the Ministry of Agriculture in Karak and Tafila Governates. The number of dams, lagoons, and ponds constructed in the desert are: 32 desert dams with a total catchment area of 10313 km^2, 44 lagoons, and 74 ponds. They serve livestock and recharge purposes and their gross storage

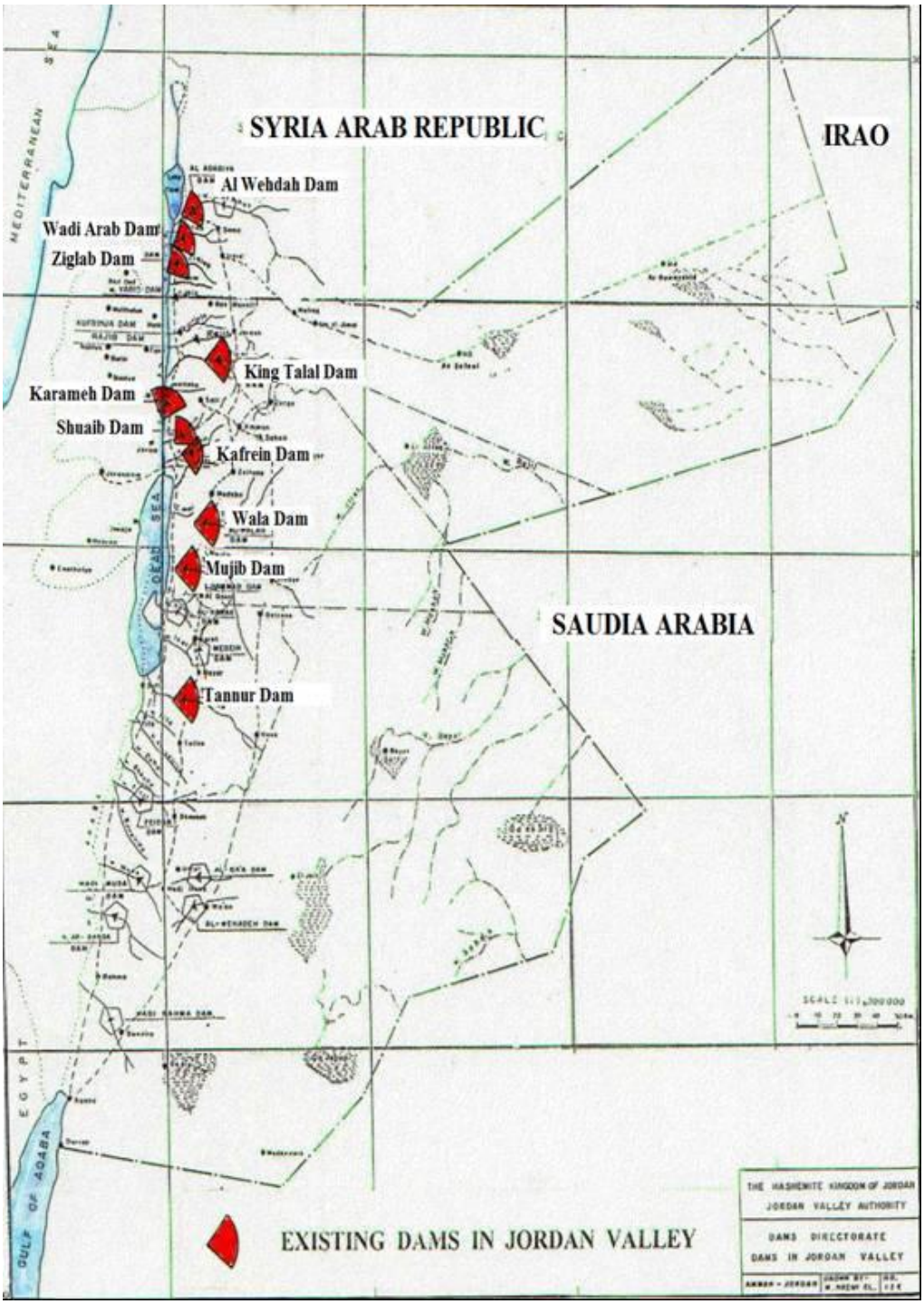

Fig. 4. Location of existing dams.

capacity is 31.25 MCM. The annual impounded of all desert dams from 1995 to 2002 is shown in table 8.

Sediment accumulation reduces the storage capacity of dams, especially King Talal, Kafrein, Wala, Mujib, Sultani and Bowedah dams. Two of JV dams were raised due to excessive accumulations of sediments, i.e. King Talal and Kafrein dams. Sediment removal was done for Sultani, Bowedah and Abu Swaneh Dams. It is found that this process is costly and not highly effective. Multilevel intakes was designed for King Talal Dam, Tender will be announced as soon as the water-level permits. Dams in Jordan face some pollution problem due to: Wastewater treatment plants, agriculture practices, mining and others.

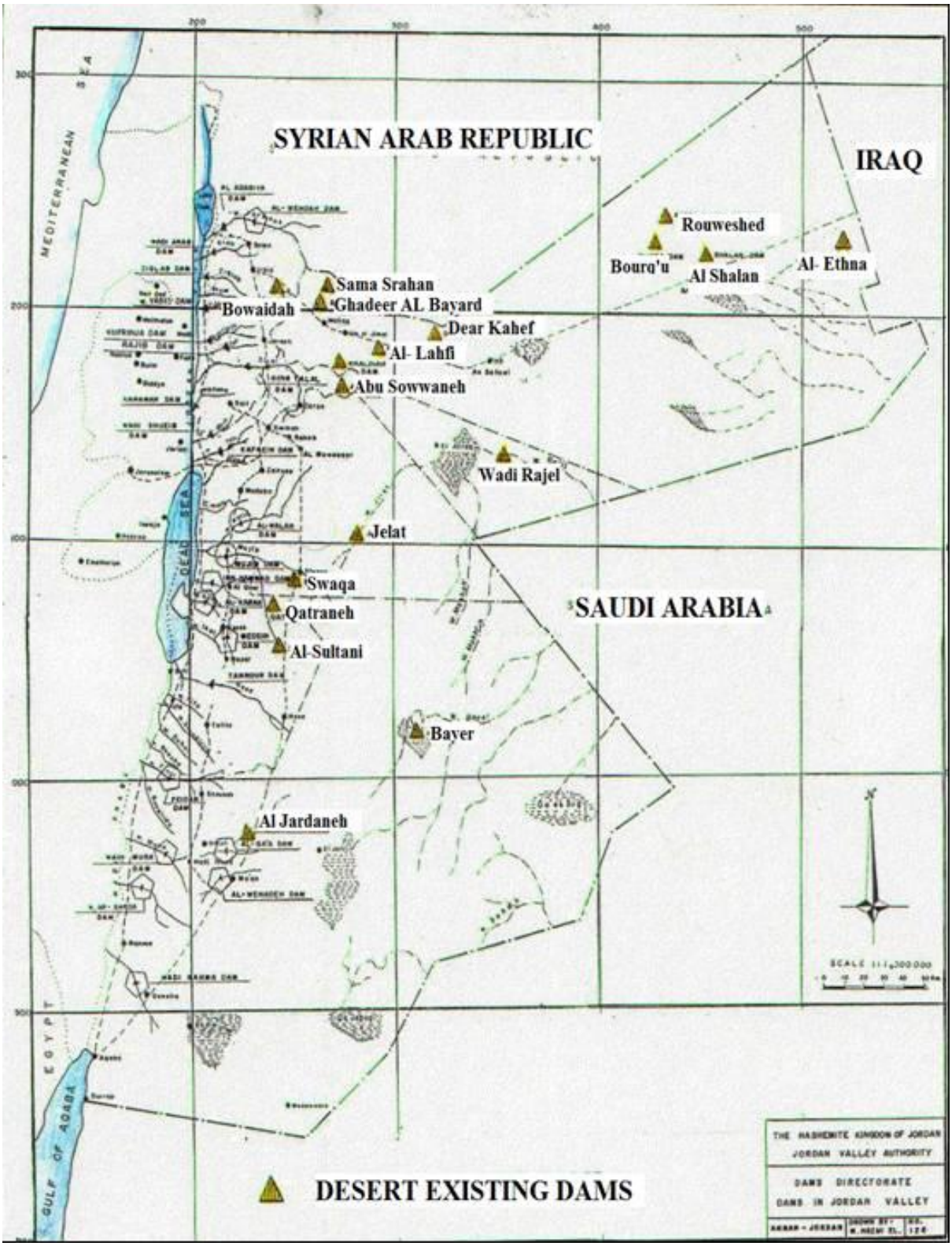

Fig. 5. Location of desert dams.

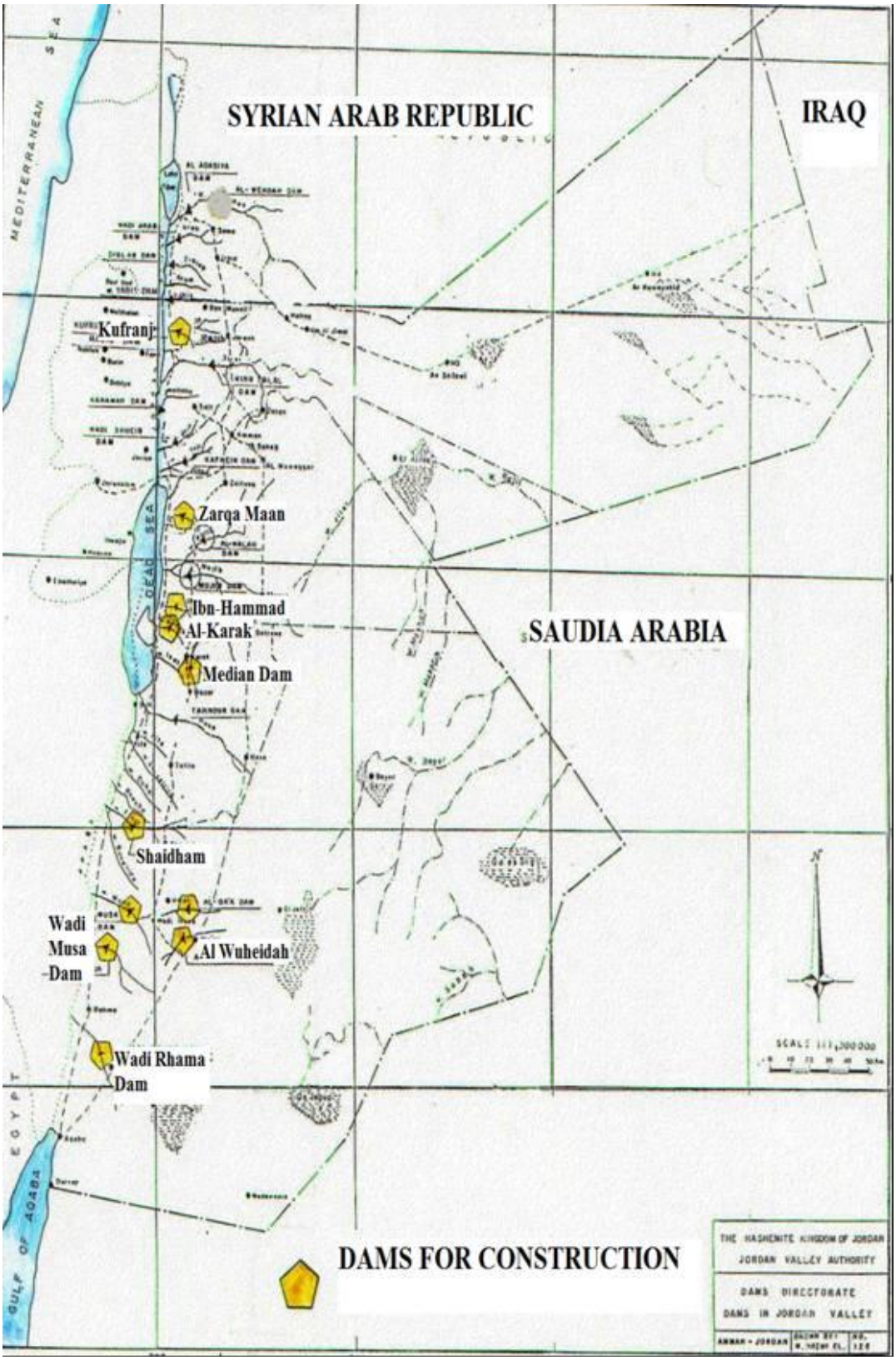

Fig. 6. Location of perspective dams in Jordan.

Table 4. Catchment areas for each dam with its type and purpose.

S. No.		Location	River / Wadi	Catchment Area Km^2	Start of Operation	Construction Cost Million J.D	Dam Type	Purpose
1	King Talal Dam	Eastern Heights	Zarqa	3,700	1977 and raised in 1987	34	Earth Fill	Irrigation & Electricity
2	Wadi Arab Dam	Jordan Valley	Wadi Arab	262	1986	20	Earth Fill	Irrigation, Municipal, Industrial and Electricity
3	Kafrein Dam	Jordan Valley	Wadi Al-Kafrein	163	1967 Raised in Year 1997	9.3	Earth Fill	Irrigation and Recharge
4	Shuaib Dam	Jordan Valley	Wadi Shauib	178	1969	0.56	Earth Fill	Irrigation and Recharge
5	Ziglab Dam	Jordan Valley	Wadi Ziglab	106	1967	0.9	Earth Fill	Irrigation , Municipal, and Industrial
6	Karameh Dam	Jordan Valley	Wadi Al-Mallahah	61.2	1997	55	Earth Fill	Irrigation, Desalination and Recreation
7	Tannur Dam	Taffaila	Wadi Al-Hassa	2160	2001	23.3	Roller Compacted Concrete (RCC)	Irrigation , and Industrial
8	Mujib Dam	Karak Governate	Wadi Mujib	4380	2003	50	RCC & Earth Fill	Irrigation , Municipal, and Industrial
9	Wala Dam	Madaba Governate	Wadi Wala	1770	2003	25	RCC & Earth Fill	Irrigation , Municipal, Industrial and Recharge
10	Al Wehdah Dam	Yarmouk District/ Irbid Governate	Yarmouk River	5000 Km^2 Jordan 1200Km^2	2006	80	RCC	Irrigation , Municipal, and Industrial

Table 5. Jordan existing dams dimension and capacity.

Dam		DIMENSIONS				CAPACITY: (MCM)				
		Height (m)	Length at Crest (m)	Width at Crest (m)	Body Volume (MCM)	Total (MCM)	Dead (MCM)	Life (MCM)	Res. Area (Km^2)	Annual Evaporation MCM/yr
1	King Talal	108	350	11.5	5.7	86	11	75	2.8	4.3
2	Wadi Arab	83.5	434	8.5	3.1	20	3.2	16.8	0.8	1.5
3	Kafrein	37	552	6	2.1	8.2	0	8.2	0.8	1.5
4	Shuaib	32	730	5	0.9	2.3	0.9	1.4	0.3	0.6
5	Ziglab	48	745	6	1.35	4.3	0.4	3.9	0.3	0.56
6	Karameh	44.5	2150	10	11	52	0	52	5	N.A
7	Tannur	60	270	8	0.215	16.8	0	16.8	0.84	N.A
8	Mujib	62	720	9	0.72 RCC and 1.0 Fill	31.2	1.4	29.8	1.98	N.A
9	Wala	45	480	9	0.205 RCC and 7.0 Fill	9.3	1.4	7.9	0.86	N.A
10	Al Wehdah	86	485	7.2	1.43	110	5	105	3.75	N.A

Table 6. Distributions of Desert dams in Jordan.

Dam	Height (m)	Type	Capacity (MCM)
SOME DESERT DAMS-NORTH			
MAFRAQ			
Sama Srahan	8	Concrete Face Rockfill Dam	1.7
Ghadeer Al Bayard	13	Concrete	0.4
Bourq'u	5	Earth Fill	1
Al Aqib	15	Earth Fill	1.1
Dear Kahef	5	Earth Fill/ Masonry Wall	0.05
Al Shalan	3	Earth Fill	0
Al- Ethna	5	Earth Fill	2.05
Rouweshed	7	Earth Fill	10
Total			16.3
IRBID			
Bowaidah	9.5	Concrete	0.1
SOME DESERT DAMS MIDDLE AMMAN			
Swaqa	19	Earth Fill	2.4
Al Muaqar	10	Earth Fill	0.08
Yajous	12	Earth Fill	0.2
Jelat	6	Earth Fill	0.05
Total			2.73
ZARQA			
Al- Lahfi	8	Earth Fill	0.4
Abu Sowwaneh	4	Earth Fill	0.25
Wadi Rajel	9	Earth Fill	3
Wadi Al- Esh	8	Earth Fill	0.05
Total			3.7
SOME DESERT DAMS SOUTH KARAK			
Qatraneh	4	Earth Fill	2
Al- Sultani	8	Earth Fill	0.08
Total			2.08
MA'AN			
Bayer	12	Earth Fill	4
Juloakh	14	Earth Fill	0.05
Al Jardaneh	15	Earth Fill	2.3
Total			6.35

Table 7. Summary of distributions of desert dams in Jordan and their capacity.

Governate	Number of Dams	Capacity (MCM)
Mafraq	8	16.30
Irbid	1	0.1
Amman	4	2.73
Zarqa	4	3.7
Karak	2	2.08
Ma'an	3	6.35
Karak & Tafila *	25	0.565
Total	48	31.825

Table 8. Recorded annual impounding of all desert dams over 8 years.

Year	1995	1996	1997	1998	1999	2000	2001	2002
Impounding (MCM)	2.67	7.89	21.56	21.27	2.89	6.93	14.95	3.00
% of Capacity	8.5%	25%	69%	68%	9%	22%	48%	10%

Table 9. Prospective dams in the near future.

	Cost (MJD)	Capacity (MCM)	Height (m)	Water Usage	Type
Al-Karak	5.4	2.1	25	Recharge	CG
Kufranja	25	8	84	Irrigation and Municipal	CFRD
Al Wuheidah	3.5	0.75	12	Recharge	EF
Ibn-Hammad	25	4	48.5	Irrigation	EF
Shaidham	2.2	0.3	19	Irrigation	CFFD
Dlaga	1.9	0.2	12	Irrigation	CFFD
Zarqa Maan	9.8	2	20	Irrigation	CFRD
Lajjon	3.5	1	20	Irrigation	CFRD
Total	76.3	18.35			

Table 10. Potential dam sites.

	Governate	Catchment area (km2)	Capacity
Al- Haleq	Amman	650	9.4
Al- Butom	Al-Zarqa	140	8.4
Al-Za'atary	Mafraq	429	1.5
Shuaib	Balka	54	1.1
Falhah	Madaba	18	0.8
Aie	Karak	10	0.92
Al-Luban	Tafailah	48	2.7
Zabda	Tafailah	80	0.87
Um Lawzeh	Ma'an	31	2.3
Others (Fanoush, DhretAl-Ramil, Basat Faras)			2.4
Total			31

Future Dams

Future plans included the construction of several dams in the future. Serious consideration was being given by government, the government was concerned that scarcity of water could ultimately place a gap on both agricultural and industrial development. The comprehensive hydrological survey should be conducted, some experts believed that demand for water could outstrip in the near future, for that construct new dams should be the viable priority.The locations of the future dams is shown in figure 6. The estimated cost and future dams and potential dam sites are shown in tables 9 and 10, respectively.

Summary of Dams Storage Capacity
Present and Future

Summary of the total capacity of existing dams, future dams, and desert dams, lagoons, and ponds is shown in table 11. The catchment area of existing dams is about 13980 km^2, desert dams is about 10313 km^2 and the prospective dams is 895 km^2, with a total of 25188 km^2 .

Table 11. Summary of dams storage capacity.

Category	Capacity (MCM)
Existing Dams in Jordan Rift Valley	317
Desert Dams	31.8
Water Harvesting Lagoons & Ponds	2
Dams Ready for Construction	18.35
Potential Dams	31
Total	400.15

CONCLUSION AND RECOMMENDATIONS

The surface drainage of Jordan consists of fifteen basins. Surface water flows in the country's basins vary greatly between seasons and years. The information in this study as well as many other studies done by international organizations differ on the amount of future supply and

demand for water, but they agree, without exception, that there is a serious gap and that simple, realistic solutions to close it are not apparent. For the purpose of this study, is to give data and information to have a look on the existing and projected water supply and needs within the coming years. Projected future water supply availability from all sources shows that the water deficit is increasing with time. Despite the huge investments in the water sector until the year 2025, a considerable water deficit will be facing Jordan. For example, the water deficit for all uses will grow from about 314 MCM in 2015 to 490 MCM by the year 2025. Construction new dams, water harvesting, suppressed demand and rationing distribution programs for domestic uses as well as irrigated agriculture can help to close the gap. Other options such as desalination of Red Sea water may also help Jordan meet future demands. Dam post construction care (operation, maintenance and safety) is essential; furthermore, technical manpower should available to perform such activities to be increased and trained. Cooperation with the Ministries of Environment, Agriculture and Public Works is necessary in the conservation of the catchment area of dams.

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