# Historical Outline of Water Resources Development in the Lower Jordan River Basin[1]

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**ABSTRACT** The Jordan River is a multinational river flowing southwards through Lebanon, Syria, Israel, Jordan and Palestine. It is totally developed except for the flow of its largest tributary, the Yarmouk River[2] which forms the boundary between Syria and Jordan before joining the Jordan River, downstream of Lake Tiberias, and forms the border between Israel, Palestine and Jordan.

In this paper, the historical development of the Jordan River basin in Jordan, the Hashemite Kingdom of Jordan (HKJ), is addressed, highlighting the most significant factors that have played a role in the process to date. Water for irrigation was and still constitutes the largest share of water use. Thus the focus of this paper is mainly on the exploitation of the water resources of the Jordan River basin in Jordan for irrigation purposes. The scope to cover other uses would be complementary.

Artifacts and historical evidences indicate human presence in the basin 400,000 years ago, while cultivation was mastered about 10,000 years ago. Literature also indicates fluctuating periods of prospers, stagnation, and declining going though the period from Paleolithic, Neolithic, Chalcolithic, Bronze Age, Iron Age, Roman-Nabataeans, Umayyad, Mamluk and Ottoman. However, the developmental momentum of the Jordan River in Jordan has taken place during the last forty years, when large-scale water development projects were initiated and implemented to harness water resources for irrigation. These projects were viewed as the most attractive solution for: 1) absorbing the unexpected influx of refugees from Palestine resulting from the three wars in the region; 2); engineering social changes by settling former nomadic tribal pastoralists or breaking the power of certain landed groups, 3) boosting the brittle economy of the young country and 4) keeping the Jordan valley away from possible military occupation attempts. Time, technical and hydropolitical constraints, population pressures, rapid and unplanned urbanization, together, accompanied by a focus on the economic dimension of development, have forced Jordan into easy and quick solutions, leaving it with out much water and resulting in the overexploitation of water resources of the Jordan River basin and sever water shortage. This poses now a great challenge to planners and politicians.

## 1. Introduction

Jordan is an arid to semiarid country and suffers from sever water shortage, with a very low per capita availability of water, estimated as 163 $m^3$/capita[3] in 1999. Water resources in Jordan are characterized by scarcity, variability and uncertainty, and depend on rainfall. Precipitation has declined over the last five decades and varies significantly throughout the country. It ranges from 50 mm in the desert, east of the

[1] This research contributes to the Comprehensive Assessment of Water Management in Agriculture (www.iwmi.org\assessment) and was supported by a grant from the Government of Netherlands to the Comprehensive Assessment.
[2] A dam is currently under construction
[3] cubic meter/capita /year

country, to 650 mm around Tiberias Lake. Climatic conditions of aridity and high evaporation, population pressure, and the rapid development of the available economic potentials of the country in terms of irrigated agriculture to satisfy the needs of the growing population has resulted in shortages.

On the world-wide scale of rivers, the only river of significant size in Jordan is the Jordan River. The total catchment area of the whole Jordan River system covers about 18,194 km$^2$ (NWMP, 1977). The riparian countries of the Jordan River include Lebanon, Syria, Israel, Jordan and Palestine. The headwater of the upper Jordan River is fully utilized by Israel, through its National water carrier to its coastal areas. The Yarmouk River is the main tributary of the Jordan River, with a catchment area of 6,790 km$^2$[4]. Its riparian countries compromise Israel, Syria, and Jordan of which it lies downstream of both rivers. The annual discharge in Adasayia, in the north of the HKJ, was 467 MCM[5] in the period between 1927 and 1954. Measurements of flow showed that the flow of the Yarmouk River has decreased considerably since the late 1980s (Salameh and Bannayan, 1993). The average water flowing from the Yarmouk to Jordan was reduced due to increasing diversion of water through ditches[6] on the Syrian territory and to the drilling of wells in its catchments. It contribution was estimated as 360 MCM/yr in 1993 (Salameh and Bannayan, 1993). The Yarmouk River joins the Jordan River 10 km downstream of Lake Tiberias. Naturally, and before the headwater development of the river, the Jordan River would discharge around 1,400 MCM of water annually to the Dead Sea, the lowest point on earth, of which 400 MCM/yr[7] came from the Yarmouk River. The Yarmouk River is not fly developed yet. However, a dam has been planned on the river since the 50s but this dam is still not constructed, due to the political hostility between the riparian countries.


Figure 1: **Jordan River Catchment Area**
**& Jordan River Basin Borders in Jordan**

[4] Source: Ministry of Water and Irrigation , WID, GIS, 2003.Yarmouk basin in Jordan total 1391.5 km$^2$
[5] Million Cubic Meter

[6] Syria has constructed more tha 30 small dams in the upper Yarmouk basin, but officials from the JVA and the National press (Jordantimes) mentioned ditches and not dams.
[7] Year

The lower Jordan River forms the borders between Jordan, on the east bank of the river, and Israel and Palestine, on the West Bank of the River. Surface water resources in Jordan mainly come from the Yarmouk River and the Jordan River's eastern tributaries. Jordan cannot use the water of the Jordan River, as its natural fresh water flow has been interrupted, with only the return irrigation flows, saline water and some winter floods remaining. The eastern lower Jordan River catchment lies completely within Jordan and consists, in addition to the Zarqa river, nine smaller *wadis* and springs. Most of them are tapped by dams and diverted to the main irrigation canal in the Jordan valley. Water flow from the eastern lower Jordan River amounts to about 145 MCM/yr. The lateral *wadis* flow into the Jordan valley from the Eastern Hills.

Groundwater resources in the Jordan River basin in Jordan include four sub groundwater basins: the aquifer of the Yarmouk River and the northern side wadis, the Jordan valley floor area, southern part of the Jordan valley escarpment, and the Amman Zarqa basin. These basins underline different aquifer systems of which groundwater tables are recharged by precipitation. Of most important is the Amman Zarqa Basin (AZB) in the highlands which covers a total area[8] of 3,918 $km^2$ with about 3,590 $km^2$ in Jordan and 327 $km^2$ in Syria. It includes the country's largest urban agglomeration, major industrial sites and irrigated areas. The AZB has significant groundwater recharge (88 MCM/year) and represents 32% of the nation's renewable groundwater resources (275 MCM/yr).

The Jordan River Basin in Jordan constitutes the wettest area in the HKJ where about 87% of the population is concentrated and the potential economic development is the highest. The Basin provides the country with about 80% of its water resources.

In this paper, the phrases of the "Jordan River Basin", the "Jordan River Basin in Jordan" and the "basin" will be used alternately to mean the Jordan River basin in the Jordanian territories.

The topographic features of Jordan River Basin can be divided into two zones: the Jordan valley depression (JV), also called Al Ghor, which is a part of the Jordan Rift Valley (JRV), with an elevation between 200 m and 400 BSL[9], the eastern mountains and plateau, also called the highlands[10], crossing the country from north to south and ranging in elevation between zero and more than 1000 m ASL[11]. The mountains slope hardly in the western direction towards the JRV depression which was created as part of the Great

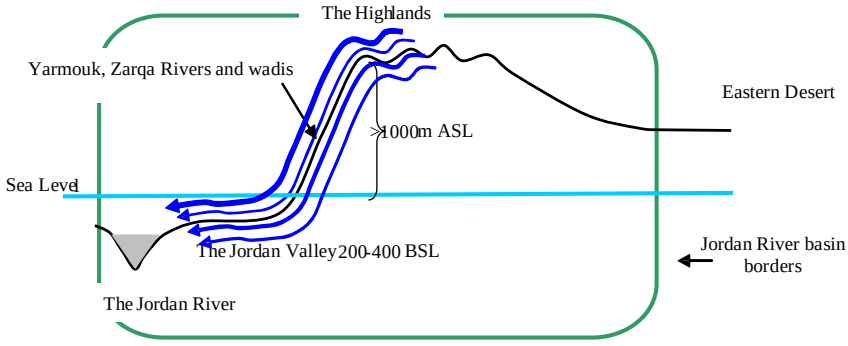


Figure 2: **The Jordan River Basin in Jordan : Topographic Features**

[8] Source: Ministry of Water and Irrigation, Water Information Directorate, GIS, 2003).

[9] Below Sea Level
[10] The highlands in this paper constitute only the part of the highlands that lies in the JRB
[11] Above Sea Level

African Rift extending from Ethiopia through the Red Sea in the south, to Lake Tiberias in the north, creating a new base level for surrounding surface and groundwater. The Jordan River itself flows in a 30-60 meter-deep gorge, flanked by a narrow flood plain. The Jordan valley (JV) is laying in the northern part of the rift valley, upstream of the Dead Sea, and bordering the river on a length of 105 km.

The agricultural activity consumes about 68% of the total water resource in Jordan and is also concentrated in the Jordan River basin (JRB). The Valley has the advantage of producing winter crops at least two or three months before other parts of the Middle East. It is located between 200 and 400 m below the sea level, acting as a natural hothouse. The irrigated area in the Jordan valley is about 30,000 ha, against about 35000 ha in the highlands.

## 2. The Jordan Basin: Historical overview

Artifacts dating back to 400,000 BC have been found in all parts of the Jordanian desert and hill sides, and even in the foothills of the Jordan valley. Unlike the rest of the country, the valley's archaeological evidence only dates back to 10,000 BC. Two theories were proposed to explain the discrepancy. The first theory assumes the existence of a large water body stretching from the read sea in the south to Tiberias Lake in the north. By 10,000 BC, it was broken up into two inland water bodies: the Lake Tebrias and the Dead Sea and two dry valleys: the Jordan valley and wadi Araba in south Jordan. The second theory assumes that human beings have lived in the valley thousand of years earlier but their remains have been covered by successive earth layers accumulated from eroded soil of the eastern and western hills to form the valley floor that exists today.

Archaeological evidence indicates that the desert of Jordan was wetter than today, with huge lakes expected to be found there until 8000-6000 BC era, when the desert was last occupied, forcing people to move westward into the JV where water was available. Rock Basins and pools as natural water collection with enhanced construction storage, were been modified for storage in the Neolithic period (Lancaster, 1999). After 6,000 BC, no evidence of villages and towns in the desert is found. By the late Neolthic and early Chalcolithic periods (4750-3750), Jordan's desert dried out and was emptied of its inhabitants. Only the Jordan Valley and the nearby hills sustained life, with population centers located near water courses (Khori, 1980). The growth and development villages and larger urban centres has taken place for at least 5,000 years and has always been determined by the location of natural water resources.

Archaeological sites in JRB date back to Paleolithic, Neolithic, Chalcolithic, Bronze Age, Iron Age, Roman-Nabataeans, Umayyad, Mamluk and Ottoman Periods. The evidences indicate that the valley's history, like its twentieth-century experience, includes widely fluctuating periods of prosperity and paucity, war and peace, development and stagnation. It reached its peak in the Mamluk era, in the thirteenth, fourteenth and fifteenth centuries AD, and its lowest point during the Ottoman era, in the sixteenth to the nineteenth centuries.

Around 12000 BC, Landscape was domesticated and regional plant repertoire was in place (Lancaster, 1999). Evidences of human activities in the Jordan valley dating

back to 10,000-6,000 BC era was found across the southern end of the valley, from Al-Jalil (Jericho), in the west bank of the Jordan River, which is considered the world's oldest occupied human settlement, to Rama, wadi Nimrin and Wadi Shu'eib in the East Bank. Human beings first mastered cultivated agriculture somewhere near Al-Jalil, near the Zerqa River basin at the wadi Kufrein, 10,000 years ago. Surface water was exploited for agriculture purposes around 8000 BC. The post-Pleistocene era witnessed a momentum towards the cultivation of plants and the earliest plant domesticates. In this age, animals were also domesticated (Lancaster, 1999).

The Neolithic period, 6500-4750 BC, witnessed the presence of large and small villages and nomad's styles of life. The economy of this period was mainly pastoral and rainfed farming of wheat, barley and legumes. Evidences of domesticated sheep, goats, cattle and pigs were found in the eastern desert of the country (Lancaster, 1999).

The early Bronze age (1300-2150 BC) was characterised by a life style similar to that of recent Bedouin. Milk was firstly to be produced in this period and crops of olives, dates, figs, grapes, almonds and pomegranate were introduced in the Jordan valley (Lancaster, 1999). Research indicates that the area of the Basin flourished during the late Bronze Age (1550-1200 BC) when it traded with Egypt, Greece, Cyprus, Syria and Iraq. Proofs of long distance trade between Jordan and Yemen also exist. The side wadis were the only possible trade communication route that was active in the Bronze Age, connecting the eastern hills, Wadi Araba and the Dead Sea, South Palestine, and south west and the Sinai in Egypt (Khori, 1981). Camels are thought to be introduced in this period of time of which they provide significant role in transportation services in trading and pilgrimage activities afterwards (Lancaster, 1999).

The Iron Age I A-C (1200, 918 BC) was a period of strong foreign influence in the valley, and one of the few times in history when it was politically separated from the Hill country in the east. The Philistines had invaded Jordan about 1150 BC from their territories along the Mediterranean coast and heartland at Gaza and Asqalan and ruled the valley for 150 years. They were then defeated by David, who established a short-lived Israelite Kingdom which was split up into two states in 922 BC, and defeated by the Egyptians, loosening their control over the three native Arab kingdoms, Ammonite, Moabite and Edomite. The period 918 to 332 BC was a flourishing period for the Arabic kingdoms and a peaceful time in the valley as most of the people farmed in the valley floor and only few fortified hill cities are thought to be found. The first small sites of urban settlement were established in this era. The Edomites moved to the west of Wadi Araba and settled in Palestine, allowing for a new tribe, the Nabataeans, to move into southern Jordan from the Arabian Peninsula. Jordan was ruled by Greece from 332 to 63 BC, after they defeated the Persians, except for the south which remained dominated by the Nabataeans.

In the era of Roman-Nabataeans, (63 BC to 332 AD), Ten Greek cities were joined together into a league of trading centers called Decapolis, after the conquest of Syria and Palestine by the Romans (Khori, 1981; Abujaber, 1988). From the middle of the first century and for about 100 years, these cites competed with each other to produce the most modern buildings, monuments and urban complexes, replicating Roman architecture (Khori, 1981). New villages were built at the edge of the desert. Building of village institution, administrative church community, houses and water channels

were other signs of the period's prosperity. The economy relied on the flourishing of irrigated agriculture, agriculture industry, trade and Christian pilgrimages (Lancaster, 1999).

The Islamic conquest of the seventh century reached Jordan in AD 630-636 and the Ummayads ruled the area from their capital in Damascus for about 100 years. Meanwhile, Jordan continued to prosper being close to the centre of power (Khori, 1981). The dominated economy was agricultural, urban trade men and crafts. However, it deteriorated when the Abbasids moved the Islamic Caliphate to Baghdad in AD 750. Jordan reverted to a neglected sidelight to historical events, away from the main power centers and trade routes. Since then, the Abbasid, Fatimid and the Seljuk-Zengid era (AD 750-1174) was a period of general decline. The period was characterized by few stable communities, little productive activity, and insignificant construction.

In 1187, the Ayyubid leader defeated the Crusaders and the unification of Syria and Egypt marked the return of Jordan as a pivotal location in the middle of two great civilizations. The Ayyubid-Mamluk era (1187-1516) was a period of general revival of economic activity in the region that lasted until the Ottomans conquest in 1516. The period was characterised by the increase in urbanisation and the institution of the Emirates of Arabs of which the government administration is not necessarily urban but peasants and Bedouin. Under the Mamluks, the Jordan valley reached the peak of its agricultural development, with sugar mills, driven by water, processing sugar cane in many parts of the valley. The area was one among few of the Mediterranean countries that had the potentiality to intensively plant and produce sugar cane on the world market size which had a high economic value at that time. The sugarcanes industry declined when sugar industry was developed in Sicily and Spain. One can conclude that the period must have been a characterised by abundant water resources to irrigate sugar cane plantation and to generate power to many mills.

The prosperity of the Jordan valley started to decline by the Mongul invasion in 1260 AD and after a second invasion in 1401 which left Syria and Jordan destroyed. Most of the cities were burned including Damascus. A period of decline and disarray had started. The poor administration and the central government of the Mamluk aggravated by natural disasters, the spread of epidemic diseases from Europe, and the infrequency of the rainfall had terminated the valley's "wet phase" (Khori, 1981).

When the Ottomans invaded Jordan in 1516, they inherited an already degraded situation and made it worse by imposing high taxes on agriculture, land, commerce, and other forms of income sectors (Khori, 1981; Lancaster, 1999; Abujabber, 1988). As a result, the valley collapsed and since the time of 1600, it was almost deserted.

The Ottomans administration period was characterized by instability and depopulation in both the JV and the high land. Up to 1866, when the Ottomans central government started a land survey, the area was considered as a poor outlying district that did not deserve any attention. Bedouins tribes were the main inhabitants, who moved in and out from the high lands to the JV according to favourable climatic conditions. They were relying on livestock and rainfed crops faming as the main source of income. Pattern of settlements declined but villages and towns remains the centre of economic and political activity. Farmers occupied the northern parts of the country around Al

Salt and Ajlun of which the village settlement was the norm. The pilgrimage and the interregional trading accompanied the pilgrimage rout was an important factor in the rural economy of Jordan. At the end of the First World War, Transjordan, previously called the "south east Bilad al Sham" area came into existence in 1926 under the temporary British administration. It became fully independent in 1946 as the Hashemite Kingdom of Jordan, HKJ (Abujaber, 1988).

The population of Transjordan in 1596 was estimated at 52,000 people, of whom approximately 31,000 occupied the main towns and villages of the northern parts of Irbid, al Ramtha, Ajlun, Jarash, al- Gour and Al Salt (Abujaber, 1988). Mobile groups of Bedouins occupied the uplands located east of these villages.

Jerash, Ajlun and the slopes used to have intensive tree cultivation, including oak, butm, seyal, and sidr. In the late 19$^{th}$ century, the expansion of agriculture, the increase in population, the replacement of local tree products by imported ones, the increase in the Ottoman central government demands for wood for building and their expansion, all contributed to the destruction of the trees. More forest trees were lost to provide firewood, building wood, and charcoal. After the 50s, land was cleared for the expansion of agriculture (Lancaster, 1999).

There is no evidence of attempts at constructing major water supply systems in the Jordan valley. Nobody ever tried to build a canal system such as that finally constructed in the 1960s and 70s to break people's historical dependence on the side wadis and springs. Smaller systems were built throughout history. Before the 1950s, streams were carried in numerous canals over the plain for the purpose of irrigation. These systems were existed in the northern Ghor and along the wadi Zerqa. In the Jordan valley, irrigation was needed at all periods and depends on the channelling of water from springs and the flood water in the wadi beds. From the main feeder channel, subsidiary channels are taken off at an angle to flow water in parcels of land. In the southern Ghor, the wadis were tapped by little channels on its left bank, so that the whole Ghor can be turned into a watered meadow (Lancaster, 1999).

In the highlands, water resources only started to be tapped for agricultural purposes in the end of 19$^{th}$ century, when agricultural expanded to the highlands areas. The last 25 years of this century witnessed the coming of new immigrants of Circassians, Chechen, and Palestinians from the western mountains, Egyptians, and people from Haurran near Damascus, for different political reasons. These populations settled mainly in the highlands. The gradual growth of population resulting from natural or migration causes, the greater stability brought by the Ottoman administration after 1867, the control gained over the countryside, the increasing interest in farming as an economic venture, all contributed to an increasing demand for agriculture land. It was then that farmers started moving to the eastern districts in the area and around Amman, where much larger areas of land were brought under cultivation (Abujaber, 1988) and dense village settlement similar to the Byzantine and early Islamic periods started to be established (Lancaster 1999).

The JV did not contribute to the development of agriculture in the country during the 19$^{th}$ century and it was only by the end of the 19$^{th}$ century and the beginning of the 20$^{th}$ century (1930s), that the valley's agricultural potential was increasingly recognized (Abujaber, 1988; Khori, 1981). Until 1950, the Valley remained only

sparsely populated and of minor significance in terms of agricultural production (Khori, 1981). Attracted by the warm weather and the availability of the food for animals, nomadic Bedouins traditionally used the valley as a winter home growing wheat, barley, and corn, irrigated with the flow of the Yarmouk River and side wadis and moving back with their herds into the cooler hills in summer season, engaging in trade with city's merchants (Khori, 1981; Lancaster, 1999).

The agricultural economy which prevailed in the 19th century defined three landscapes. The upland relied on producing staple cereals, commercial crops of dried fruits, sheep and goats. The irrigated valleys produced grains and commercial vegetables, while the rainfed plains grew grains and provided commercial services. Cereals were planted around lowland springs while commercial fruits of grapes and figs were grown in the upland. Exchange of products and services took place through pilgrimage seasons (Lancaster, 1999).

## 3. The Basin until the early 70s

The twentieth century has witnessed fast moving political events. During the turbulent decades of Jordan's birth and youth (1926-1956), Jordan was established cautiously on erratic foundation of domestic, regional and international uncertainty and conflict.

By the early 1930s, a decade after the establishment of the Emirate of Transjordan, the developmental momentum in the young country started by addressing socio-economic aspects of the small, sparsely populated country. Several attempts of national hydrographic surveys and schemes were initiated in the late 1930s but the unruly political climate in the area blew them away. The idea of harnessing the valley's water resources for agricultural development was compelling to the Jordanian central government in the late 1940s, but due to financial and technical constraints only a few simple and inexpensive projects were implemented.

The clash between the native Palestinians and the hundred of thousands of Jewish immigrants who were pouring into Palestine intending the establishment of a Jewish state in Palestine happened during the 30s. Transjordan with its untapped water and agricultural potentials was envisioned by the international organizations as a destination for either the Jewish immigrants or for the resettling of Palestinians refugees. The Arab-Israeli war of 1947-48 resulted in a sudden influx of Palestinian refugees who settled in the west bank or crossed the Jordan River and gathered in the HKJ. The West Bank was annexed as an expanded area of the Kingdom. The refugee's factor had to be considered in Jordan development plans. The need for a strict control of water resources to make living on the land possible was obvious. Many water projects and plans were proposed to tap water for agricultural purposes and to resolve the growing conflict between the riparian countries of the Jordan River. The projects were politically controversial and thus never implemented.

Due to the crucially importance of the surface water as a national water resource, the historical changes altered the politics of the Jordan and Yarmouk rivers watershed is highlighted in the following section.

### 3.1 The hydro-geopolitical context of the Jordan River

Plans to develop water resources go back to the 1940s and 1950s, when different riparian countries developed individual programs for water utilization leading to disparities over water sharing. The special envoy of the US president, Eric Johnston, devised a plan to placate all the parties to the disputed waters of the Jordan River. The Johnston plan allocated 45 MCM to Syria, 774 MCM to Jordan[12], and 394 MCM to Israel annually. The Arab countries objected that this water allocation was not fair and the Israeli also objected the plan claiming that their water share was not sufficient and that the Lebanon's Litani River should be included if a regional agreement over water dispute was to be reached.

Based on a set of proposals from both parties, Johnston revised his plan and came up with the Unified Plan of 1955, which presumed that water would be diverted outside the basin only after in-basin users satisfied their water needs. The plan allocated annually 132 MCM to Syria, 720 MCM to Jordan, 35 MCM to Lebanon and 394 to Israel. The plan was technically accepted but not finally approved. Israel continued in the implementation of its National Water Carrier project and since it completion, the water of the Jordan River is being utilized by Israel. As a corollary, Jordan and the West Bank have been denied to have their annual water share from the Jordan River.

A bilateral agreement was established between Syria and Jordan which compromise the construction of the Unity dam, *Wehdah* in Arabic, on the Yarmouk River, which would have a gross storage capacity of 225 MCM with effective storage of 195 MCM. Because of the regional political tension and the Israeli reservations over the project, a final settlement was not reached, undermining progress to set up the dam that was agreed upon in the 1987 agreement between the two countries.

Another bilateral agreement over the Jordan River was reached between Israel and Jordan and annexed as article 6 in the peace treaty between them. Based on the agreement, Israel is entitled to pump annually 25 MCM of the Yarmouk River and 20 MCM from the flood of the Yarmouk River in winter but in return has to transfer 20 MCM from the Jordan River to Jordan in summer. Israel is also committed to desalinate 10 MCM/yr out of 20 MCM/yr that already diverted as saline springs to the HKJ. Israel is entitled to provide Jordan with additional 50 MCM/yr of desalinated water. Since the 1950s and despite the diplomatic approaches to have a good share of the Jordan and the Yarmouk Rivers, Jordan couldn't improve the situation which still leaves it with much less of anticipated water that it should have (Hof., 1998).

**3.2 The implementation of the first water project in the JV**

In the early 1950s, Jordan was a country of chaotic finance, general unemployment, with no economic activities or infrastructure. In the period between 1950 and 1960, farming developed in the valley due to two main reasons: the influx of agriculture-oriented Palestinian refugees and the capitalist impulses of famous landowning Jordanian families. Farmers moved from cereals production into the more profitable vegetable production. Cultivated area was estimated at 5500[13] ha. Minor irrigation schemes were started on the east bank of the valley as far as the early 1940s, generally related to harnessing the waters of the side wadis (JVC, 1972). Water irrigation rights were arranged informally between farming communities. In the period between 1949

[12] The West Bank was administratively annexed to follow the Hashemite Kingdome of Jordan after the Arab-Israeli war of 1948.
[13] This figure is estimated and provided from Mr. Avedis Serpekian, JVA

and 1956, diversion weirs and concrete canals were built on the most important East Bank side wadis to irrigate farms located along the wadis.

The implementation of the first water development project was initiated in 1958 when a 69 km long canal started to be constructed. The concrete-lined gravity canal fed by a one km long diversion tunnel running underneath the mountain between the Yarmouk River and the village of Adasiyeh in the north. Lateral channels branch off the main canal to reach the farmlands. The work was divided into three sections to irrigate a total of 11,700 ha in the northern Jordan valley or Al Ghor. The ambition of the time was to construct a 105 km canal along the whole JV. A land distribution scheme was launched in 1962 according to the terms of the East Ghor law, breaking up very large land holdings and allowing more families to live off the rich land. The canal -the East Ghor Canal (EGC)[14] started to operate in the early 1960s. It was a turning point in the modern history of the JV, marking a shift from classical cereals planting to large scale irrigation of high value production of marketable fruits and vegetables.

The construction of the Esat Ghor Canal shifted the control over water resources to the state. Before any government was involved, farmers had traditional systems for sharing water resources. A complicated, but workable system of water distribution, based on both social connections and financial arrangements had developed over hundred of years. The system became obsolete when the government took over management of JV irrigation in 1977. Since then farmers have to apply for acquiring irrigation water based on their land size and plot according to pre-setup irrigation schedules (Nims, 2001; GTZ, 2002).

Fields above the canal were irrigated by wadis and springs. Pumps and plastic pipes take water from springs in the wadi bed gravels to new gardens on the slopes high above the springs. Water was pumped into artificial ponds made by excavating a large pit with a bulldozer and lining this with heavy polythene. The ponds were located at the highest point of the garden and the water is gravity fed through plastic pipes to trickle irrigation piping along the crops rows (Lancaster, 1999). The development of the southern part of the valley (Karamah area) was mainly based on the usage of the groundwater resources, with more wells drilled and more land irrigated.

The progress that had been achieved in the few years following the canal operation was dramatic but all was disrupted again by the events of war and peace in the Middle East (Khori, 1981). The June 1967 war was another historical benchmark which resulted in another massive influx of Palestinian refugees into the east bank. People could not stand the four chaotic and frustrating years which followed the war. The destruction and human displacement caused by the Arab-Israeli war threatened not only agriculture production in the valley itself, but also the very fabric of the Jordanian economy as a whole. The Valley was emptied of its pre-war 60,000 population who fled to the highlands of Amman, Irbid, Salt and Zarqa. The internal clashes between Jordanian and Palestinian forces in 1970-1971 extended the period of chaos in the valley.

When calm was restored in late 1971, the development and rehabilitation of what had been destroyed was vital. A comprehensive and a regionally integrated socio-

[14] It was later called King Abdullah Canal (KAC) after the first King of Jordan.

economic plan was formulated by the Jordan Valley Commission from which today's Jordan Valley Authority originated, during the period 1971-1972. The plan was differed significantly from past attempts by the provision not only of agricultural services but also of all village-based and rural society human services such as roads, housing, schools, electricity, and health caring and commercial centres. The plan was extended beyond the scheduled time implementation due to different reasons and spanned the period from 1975 to 1982. It included a political dimension-to test the attachment of people to the land in order to prevent any further occupation attempts by the Israelis, to invest in the middle of the war zone, and to inject money in a traditionally erratic sector of the national economy.

In the Highlands before the 1950s, most of the inhabitants were nomadic Bedouin tribes who occupied mainly the area of Mafraq and Zarqa governorates in the AZB and who referred to their region as the Badia. In the early 1940s, the government introduced irrigated agriculture in an attempt to test the dubious Bedouin attachment to land and to assist them in settling down. They shifted from animal husbandry to agriculture activity, in which they had virtually no knowledge or experience (Jabarin, 2001). In the 1930, the first wells were dug and water was pumped from Azraq to Mafreq (Lancaster, 1999). The shift initiated the exploitation of groundwater resources. However, the sizable exploitation of ground water in the highlands can be traced back to the 50s and 60s when the diesel motors pumps were heavily introduced.

## 4. The Jordan River basin in the last three decades

### 4.1 The Jordan Valley

The Implementation phase of the socio-economic plan of the Jordan valley moved ahead and other hydraulic investments were realized. The EGC was extended by 18 km to irrigate 3,650 ha and later on by 14.5 km to irrigate 6,000 ha in the south Ghor. Other dams were constructed and agricultural land expanded. It is worth noting that the land allocated along the 14.5 km extension canal is still not distributed as planned and is not being irrigated from the canal due to the declining contribution from the Yarmouk River, except for the rainy seasons in winter. In summer, groundwater from private wells is being used for irrigation.

The agriculture sector has witnesses two periods of farming prosperity and decline.
The first period started to bring the planned benefits after the impressive hydro-construction projects. In the late 1970s, the technical capacity of farmers started to rise rapidly due to the competition for market shares in the Gulf States and to the competition between farmers themselves after the introduction of new technologies such as drip irrigation, plastic houses, row tunnels and application of mulch[15] systems. This was facilitated by soft loans and tax waivers for the import of agricultural inputs. The agricultural development reached a momentum during the 70s and the early 80s of which the agricultural revenues increased tenfold for vegetables and more than doubled for fruits planting. This caused inward migration from the cities to the JV. However, the successive socio-political conditions in the Middle East region have led

[15] The mulch system is a kind of a black plastic sheet covering crops. It was used to suppress the growth of adventives and to minimize the evaporation. The drip irrigation was the most suitable irrigation system to be combined with the mulch.

to the shrinkage of the export market of agricultural products, starting a decline in the Agroeconomic business (Nims, 2001).

The development programs have had other side outcomes. As previously mentioned when the East Ghor Canal was constructed, irrigation responsibility was transferred to officials from the Jordan Valley Authority who could not develop proper communication channels between officials and the farming community. The farmers felt threatened by the loss of their formerly unchallenged decision making powers. The Jordan Valley Authority (JVA) favoured the biggest tribes at the expense of the smaller families and it did not respect the existing socio-political powers structure (Khori, 1981). The consequences of misdistribution of irrigation water, illegal use of water, and inefficiency of water irrigation use are still present to date. Other shortcomings are referred to by Nims (2001), including: the change from subsistence farming to surplus accumulation farming coupled with the shrinkage of export markets and the overlooked growing water scarcity problem, and the overlap between formal and informal water property right systems.

The period of decline in the JV started in the middle of the 1980s. In 1979 at the beginning of the first gulf war, the Iranian-Iraqi war, and at a time when Jordan agricultural productivity was expanding, the changes in regional trade began to alter Jordan‘s position as the main fruit and vegetables supplier of the region. This was also paralleled with the growing water scarcity that was overlooked by the politician's elite.

### *4.1.1 The emergence of water shortages in the Jordan Valley*

According to the JV development program, water was initially allocated to irrigation. In the third consecutive year of drought, in 1978, the National Planning Council was forced to perceive the JV's water resources in a national context. Groundwater and surface water throughout the country were being fast depleted as a consequence of a rising demand relative to limited supplies, and the country fell short of water. The only perceived solution was to construct a conveyance system to divert annually 15, 45 MCM of the Yarmouk surface water to the northern city, Irbid, and to Amman respectively. The Zai water treatment plant was implemented in 1990 to receive the Yarmouk water pumped up from KAC (300 m BSL) to provide Amman (1,350 m ASL) with 45% of its drinking water demand through a 35 km long system of underground steel pipelines. The reduction in the available amount of water for irrigation resulted in the reduction of the irrigated land from the full development of 36,000 ha to 30,000-33,000 ha (Khori, 1981). Since the early 1990s, other measures were adopted to cope with the rising shortage situation. New banana plantation was prohibited and decisions were taken to reduce the water allocated to agriculture and to allocate water for municipal supply of Amman. The amount of water allocated by the JVA to farms was reduced since 1998. However, the reduction of allocated water was not only attributed to regulations but also to the five consecutive years of drought of 1998.

### *4.1.2 The reuse of treated wastewater*

In the 1980s, the reuse of treated wastewater for agricultural purposes was imposed by the increase in domestic and agricultural water demand. Several wastewater treatment plants were built to treat the sewage of the major big cities in Jordan. Treated wastewater used for irrigation increased significantly and reached about 60/yr MCM,

mainly irrigating the areas of the middle and southern Ghor. The treated effluents of Amman and Zerqa are mixed with the water of the Zerqa River, part of which is used locally and then stored in King Talal Reservoir (KTR) to supply irrigated land in the Zaqa triangle and the Jordan valley.

**4.2 The Highlands**

Ironically, when the JVA started to pay attention to the conservation of water, in the late 1970s and beginning of the 1980s regarding the valley, and in the 1970s regarding the highlands, the government was launching a program aiming at encouraging the development of irrigated agriculture. It was granting licenses and soft loans for drilling private wells. It even took further steps. In 1985, the government generously encouraged individuals and private investors to exploit groundwater to expand agriculture into desert land, at the expense of the sustainability of the renewable water resources, and also using non-renewable water basins[16] far away from the population centres (Hadidi, 2002). The government intension was to control people's migration to urban centres and to control un-employment rates. Local circumstances have facilitated farming investments. Some Bedouins sold their land proprieties after they got their well licenses as legally, the land is linked by the water rights. As a result, the pattern of farms ownership shifted to private investors. The shift of irrigated agriculture in the highlands to private sector has been also motivated by the good quality of groundwater of less contamination and salinity, the low cost of irrigation water and the convenient climatic conditions to produce and market profitable crops. The irrigated area expanded from 6,575 ha (NWMP, 1977) in 1975 to 35,000 ha today. The main important crops are vegetables crops and fruit trees such as olive, grapes, apples, and peaches.

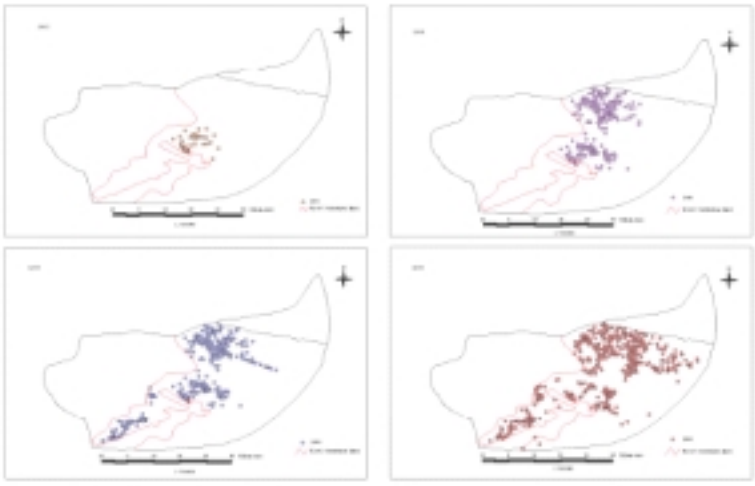

Figure 3: **Increase in Groundwater Abstraction in AZB (1956-1998)**

Irrigated land in the highlands relies on groundwater. In the 1960, groundwater abstraction was estimated at 8.46 MCM and continued to increase during the 1980s. Pumping expanded to the east, north and northeast (see figure 3). Groundwater abstraction in the AZB exceeded the safe yield of 88 MCM by 55% in 1989 and 70 % in 1998. The 1998 extraction rates of groundwater in the AZB were estimated at 150 MCM (MWI and USAD, 2001). Overpumping has resulted in significant water level decline, salinity increase, drying up of springs and reduction of water quality and quantity. Should abstraction proceed without control, about 70 % of the wells located in the north-east AZB would be expected to dry up (MWI and USAID, 2001).

[16] Al-disy and Al-Jarf basins in south of Jordan

Currently the total number of wells used for agricultural purposes in the Jordanian highlands is about 1,150 out of a total of 1,648 for the whole Jordan. In 1995, the groundwater abstraction for irrigation in the uplands was estimated at 190 MCM, accounting for 38% of the total estimated volume of groundwater in Jordan (509 MCM), (Hagan, 1999). Efficiency in the use of irrigation water is not a main concern for farmers. Despite that fact that they use modern drip irrigation system, farmers use this system improperly. They have little experience and knowledge about the efficiency in usage. Agricultural services are almost absent and irrigation water losses are high, since field observations indicate considerable over-irrigation (Chebaane, 2001).

In the 1980s, Amman and Zarqa cities began to be supplied with drinking water from basins outside the Azraq[17] aquifer. The Azraq aquifer was in fact seriously exploited for drinking purposes since the late 1970s. The city of Irbid in the northern part of the western highlands was the first to be supplied with drinking water from Azraq (NWMP, 1977). The pumping of Azraq oasis water to supply the urban centers of Amman, Irbid and Zarqa with drinking water and the illegal uses have destroyed the wetland and its wildlife, incurring a drop in groundwater level of 0.5 to 1 m annually (Lomas, 2002).

The shift from animal husbandry to agriculture during the last four decades in the AZB high lands has resulted in direct improvement of the living standards in the basin and indirect socio-economic benefits to the whole country. Irrigated agriculture represents the main economic activity in terms of population employed and economic return. Currently, the increase of agricultural activity in this basin has led to the establishment of input and output industries that constitute about 85% of the agribusiness firms in the country (Jabarin, 2001). It is the most developed watershed in Jordan and the fastest growing region both industrially and in terms of population. The petroleum boom of 1973 in Gulf countries and its economic impact on the region contributed to the overall economic growth. However the overabstraction of water by private and public sectors and the expansion of unplanned irrigated cultivable land are threatening what has been achieved to date (Jabarin, 2001).

The second Gulf war has significantly impacted the country. On one hand, the beginning of the 1990s was marked by the arrival of more than 400, 000 wealthy Jordanian and Palestinian immigrants from the Gulf countries who mainly settled in the Amman-Zarqa basin increasing the water demand in the basin. On the other hand, agricultural exports have decreased dramatically. Gulf countries have discontinued importations of agricultural products from Jordan because of its political position and support of Iraq during the war. Saudi Arabia blocked its fruit and vegetables market to the Jordanian products that are irrigated with wastewater. Consequently, the agriculture income has substantially dropped by around 40% from 1994 to 1999.

The government then started to be aware that agriculture could not expand any more in both the Jordan valley and in the highlands, and different measures to alleviate the supply demand deficit were taken. These are:

- Reduction of irrigation water allocated to the Jordan Valley

[17] It lies in the eastern side of the country

- In 1992, drilling agriculture wells was prohibited in all the areas of the country (Hadidi, 2002).
- Control of the abstraction of ground water. In 1994, the Ministry installed water meters on agricultural wells to measure and control the extracted water.
- In 1995, the Jordanian authorities adopted a new strategy aiming at the implementation of a water allocation policy. The priority for water allocation was firstly attributed to the urban sector then to the industrial and tourism sector, and finally to the agricultural sector.
- Investigations have been carried out to bring water from Disi aquifer[18] in the south of the country to Amman city.
- The Ministry began to review the water sector and to publish policy paper concerning its strategies to manage water utility, groundwater, surface water and wastewater resources.
- Imposition of a fee of JD 0.25 per $m^3$ of exploited groundwater for drinking purposes in the middle of April 2002 (Hadidi, 2002).

### 4.3 New strategy context

The council of ministries approved a water strategy for the country in 1997 and 1998. The strategy aims at securing reliable supplies of adequate quality and quantity, the protection of water resources, enhancement of distribution and allocation efficiency. The strategy also focuses on a more commercial approach to the distribution of available water resources and explores the notion of Water User Association. To bridge the gap between demand and supply of fresh water, the government has taken the initiative to integrate marginal water resources (treated wastewater and brackish water) into the strategy for irrigation. Irrigation is still the dominant user of water in Jordan (Hunaiti, 2002), and thus a special attention is given to irrigation water management policy. The policy underlines the importance to keep irrigated agriculture and to attain sustainability. It emphasizes resource development and use and stresses the need for technology transfer. It also encompasses control through installing water meters on the groundwater wells and pricing of irrigation water.

The new strategy allowed the involvement of the private sector in the management and operation of the water utilities. In 1999, a management contract was awarded to Lema Water Company which is a consortium including the international French water company Lyonnaise des Eaux[19] and the local company of Montgomery Watson-Arabtech Jardaneh. The government intends to carry out other privatization projects in other governorates in the south and north of the country (Suleiman, 2002).

## 5. Institutional arrangement and water administration

Three public agencies are vested with primary responsibility of water sector in Jordan: the Jordan Valley Authority (JVA), the Ministry of Water and Irrigation (MWI) and the Water Authority of Jordan (WAJ).

[18] The Disi aquifer is lying in the extreme south of the country. It is a fossil aquifer. It is now used for municipal agricultural and industrial purposes.

[19] Called later: Ondeo water service

*The Jordan Valley Authority* (JVA) is the governmental organization responsible for the social and economic development of the JRV. Originally established in 1972 as the Jordan Valley Commission, it was renamed "Jordan Valley Authority" in 1977, under the Jordan Valley Development Law of the JRV and its evolution as a permanent and structured development planning body for the Jordan Valley was a major new initiative in the evolution of integrated planning concept in Jordan (Mallat, 2001). This law was subsequently modified in 1988. The Jordan Valley Development Law (Law 19/88) constitutes a general law aiming at implementing an integrated water and socio-economic project taking into consideration all aspects of relevant to development (Mallat, 2001).

The JVA responsibilities are beyond the provision of infrastructure and waterworks and extend to the development of water resources and environmental conditions, protection and conservation of resources, and facilitating conditions for the welfare of the valley (Daher, 2001). Although the responsibilities of the JVA are identified by the Jordan Valley development law of 1988, it lacks autonomy and has a conflict of interest and unfair reciprocity relationship with several of the government's institutions, creating confusion with respect to its mission statement. The JVA provides services for other institutions while all sales taxes and revenues accrue to the central governmental treasury (Daher, 2001).

*The Water Authority of Jordan* (WAJ) was created under the law No. 18 of 1988. The WAJ is an autonomous corporate body with financial and administrative independence but its provisions could be partly in contradiction with rules binding official authorities. It has the responsibility to manage all the water and sewerage systems and related projects. The responsibilities and tasks cover areas like survey, development, regulation of water resources and study, design, construction, operation and administration of water and public sewerage project (Suleiman, 2002).

*The Ministry of Water and Irrigation* (MWI) was created under by-law 54 of 1992. The responsibilities of MWI include the formulation of national policies and strategies, planning of water resources development, procuring financial resources, and monitoring water and wastewater projects. The establishment of the MWI was in response to Jordan's recognition for a more integrated approach to effective national water management (Nemer, 2001; Suleiman, 2001).

## 6. Water pricing

A water tariff for irrigation water in the Jordan Valley was first introduced in 1961, when the price was set at 1 fils[20] per $m^3$. In 1966, this rate was raised to 2 fils/$m^3$ for users above 1800 $m^3$/month. The JVA allocates water to farmers every month according to the irrigated area and to crops water needs. In 1974 the price was raised to 3 fils/$m^3$ regardless of consumption. Again in 1989, the price was raised to 6 fils/$m^3$. The price of 6 fils/$m^3$ was estimated to cover 12% of the capital costs and 40% of the operation and maintenance cost (Salameh and Bannayan, 1993). Today, water charges for irrigation averages about 15 fils/$m^3$. Water metering based on consumption is applied for irrigation water in the Jordan Valley with the exception of farmers in the southern part of the valley where private wells are the source of water.

[20] One US Dollar is equal to 700 fils.

In the high lands, farmers themselves have to cover all the costs for their water supply, which is generally extracted by pumping from groundwater wells of 200-600m deep or obtained from neighbours within the farm areas. Before 1984, there were no abstraction limits on well irrigation water. Since then, abstraction quotas or upper limits of 50000, 75000, 100000 $m^3$ /year are imposed on irrigation well licenses issued by WAJ but have been not enforced. Until now, water charges for irrigation averages about 200-250 fils/$m^3$. Water metering on private wells started in 1994, but still is not successful yet (Taha and Bataineh, 2002). About 94% of the groundwater wells in AZB have meters installed of which more than 40% of them are not in a working order.

In Amman and until 1997, the price of domestic water increases with increasing consumption following a block tariff system of water use to which definite progressive prices are assigned. Water for municipal uses was heavily subsidized. Effective in October 1997, and after the water sector review assisted by the World Bank, the entire tariff system was changed to a two part tariffs: volumetric lifeline rate, fixed charges, and water use charges proportional to consumption. The revamped tariff was expected to increase revenues and to attract private sector participation (Suleiman, 2002). Municipal water and wastewater tariffs recover only the cost of operation and maintenance but recovery of the capital cost have started as a part of the on-going pricing actions. Tax payers subsidize the difference of the real cost of water and collected revenues (Taha and Bataineh, 2002). Water charges for domestic uses totals about 600-700 fils/$m^3$ but this figure also includes the sewerage services for the same amount of consumed water.

## 7. Water Balance: A critical Situation

The demand for water in Jordan exceeds the available water resources and the gap between both is projected to widen. The surface water resource has developed to a large extent to be used for irrigation while undeveloped water resources are limited and their exploitation expensive. One of the planned projects is the Wehdah dam on the Yarmouk River which is supposed to supply Jordan with additional 100 MCM/yr of good water quality. The dam may moderately alleviate the water shortage problem if the water supply-demand gap has not been widening by the time of its completion. Also, the government has to carefully scrutinize the planned size of the dam in order to achieve the maximum feasibility of the project as the water of the Yarmouk River entering Jordan's territory has been declining.

In 1997, water demand was 950 MCM. Of this, 450 MCM was taken from surface water and the remaining came from renewable and non-renewable groundwater resources. The gap between the national supply and demand, i.e. the shortfall, is being met by over-abstraction from renewable aquifers at a rate of 180-200 MCM per year that corresponds to about 160% of the sustainable yield from the aquifers (Jaber and Mohesen, 2000). This overexploitation has led to the depletion of some groundwater basins like Jafer and Dhuleil in the 70s and 80s, while others show a sign of depletion with increase in salinity and declining water level (Salameh and Bannayan, 1993). The increase in salinity has initiated the introduction of costly external water sources of less saline from outside the basin to be mixed with the high saline water inside the basin in order to be used and to meet the increasing water demand.

In the past, the major element of the solutions to water scarcity was to increase supply. Recently, some solutions have also come up with options for reducing demand through a more efficient water technology or through water conservation options. However theses solutions did not succeed to alleviate the water shortage problem and to change the overall system. Future water polices have been proposed and focused on both the demand and supply sides and aiming to:

- Enhance increase supply from conventional sources
- Develop supply from non-conventional sources
- Promote greater efficiency and conservation
- Develop an integrated water planning and management framework

## 8. Conclusions

The Jordan River Basin in Jordan went through a fluctuating periods of stagnation and prosperity. However, the most dramatic evolution of the basin was quick and took place during the last forty years, leading to the present deterioration. Regional politics have played the most significant and critical role in that process. In fact, if the Israeli state had not been established on the west bank of the River and if Jordan had not been faced with the sudden flows of refugees during the years 1948, 1967 and 1990, one could imagine a completely different scenario for the basin trajectory, with much less pressure over water resources. The basin was always a victim of the regional hostilities that required the basin to support more than its capacity in a sort lapse of time. This was compounded by faulty policies that exhausted the basin resources to a large extent, while overlooking consequences.

Until the late 1940s, the basin was characterised by abundant water resources in relative to water uses, sparsely and few population who lived mainly on irrigated rainfed agriculture and other complementary economic activities, and limited available technology. All of this has been suddenly changed in the beginning of the 1950s. More advanced technology linked to pumps, canals, pipes, dams, and wells drilling was introduced. This was also accompanied by the increase of populations, the oil boom in the Arabian Gulf states and the availability of export markets, the expansion of irrigated agriculture, and the climatic convenience of the basin in both the JV and the highlands to plant various crops at different seasons. These factors have contributed to a rapid growth and development of the whole country but not in a sustainable approach. The development has resulted in overexploitation of water resources and significant deficient in the water supply- demand equation.

Population pressures coupled with financial, technical and time constraints have in the last few decades given the decision makers only limited choices to absorb the unemployed labour force. Jordan, over the last 40 years, was forced into quick and easy solutions to strengthen its brittle economy and viewed the irrigated agriculture as the most attractive business to overcome prevailing conditions.

Water management of groundwater resources in the last 40 years did not examine deliberately the impact of issued acts and legislations on the water reservoir. One of major reasons leading to the water crisis in Jordan was the uncontrolled expansion of the irrigated agriculture especially in the highlands and the lack of groundwater investigation and studies. The first real groundwater study was lunched at the early

1990s. The late prohibition of digging was too belated, although the bad water situation was recognized. The government focused mainly on the mobilization of the economy and how to increase the agricultural exports.

## Bibliography


**Abujaber, R.** (1988). Pioneers over Jordan: The Frontier of Settlement in Transjordan, 1850-191

**Al-Weshah, R.** (2000). *Optimal use of irrigation Water in the Jordan valley: A Case study*. Water Resource Management 14: 327-338, 2000

**Al-Zabet, T. (2002)** *Modern and Traditional Irrigation Technologies in the Eastern Mediterranian.* It accessed at http://www.idrc.ca/books/focus/953/06-chap05.html on 10/06/02.

**Bataineh, F.; Najjar, M and Malkawi. S**. (2002). *Water Demand Forum; Wastewater Reuse*. Beirut, Lebanon-June 2002

**Daher, R.** (2001). *Jordan Valley Improvement Project Phase A-Report 6*. The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Jordan Valley authority, February 2001

**Davey, J.** (2001). *Jordan Valley Improvement Project Phase A-Report 10. Engineering.* The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Jordan Valley authority, 2001

**EXACT.** (1998). *Temporal Trends for Water- Resources Data in Areas of Israeli, Jordanian, and Palestinian Interest.* Middle East Water Data Banks Project.

**Goussous, R. and Arafat, A** (2000) .*Agriculture*. Research and Studies. Investment Banking Unit.

**GTZ** (1998). *Middle East Regional Study on Water Supply and Demand Development*. GTZ Evaluation Report, Eschborn 1998

**GTZ** (2002). Water *Resources Management for Irrigated Agriculture, Annual Progress Report-June 2001-May 2002*. Amman, June 2002

**Hadidi, K**. (2002). *Water Demand Forum; Water Valuation-The case of Jordan, Valuation of Irrigation Water*. Beirut, Lebanon-June 2002

**Hagan, R**. (1999). *Water Supplies and Use. Hashemite Kingdom of Jordan*, 1999.

**Hasanat. A**. *Jordan's Water Challenge in the New Political Eral*. It accessed at http://www.jordanembassyus.org/081899002.htm on 19/10/2003. PalEco: PeaceMedia, Chapter 9.

**Hof, F. C**. (1998). *Dividing the Yarmouk's Waters: Jordan's Treaties with Syria and Israel*. Water Policy 1 (1998) 81-94.

**Hunaiti, H**. (2002). *Jordan Valley Improvement Project*[21] *Phase A-Report 9*. The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Jordan Valley authority, February 2001

**IWLO**. *Managing water for Peace in the Middle East: The Jordan River*. It accessed at http://www.internationalwaterlaw.org/RegionalDocs/Jordan-Israel.htm on 19/10/2003

**Jabarin, A.** (2001). *Curtailment of Groundwater Use for Irrigated agriculture in the Amman-Zarqa Basin Uplands: A socio-economic analysis.* MWI and USAID-WRPS, 2001.

**Jaber, J. and Mohsen, M**. (2000). *Evaluation of Non-conventional water resources supply in Jordan.* Desalination 136 (2001) 83-92.

**Jayyousi, O**. (2001). *Jordan Valley Improvement Project Phase A-Report 2*. The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Jordan Valley authority, February 2001

**JICA** study team. (2001). *Understanding of Present Conditions of Water Resources Management in Jordan*. JICA 2nd Seminar April, 2001.

**Jordan Valley Commission (JVC)**. (1972). *Rehabilitation and Development Plan of the Jordan Valley (1973-1975)*. The Hashemite Kingdom of Jordan, Jordan Valley Commission, Amman, 1972.

**Khatib A.** (1998). *Jordan, Syria Open Talks on Yarmouk River Water Sharing*. It accessed at http://www.jordanembassyus.org/112298002.htm on 19/10/2003.

**Khatib A.** (1999). *Israel Agrees to Jordan's Request to Take its Share from the Yarmouk's Water*. It accessed athttp://www.jordanembassyus.org/081899002.htm on 19/10/2003.

**Khori, R.** (1981). *The Jordan Valley: Life and Society below Sea Level*. Longman Group Ltd. London and New York, 1981

**Klein, M.** (1998). *Water Balance of the Upper Jordan River Basin*. International Water Resources Association, Water International, Volume 23, Number 4, Pages 244-248, December 1998.

**Lancaster, W.** (1999). *People, Land, and Water in the Arab Middle East*. OPA (Overseas Publishers Association.

**Lomas, N.** (2002). Azraq Basin


[21] The Government of Jordan Obtained a Japanese Grant for the preparation of the Jordan Rift Valley Improvement Project that aiming at water efficiency and reuse and adopting related environmental protection measures, supporting non-agriculture activities and promotion of sustainable irrigation services.

**Mallat, H.** (2001). *Jordan Valley Improvement Project Phase A-Report 1. Institutional Reform.* The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Jordan Valley authority, 2001
**McCornick, P, Taha, S and El Nasser, H.** *Planning for Reclaimed Water in the Amman-Zarqa Basin and Jordan Valley.*
**MWI and USAID**-WRPS. (2001). *Options for Artificial Groundwater Recharge With Reclaimed Water In The Amman- Zarqa Basin And Jordan Valley.* 2001.
**MWI and USAID**-WRPS. (2001). *Plan for Managing Water Reuse in the Amman-Zarqa and The Jordan Valley, Final Report.* 2001.
**MWI and USAID**-WRPS. (2001).*Hydrological Impacts of Overpumping and Assessment of groundwater management options in the Amman-Zarqa Highlands.* May, 2001.
**MWI, WRPS.** (2001). *Progress Report on the Development of Groundwater and Water Reuse Management Plans.* USAID/ARD, April, 2001.
**MWI,USAID-WRPS**, Outline of The Hydrology of the Amman-Zaeqa Basin, May 2000.
**NWMP** .(1977). National Water Master Plan of Jordan, National resources Authority in cooperation with GTZ, HKJ, 1977
**Nazzal, *et al***. (2000). *Wastewater Reuse Law and Standards in Jordan*. Ministry of Water and Irrigation, Amman, Jordan, 2000.
**Nemer, R**. (2001). *Jordan Rift Valley Improvement Project Phase A-Report 3, Water Quality*. The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, February 2001.
**Nims, S.** (2001). *Dynamics of Socio-environmental Conflict within the Changing Contexts of Common Pool Resources: Water Management in the Jordan Valley.*
**Orthofer, R**. (2001). *Land Use and Water Use in the Jordan Valley*. Water, Land, agriculture, and Politics in the Mediterranean Workshop, Brussels 19-20 Apr 2001
**Orthofer, R**. (2001). *Options for a More Sustainable Water management in the Lower Jordan Valley*. Workshop" Rewriting the Water History in Palestine", Oxford Environment Week, 24 Oct 2001
**Qaisi. K.** (2001). *Jordan Valley Improvement Project Phase A-Report 8.Environmental.* The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Jordan Valley authority, 2001
**Radaideh, K**. (2001). *Legal Assessment of the Groundwater Management Recommendations.* MWI and USAID-WRPS, April 2001.
**Salameh, E and Bannayan, H.**(1993). *Water Resources of Jordan Present Status and Future Potentials*. Published by Friedrich Ebert Stiftung ,Amman, 1993
**Salman, A.** (2001). *Jordan Valley Improvement Project*[22] *Phase A-Report 5.Agricultural economics.* The Hashemite Kingdom of Jordan, Ministry of Water and Irrigation, Jordan Valley authority, February 2001
**Suleiman, R.** (2002). *Privatisation of Jordan's Capital Water Utility: Assessment and Evaluation of Water Supply and Wastewater services of Amman Governorate*. Stockholm, 2002
**Taha, S. and Bataineh F**. (2002) *Water Demand Management Forum, Valuation of Water for Domestic Use*. Beirut, Lebanon-June 2002

[22] The JRVIP is a World Bank funded initiative to review the many studies and projects have been undertaken throughout the JRV in recent years, and to identify and assess project components for further sustainable development of the Area.