The Hashemite Kingdom of Jordan

نقابة المهندسين الأردنيين
Jordan Engineers Association

مؤتمر التعدين الأردني الدولي الثامن
8th Jordanian International Mining Conference
JIMC8

19-21 September 2017 Amman

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Prof. Dr. Bashar R. Al-Shreideh

General Manager of Efficiency Development for Energy and Food Co. (EEFCO)

مدير عام شركة تطوير الكفاءة للطاقة والغذاء (إيفكو)

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1.1 Abstract.

Jordan is classified among the countries of very limited water resources with shallow and fragile eco systems. Jordan shares some of its most important water resources with its neighboring countries. These resources from a large percentage of the presently exploited water resources, which the country depends on for meeting present and future water demand.

One of the most important shared water resources is the Jordan River system. Other important shared water resources include the groundwater resources of north Jordan (Disi, Azraq, Yarmouk and Amman Zarqa basins), where a large percentage of the natural recharge occurs in the Syrian territories.

Water resources in Jordan consist of surface and ground water resources as conventional water resource and treated wastewater used in irrigation as a non conventional water resource. Renewable water resources are estimated at about 938 MCM per annum, 276 MCM per year ground water and 662 MCM per year surface water. An additional 143 MCM per year is expected to be available from fossil aquifers

and 50 MCM from brackish aquifers after desalination. Available treated wastewater for irrigation is about 155 MCM per year. Water sector suffering mainly from un accounted of water which keep on a level of 50% , more over water resources suffers of evaporation tension which come to 2600 mm/year from the free surfaces with fluctuation and limitation to the precipitations.

Due to the up normal population growth resulting from Syrian refugees and Arab spring (about 2.5 M) with extra 1.5 M staying for different purposes (study, work..etc,), the total population is about 11 M, the available renewable water resources per capita share are falling from around 170 m^3/cap/year at past to < 90 m^3/cap/year this year 2017. current use is already exceeding the renewable supply. The deficit is made up by overdrawing highland aquifers, resulting in lowering water table and declining water quality. The agricultural sector is the most affected sector in the country it's consume about 78.2% from the ground water, 2519 official well around the country pumping about 280 MCM/ year, more over 735 infracted well were damage by MWI teamwork's within the last few years, unless new resources are made available. The scarcity of water will affect the socio economic and well-being of the people.

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1-2 Physiography.

Jordan is an arid to semi-arid country with land area of 89 thousand sq. Km, extending from the border with Syria in the North to the Red Sea in the South, and From Jordan River border with Palestine in the West to the deserts of the East bording Iraq and Saudi Arabia.

Jordan's topographic features are variable. A mountainous rang runs from the north to the south of the country. To the east of the mountain ranges, ground slopes gently to form the eastern deserts, to the west ground slopes steeply towards the Jordan Rift valley. The Jordan Rift valley extends from lake Tiberias in the north, at ground elevation of 220 m BSL, to the Read Sea at Aqaba at sea level elevation. At 120 Km south of lake Tiberias lies the Dead Sea with water level at approximately 417 m BSL. The southern Ghors and Wadi Araba, south of the Dead Sea, from the southern part of the Rift Valley. To the south of Wadi Araba region lies a 25-km coastline, which stretches, along the northern shores of the Red Sea. The length of the rift valley is 375 km, with width of about 30 Km in the area of Wadi Araba and narrows to around 3 km in the lake Tiberias area.

The highlands East of the Jordan rift valley rise to elevations of more than 1000 m ASL in the north at Ajlum and Belqa and to more than 1200 m ASL in Shoubak and Ras El-Naqab areas. The width of this zone ranges from 20 to 50 Kms and extends from the Yarmouk River in the North to Aqaba in the South. These elevations drop gradually to the plateau in the East, but more sharply to the rift valley in the West.

The plateau of Jordan developed at the eastern toes of the highlands with elevations of drainage areas ranging from 1000 m ASL in the south to 700 m in the northeast. The deepest part of this plateau lies at an elevation of 500 m ASL; Azraq Oasis.

1-3 Climate.

Jordan can be classified as a Semi-desert area. Only the highlands enjoy a Mediterranean climate with a semi tropical climate in the Jordan valley. Summer maximum temperatures average 32°C for the highlands and 38°C for the Jordan Valley and the eastern deserts.

Winter maximum temperatures average 14-17°C in the highlands and the desert areas, and 21°C in the Jordan valley. Winter's minimum temperatures average is 1-4°C in the highlands and desert area with occasional snowfalls on the highlands, while it rarely falls below 8°C in the Jordan valley.

The raining season in Jordan extends from October to April, with peak taking place during January and February. Due to the variable topographic features of Jordan, the distribution of rainfall varies considerably with location. The highest rates of

Precipitations are over the highlands at Ajlun, Belqa, Karak and Shoubak which receive long term annual averages of 600, 550, 350 and 300 mm respectively. Rainfall

amount vary from an average of 600 mm/year in Ajlun (northwest) to 250 mm/year in Jordan valley to 50 mm in the eastern and southern deserts.

The average total quantity of rainfall, which falls on Jordan, is approximately 8558 MCM/year, and it ranges over years between 4000 and 17800 MCM/year. 1.3% of Jordan's area receive an average annual ppt of more than 500 mm, 1.8% between 300 mm, 3.8% between 200 and 300 mm, 12.5% between 100 and 200 mm and the rest of 80.6% receive less than 100mm/year.

Climatic conditions not only affect amount and distribution of rainfall, but also has effect on potentials of evaporation. Potential evaporation range from about 1300mm/year in the extreme northwestern edge of the country, to more than 1900 mm/year in the Aqaba.

Approximately 86% of rainfall evaporates before reaching the surface, 7.2% evaporates from the surface, the rest nearly 5.4% is used to recharge groundwater and 2.4% goes to surface water.

Table (1): illustrates the long-term averages of rainfall and potential evapotranspiration in mm.

Table (1)
Long term averages, rainfall and potential evapotranspiration

Month	Rainfall mm	Evapotranspiration mm/d
Jan	22.16	3.38
Feb	21.85	4.15
Mar	15.30	5.91
Apr	4.90	7.08
May	1.20	9.88
Jun	0.02	11.51
Jul	0.00	10.98
Aug	0.00	10.70
Sept	0.12	8.35
Oct	2.30	6.68
Nov	9.98	5.16
Dec	17.18	3.55
Total mm/year	95.00	2662.68

1-4 Area and Population.

Jordan covers a land area of 90 thousand sq-km. Due to the up normal population growth resulting from Syrian refugees and Arab spring (about 2.5 M), with extra 1.5 M staying for different purposes (study, work..etc,), the total population is about 11 M (2017) is growing rapidly with annual growth rate of about 2.2% (2017) with un expected growth rate of refugees (daily enter) which declining planning. More than 80% of the population is located in urban areas concentrated in the northern governorates of Amman, Zarqa, Irbid, Mafraq, Jerash, Ajloun and Balqa. Were 55% living in Amman and Zarqa area.

The settlement pattern is heavily influenced by water availability. The uneven natural distribution of water resources had resulted in the formation of three demand areas with regard to water availability:

a. Areas where available local water resources, are meeting the demand.
b. Areas where available local water resources, are in excess of the demand.
c. Areas where available local water resources are not sufficient to meet the demand, which necessitated the conveyance of water from distances exceeding of 100 km, and hence required heavy capital expenditure in conveyance of water resources to consumption centers. Table (2) shows area and population information.

Table (2)
Area, population, population density and economy

No.	Description	Unit	Jordan
1	Surface area	Km^2	890000
2	Total population (2016)	000's	11000
3	Urban population	000's	9500
4	Rural population	000's	1500
5	Population density	People/km^2	123.6
6	Population growth (2004 - 2016)	Percentage	5.3
7	GNP 2016	(billion USD)	30
8	GDP/ capita (2016)	USD/ capita	4000

1-5 Water Resources.

Jordan is classified among the countries of very limited water resources. Jordan shares some of its most important water resources with its neighboring countries. These resources from a large percentage of the presently exploited water resources, which the country depends on for meeting present and future water demand.

One of the most important shared water resources is the Jordan River system. Other important shared water resources include the groundwater resources of north Jordan (Azraq, Yarmouk and Amman Zarqa basins), where a large percentage of the natural recharge occurs in the Syrian territories. Table (3) includes some water resources indices for the years 2000 and 2025 (the planning) & the reality on 2017

Table (3)
Water resources indices for the years 2000 and 2025 (the planning) and the reality on 2016

No.	Description	Unit	Jordan
1	Natural renewable resources	Km^3/year	0.94
2	Population 2000	000's	4900
3	Population 2025 minimum	000's	9240
4	Population 2025 medium	000's	9950
5	Population 2025 maximum	000's	11150
6	Resources per capita 2000	m^3/cap	170
7	Resources per capita 2025 min	m^3/cap	84
8	Resources per capita 2025 med	m^3/cap	91
9	Resources per capita 2025 max.	m^3/cap	95
10	Resources per capita 2016	m^3/cap	<90

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Water resources in Jordan consist of surface and ground water resources and treated wastewater used in irrigation. Renewable water resources are estimated at about 940 MCM per annum, 276 MCM per year ground water and 662 MCM per year surface water, Table (4) shows natural renewable water resources. An additional 143 MCM per year is expected to be available from fossil aquifers and 50 MCM from brackish aquifers after desalination. Available treated wastewater for irrigation is about 155 MCM this year. Table (5) illustrates the different water resources.

Table (4)
Natural renewable water resources

No.	Description	Unit	Jordan
1	Surface area	km^2	89000
2	Average precipitation (Internal)	mm/Year	95
3	Average precipitation (Internal)	km^3/Year	8.56
4	Actual Evapotraspiration (Internal)	mm/Year	2662.68
5	Renewable resources (Internal)	km^3/Year	0.80
6	Runoff/Precipitation	%	2.37
7	External water resources	km^3/Year	0.14
8	Total natural water resources	km^3/Year	1.083

Table (5)
Estimated different water resources in Jordan

No.	Description	Mm^3/Year
1.	Renewable water resources (Conventional)	940
1.1	Internal	800
1.1.1	Surface	520
1.1.2	Groundwater	280
1.2	External	140
1.2.1	Surface	140
1.2.2	Groundwater	0.0
2.	Non renewable water resources (Conventional)	143
2.1	Groundwater	143
3.	Non conventional water resources	220
3.1	Re-use	155
3.2	Desalination	50
3.3	Water Harvesting	15
4.	Total water resources (sum of 1+2+3)	*1303

*60% of this amount use for irrigation to irrigate more than 1.2 M Donumes = 0.12 M Ha
19% of this percentage is from TWW resources

Due to the up normal population growth resulting from Syrian refugees and Arab spring (about 2.5 M) with extra 1.5 M staying for different purposes (study, work..etc,), the total population is about 11 M, the available renewable water resources per capita share are falling from around 170 m^3/cap/year at past to < 90 m^3/cap/year this year 2017.

current use is already exceeding the renewable supply. The deficit is made up by overdrawing highland aquifers, resulting in lowering water table and declining water quality. The agricultural sector will be the most affected sector in the country, unless new resources are made available. The scarcity of water will affect the socio economic and well-being of the people. Below is a detailed description of water resources in Jordan.

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1. Surface water.

Surface water can be defined as that water which flows permanently in rivers, springs and flood flows.

Permanent flows in rivers, valleys and springs vary monthly and it depends on the quantity and the duration of rainfall. Surface water contributes partly to groundwater. Jordan's surface water is distributed unevenly in 15 basins. The total average surface flow is about 662 MCM per annum, only an estimated 595 MCM can be economically developed.

The Yarmouk basin accounts for 40% of the total surface water in Jordan. This includes water contributed from the Syria part of the Yarmouk basin. Since the water forms the major tributary of the King Abdullah canal, it is considered the backbone of development in the Jordan valley. Other major basins are; Amman/Zerqa, Jordan Riverside, Wadi Mujib, Dead Sea, Hasa, and Wadi Araba.

The flow in Jordan River, which was one of the main water resources before the control of releases from lake Tiberias by Israel in 1962, has dropped enormously except during flood season when the lake is full.

Surface water resources in Jordan, have been extensively developed by the Jordanian Government. Priority being given to the construction of Dams and Irrigation Projects in the Jordan Rift Valley, in order to maximize the utilization of water resources before being discharged to the Dead Sea or the Jordan River.

2. Ground Water.

Ground water is considered the major resource in many areas of Jordan, and the only water resource in some other. It is comprised of both renewable and nonrenewable resources. Jordan's ground water is distributed among 12 basins. Total renewable annual supply "Safe Yield" is about 276 million. Over-abstraction is evident in seven of the basins. The total ground water abstraction from the renewable basins in 1998 was about 395 million cubic meter, an over draft of above 119 MCM.

Water levels in the main aquifers have dropped and are showing considerable deterioration in quality due to salinity. In addition fossil water from Disi (65 MCM) and Jafar (23 MCM) are annually abstracted. Recent estimates indicate that an annual abstraction of 100 MCM from the Disi can be sustained for 100 years and 18 MCM from Jafar basin for 40-year period. Some of the renewable groundwater resources is presently exploited at its maximum capacity and in some cases beyond its safe yield capacity and is approaching the red line limit of exploitation.

3. Wastewater.

According to the Jordanian National Water strategy (2009 – 2022) which concentrated on treated Wastewater as a non conventional water resource. Treated wastewater discharged from 33 exiting treatment plants is an important component of the kingdom's water resources, about 155 MCM per annum of WW is treated and discharged to surface water or directly reused for irrigation, mostly in the Jordan valley.TWW consumes about 19% of the total resources which use for irrigation in Jordan. There's 218 contracts signs between WAJ & reuse farmers covers the direct

reuse locations around the WWTP,s. Wastewater quantity is increasing with population growth, increasing water use and development of sewage systems, which means that we can plan for this non - conventional water resource, spatially that we can expected the future quantity & quality of the output, which should be subjected to the Jordanians reuse standard No. JS893/2007. More over WW regarded as a source of nutrition's to the crops. In Jordan valley (which receives about 91% of the total TWW outflow), TWW mixed with dams water, so it becomes as a source of mix water which can be used for different irrigation purposes, but around the WWTP,s it used mainly for Irrigation of fodder crops & trees, other reuse purposes as fire contending, gardens & golf yards irrigation and artificial purposes could be arrange for it.

The total water use for irrigation in the Jordan valley is about 165 MCM, 80 MCM of this quantity is from TWW source which flow from Khirbet AL – Samra WWTP, other 30 MCM flows from the same TP reused around the plant itself and among the valley between the plant and King Talal Dam.

1-6 Water Use and Demand.

Past & projected future water supply availability from all sources is shown in table (10). The significant features are the large increase in utilization of surface water from the Jordan and Yarmouk rivers, the reduction in the rate of renewable ground water extraction, the development of brackish and fossil groundwater resources, and the increasing significance of reclaimed wastewater.

Irrigation water demand depends on the cropping pattern implemented, cropping intensity, soil types, climates, and irrigation methods used.

Irrigation accounts for almost 60% of all water use. Farms in the highlands are irrigated by groundwater from private wells, highland irrigation expanded from 3.000 ha in 1976 to an estimated 43.000 ha at 1998 and uses about 60% of groundwater. An additional 3000 ha is irrigated by fossil groundwater in the Disi area, using center pivot systems.

Table (6)
Past & projected available water supply (MCM)

Source	1990	2000	2010	2020
Surface	324	375	505	505
Renew. Gr'water	434	407	325	285
Fossil Gr'water	63	61	143	143
Recl. Wastewater	35	74.6	177.8	265.3
Brackish Water	0	0	15	50
Peace Treaty	0	30	50	50
Lower Jordan	0	0	30	30
Total	**856**	**947.6**	**1245.8**	**1328.3**

Irrigation in the Jordan valley covers 26.000 ha (3.200 ha by private wells, the remainder from the King Abdullah canal), 6.000 ha in the southern part of the valley north of the dead sea that is restricted by water availability to winter use only, and 4850 ha in the southern Ghors, south of the dead sea. Water delivery is by pressure pipe; conveyance and distribution efficiency is in the range 60-90%. On farm efficiency of water use varies from less than 60% (Surface Irrigation) to over 80% (drip irrigation).

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Projected irrigation water demand based on crop requirements and estimated irrigation efficiency is expected to be 890 MCM in the year 2020. one of the water resources that are available is the recycled wastewater from municipal and industrial wastewater treatment plants. Obviously, this water will be used for irrigation and more fresh water will be available for domestic and industrial uses. Municipal demand is growing rapidly at 7.4 percent per annum in the normal cases. Average consumption is 130 L/cap/day in the last decade come now to less than 100 L/cap/day, municipal water accounts for about 28% of all water use. Demand cannot be met in most urban areas during half of the year. The shortage results not only from lack of resource, but also from decisions of resources allocation (half of water goes to agriculture), inadequate infrastructure, and inefficiency of water distribution (unaccounted for water average 40-45% in 2016).

The projection of municipal water demand for any country depends on the future growth in population, the growth in the per capita water demand within acceptable social and health limits, and the percentage of projected losses from the municipal water system. All of these rolls were broken in Jordan after 2011, when un accountant of refugees beginning to cross the borders, the same situation happens before in the years 48, 67, 2003.

Future domestic water requirements are calculated as related to the expected average per capita consumption and the projected population. This increase is projected as the result of expected improvement in standards of living and the adequacy of services to most communities. Domestic demands are expected to be 611 MCM (125 m^3/cap/y) (346 L/cap/d). The proposed level of consumption is below the international average water consumption level (500 m^3/cap/y). Even this low figure can be achieved only if accompanied by better guidance, improved efficiency and good management of the operation and maintenance of water systems, mainly to minimize the unaccounted for water average to not more than 15%.

Industry consumes around 4% (39 MCM – year 2014 / no move to this number exceed the year 1998 / table 11) of all water use. Because of the unreliability and relatively high cost of public water supplies, many industries install their own private wells to reduce cost and improve reliability.

Future industrial water demand depends on future industrial development in Jordan. The projected industrial water demand in year 2020 is expected to be 146 MCM.

With growing demand on water due to population increase conditions and the improvement of their standard of living, the gap between demand and supply will increase. The increase in water demand is far exceeding the rate of finding additional supplies. Table (11) shows the actual and projected water balance in Jordan.

Table (7)
Actual and projected water balance in Jordan (1998-2020) in MCM

Year	Municipal	Industrial	Irrigation	Total Actual	Total Requirement
1998	236 297	39 45	623 863	**898**	**1205**
2005	283 282	80 81	679 858	**1042**	**1321**
2010	387 434	99 99	764 904	**1250**	**1436**

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2015	470 518	119 122	693 897	**1283**	**1536**
2020	524 611	136 146	627 890	**1287**	**1647**

Table (8)
Some of the parameters shows the case development

Year	**1960**	**1975**	**2010**	**2017**
Per capita share CM/capita/year	**1000**	**500**	**140**	**<90**
Population/M	**0.884**	**1.81**	**6**	**11**
%irrigation water from the fresh water resources	**---**	**80%**	**60%**	**50%**

1-7 Institutional and Legal Framework.

Three public agencies are responsible for the water sector in Jordan. The Ministry of Water and Irrigation. The Water Authority of Jordan and The Jordan Valley Authority.

A secretary general heads each of them, reporting to the minister of Water and Irrigation.

Ministry of Water and Irrigation is responsible for formulation and implementation of water and wastewater development programs. Its main duties are to plan water resources development, carry out research and studies, monitor water and wastewater projects, establish information systems, and obtain financial resources.

The water Authority is responsible of provision of water and sewage service and water resources management, its job includes monitoring water resource and regulating ground water use.

Development of water resources in the Jordan Valley is the responsibility of the Jordan Valley authority, its functions include provision and monitoring of irrigation, domestic, industrial and municipal services.

Distribution of water responsibilities over three agencies has resulted in duplication of administration and support services, overstaffing, lack of procedures and integration and many other shortcomings.

The Environmental Health Directorate in the Ministry of Health participate in monitoring drinking water quality, wastewater reuse and all other water quality issues. Non-governmental agencies are also involved in the environment and water sector, their aim is to help the governmental agencies in the water and environment protection and availability through awareness programs, some of these agencies are, Jordan

Environment Society, Friends of Environment Society, National Environment and Wildlife Society, The royal Society of the conservation of Nature.

1-8 Recommendations.

1. Activation of water harvesting techniques as :
   a. Building's roof collecting & drainage wells.
   b. Use of fog harvest techniques.
   c. Use of green house roof harvest.
   d. Collect of EC distilled water (10 - 20 L/1 EC/day).
2. Activation of artificial recharge processing's as drainage wells & deep percolation holes.
3. Use of Executive Agriculture in green houses field which can save 70 – 85% of water. The total save com to 20 MCM/year in agricultural sector in Jordan & maximize the crop productivity 40%.
4. Use of O – scoop sub irrigation system for trees, which can save 50% of the modern irrigation techniques.
5. Use of solar irrigation systems & Hygienic systems (sun & air).

1-9 References.

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