Economic Feasibilities of Al-Karak Dam Project

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ABSTRACT

Jordan is one of the ten most water-deprived countries in the world. The scarcity of water resources is one of the main challenges facing the country considering the increasing demand on water resources due to high growth in population and improvement in the quality of life. To meet the increasing demands, the country has undertaken extensive reform and investment measures in the water sector over the past decade including the construction of several dams for irrigation, municipal uses and recharge. However, the construction of dams is costly and may have diverse social and environmental impacts. Therefore, a decision to construct a dam is typically based on its financial and economic feasibility as well as on the assessment of its social and economic impacts. This paper presents the economic feasibility of the proposed Al-Karak dam. The dam is intended for efficient utilization and management of Wadi Al-Karak flood and base flow for irrigation of Ghor Al-Mazra farm area and for possible industrial use of several Dead Sea industrial and touristic establishments. The feasibility is performed for two scenarios: one based on observed irrigation requirements and one based on analysis of irrigation requirements for the typical crop patterns. The second scenario adopts an integrated approach of water supplies from Wadi Al-Karak and the adjacent Wadi Ibn Hammad. The results indicate that the dam is feasible; however, it is recommended to evaluate the project as a component of an integrated system of two potential dams on Wadi Al-Karak and Wadi Ibn Hammad. It is believed that this integrated approach will further enhance the feasibility through efficient utilization of the base flow and floods of the two wadies.

KEYWORDS: Economic feasibility, Dam feasibility, Dams, Irrigation feasibility.

INTRODUCTION

Jordan's water resources are, on a *per capita* basis, among the lowest in the world. With a high rate of population growth and a continuously improving quality of life, the *per capita* share of water will further deteriorate to unsafe levels in the near future (Alkhaddar et al., 2005). As of 2007, Jordan has annual freshwater resources of 867 million cubic meters per year (MCM/yr) with a total demand of 1505 MCM/yr, creating a demand deficit of 638 MCM/yr. By the year 2040, this deficit is anticipated to be nearly doubled if a solution is not implemented (Jordan Ministry of Water and Irrigation, 2008, 2009).

The problem has two dimensions. The first, and most obvious, is total supply. However, there is an equally important dimension, that of management of the resources available in an integrated manner. Accordingly, Jordan’s economic prospects depend heavily on its ability to improve the harvesting and management of its scarce water resources (USAID 2006).

The primary sources of water supplies in Jordan are surface and ground waters. The annual supply of surface

Accepted for Publication on 15/10/2011.

water is 214.69 MCM, with the Jordan Rift Valley contributing 108 MCM (Khamis, 2005). Springs account for 57.2 MCM and base flows and floods account for 49.4 MCM. Most of the surface water is allocated for agricultural activity, with about 152 MCM allocated for the purpose of irrigation, mainly in the Jordan Valley. In addition, all treated waste water (75.4 MCM) for irrigation purposes is mixed with fresh water to ensure dilution of pollutants from the treated water. The remaining surface water is allocated to municipal, industrial and livestock uses on the averages of 54.4, 2.5 and 6.0 MCM per year, respectively.

Groundwater is abstracted by both public and private sectors. The average total quantity of abstracted groundwater is 520 MCM per year of which 432.8 MCM is renewable and 87.2 MCM is non-renewable (Khamis, 2005). The agricultural sector uses about 54% of groundwater. The municipal sector uses about 40% of groundwater, and the remaining 6% is used for industrial activity.

To overcome the immense water shortages, Jordan is undertaking extensive reform and investment measures in the water sector. These are mainly directed towards decreasing demands (e.g., improving the water distribution system, encouraging efficient irrigation systems and water saving devices and adopting progressive pricing policies), and towards increasing supplies through seeking new sources, harvesting of surface water, reuse of treated water for irrigation and adopting an integrated approach to water management (USAID, 2006).

Long-term solutions, however, are beyond the capacity of the country as they are costly and require regional cooperation and international finance. Among such projects is the proposed Red Sea - Dead Sea project that entails a controlled flow of sea water from the Red Sea to the Dead Sea, desalination of sea water for irrigation and domestic use, generation of cheap electricity and replenishment of the Dead Sea (Jordan Red Sea Project Company, 2011). Feasibility studies and regional negotiations are ongoing but the project implementation will be determined in part by the will of the Jordanian, Israeli and Palestinian authorities.

The country embarked on several ambitious and costly projects that provide short- and medium-term solutions to the water shortage problem. Among those is the Disi water conveyance project under construction (Consolidated Consultants, 2011). It is designed to pump underground water from the Disi aquifer (Allen, May 2010), which lies beneath the desert in southern Jordan, through a 325 km pipeline to supply the Greater Amman Municipality with 100 MCM annually. The project has high initial (USD 1.1 billion) and operating costs due to pumping in the presence of about 800 m difference in elevation. It is estimated that the cost of one cubic meter of water from the project will be 0.74 JD ($1.05 USD) (Namrouqa, August 2010).

The country also invested heavily in the construction of several dams over the past decade. These include Al-Wehdah, Mujib, Tannur and Walah major dams in addition to several medium dams such as Al-Megrin and Feddan dams and several desert water harvesting small dams. There are also several dams under consideration including Kufranjeh, Al-Karak and Ibn-Hammad dams.

Dams have always played a major role in generating cheap and clean electricity, preventing floods and supplying water for drinking and irrigation; however, dams could result and had in some instances resulted in social and ecological disasters.

The contributions of dams to human development cannot be ignored. Dams around the world helped many communities and countries' economies in utilizing and harnessing water resources for food production, energy generation, flood control and other domestic uses. Dams supported 30-40% of the entire irrigated area of the world and thus supported 12-16% global food production (WCD, 2000).

The merits of any dam must be carefully evaluated during the planning and initial design stages. The decision to go ahead with dam final design and construction depends primarily on economic feasibility, social and ecological impacts and availability of finance. The economic feasibility of the dam is a function of estimated costs and benefits of the project and is measured by many indicators, the most common of which are the Benefits to Cost (B/C) ratio and the Internal Rate of Return (IRR).

This paper presents the feasibility study of the Al-Karak dam at the planning and initial design stages of the project. The work has been authorized by Jordan Valley Authority (JVA) being the government agency in the Jordan Valley. JVA has constructed several dams and established an irrigation network system to serve more than 30,000 ha of fertile valley land on Jordan's western border; an area which makes a significant contribution to the total tonnage of fruit and vegetables produced in Jordan.

The Proposed Al-Karak Dam

The proposed Al-Karak dam is to be built on Wadi Al-Karak in the southern region of the Jordan Valley having an average base flow of 99 l/sec. This base flow in addition to the base flow of Wadi Ibn-Hammad of 254 l/sec are currently utilized in irrigating Phase I of Ghor Al-Mazra with a total area of 14,00 dunums located 5 km west of the proposed dam location. Wadi Al-Karak base flow is currently being collected in a weir and conveyed to Phase I area through an existing pipeline designed for a flow of 146 l/sec.

The proposed dam axis is located about 6 km upstream of the main Dead Sea Highway in Jordan Valley. Along this road runs a main water pipeline (1000 mm) that conveys water from Al-Mujib weir southward and supplies water for industrial and touristic establishments at the Dead Sea. This water is pumped from Al-Mujib weir to a storage tank located in Ghor Al-Mazra about 8km south of the proposed dam location, and then flows southward to destination by gravity.

Al-Karak dam yield of 1.9 MCM is envisaged to provide supplementary irrigation water for Phase I of Ghor Al-Mazra and provide water for the several industrial and touristic establishments in the Dead Sea region which are currently being supplied from Al-Mujib basin. The replaced water from Al-Mujib weir will be utilized for the much needed municipal uses in Amman and/or north Jordan through the existing pipe network. This process will also save energy and money as water supplies from Al-Mujib weir are being pumped to Al-Mazra storage tank; whereas water supplies from Al-Karak dam are conveyed to the same tank by gravity.

The project consists of the following works:

1) Dam construction: 30 m high, 201 m long, 1.9 MCM gravity dam. Works include excavation, grouting, dam body, spillway and electromechanical works.
2) Partial realignment and relocation of the irrigation pipeline with a controlled flow of approximately 146 l/sec.
3) Construction of approximately 5km long, 500 mm pipeline from the dam to an existing storage tank.

This paper presents the economic feasibility of the dam for different scenarios pertaining to water usage and the underlying assumptions thereto. The different scenarios and the underlying assumptions of water usage are presented first. The costs and benefits of each scenario and the associated economic feasibility are then presented.

Water Usage Scenarios

The underlying assumption for water usage scenarios is based on the explicit Jordan Valley Authority (JVA) strategy that irrigation usage has priority over industrial usage. Under this assumption, the primary usage of dam water is for irrigation of Phase I crops and the surplus from irrigation will be available for industrial use.

Water for Irrigation Use

Two scenarios of irrigation water requirements of Phase I are considered:

A) Irrigation requirement based on JVA officials assessment of 146 l/sec, i.e., 47 l/sec over the average base flow of 99 l/sec.
B) Irrigation requirement based on the analysis of irrigation requirements of crops 2008 patterns.

These will be referred to throughout this paper as scenarios A and B, respectively. Under both scenarios, irrigation has priority over industrial usage. That is, dam yield in excess of the irrigation requirements is available for industrial use.

Table 1. Open Field Cropping Pattern in Phase I (2008 Data)

Crop	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Used
Tomato (Aut.)	9,739	9,739									1,267	9,739	9,739
Tomato (Spr.)			8,745	8,927	8,927	8,927	8,927						8,927
Jew's Mallow								100	50	50	50		50
Melons						350	350	350	350	350	350		350
Green Beans (Spr.)			301	301	301	301	301						301
Eggplant (Spr.)			493	493	493	493	493						493
Pepper (Spr.)			121	121	121	121	121						121
All Vegetables	9,739	9,739	9,660	9,842	9,842	10,192	10,192	450	350	400	1,667	9,739	10,192
Banana	691	691	691	691	691	691	691	691	691	691	691	691	691
Other Fruits	371	371	371	371	371	371	371	371	371	371	371	371	371
All Fruits	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062	1,062
All Crops	10,801	10,801	10,722	10,904	10,904	11,254	11,254	1,512	1,462	1,462	2,729	10,801	11,254

Source: JVA, 2009.

Table 2. Greenhouse Cropping Pattern in Phase I (2008 Data)

Crop	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Used
GH Pepper			NA	NA	25.5	25.5	25.5						25.5
GH Tomato			NA	NA	3.0	3.0	3.0						3.0
GH Cucumber			NA	NA	15	15	15						15.0
GH Melons			NA	NA	0.5	0.5	0.5						0.5
GH Green Beans			NA	NA	6.0	6.0	6.0						6.0
GH Flowers			NA	NA	5.5	5.5	5.5						5.5
Total					55.5	55.5	55.5						55.5

Source: JVA.

A) Irrigation Requirements for Scenario A

Meeting with JVA officials responsible for the irrigation of Phase I of Al-Mazra revealed that Phase I, with a total agricultural area of 14,000 dunums, is operational with an irrigation water requirement of 400 l/sec. Due to water shortage, the area is currently being irrigated with only 354 l/sec from two sources:

1) Wadi Ibn Hammad base flow of approximately 254 l/sec, and
2) Wadi Al-Karak base flow averaging 99 l/sec. The base flow from WADI Al-Karak is currently being collected in a weir located upstream of the proposed dam axis and transported via an existing pipeline designed for a flow of 146 l/sec. The irrigation water shortage of about 47 l/sec is only required for a period of 300 days.

The existing weir will be abandoned and the pipeline shall be relocated and supplied directly from a dam outlet with a controlled flow.

Roughly, the total quantity of water to be supplied from the dam to Phase I amounts to almost 3.8 MCM per year; i.e., annual flow of 1.2 MCM over the annual base flow of 2.6 MCM. However, this quantity is better estimated through an analysis of the irrigation requirements of the cropping patterns in the area. This analysis is presented next.

B) Irrigation Requirements for Scenario B

The irrigation requirements under this scenario are based on the irrigation requirements of the typical 2008 cropping patterns data obtained from JVA records. This scenario takes into consideration the seasonal water requirements and the available flow from Wadi Ibn Hammad and Wadi Al-Karak. The assumption here is that water from the dam will only be required for the months in which the irrigation requirements exceed the base flow from Wadi Ibn Hammad.

Table 1 shows the open field cropping patterns data of Phase I for the year 2008. Open field Autumn vegetable crops are limited to 9,739 dumums of tomato. Open field Spring vegetable crops total 9,842 dunums: 8927 of tomato, 301 of green beans, 493 of eggplants and 121 of pepper. Other planted vegetables include 50 dunums of jew's mellow and 350 dunums of melon. Planted areas of fruits include 691 dunums of banana and 371 dunums of other fruits, mainly grapes.

Table 2 shows the greenhouse cropping pattern data of Phase I for the year 2008. The data reveals that greenhouse plantation is limited to only 55.5 dunums of spring plants.

Table 3. Net Irrigation Requirement of Open Field Crops (mm/du)

Crop	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Total
Tomato (Aut.)	168	102	30	0	0	0	0	0	0	0	121	109	530
Tomato (Spr.)	0	0	0	0	22	53	146	133	55	0	0	0	409
Jew's Mallow	0	0	0	0	81	117	186	150	0	0	0	0	534
Melons	0	0	0	0	22	41	103	175	209	173	0	0	723
Green Beans (Spr.)	0	0	0	0	2	51	140	24	0	0	0	0	217
Eggplant (Spr.)	0	0	0	0	24	63	147	182	125	0	0	0	541
Pepper (Spr.)	0	0	0	0	27	69	147	182	125	0	0	0	550
Banana	219	113	49	23	26	48	103	140	209	267	294	252	1,743
Other Fruit Trees	128	63	17	0	30	42	103	130	160	165	159	137	1,134

Table 4. Water Requirement of Greenhouse Spring Crops (mm/du)

Crop	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Total
GH Tomato (Spr.)					14	41	92	147	132	53			479
GH Cucumber	61	83	53	62	73	78	34						444
GH Melons				10	40	90	180	240	190	30			780
GH Green Beans	41	14	12	31	55	81	78						311
GH Pepper				28	36	117	104	71	14				370
GH Flowers			60	120	160	100	60						500

The total water requirements for open field and greenhouse crops are shown in Tables 3 and 4, respectively. These requirements are based on JVA data of net irrigation requirements of crops in the southern region of the Jordan Valley, the average rainfall in the region, 90% conveyance system efficiency, irrigation system efficiencies of 80% and 90% for open field and greenhouse, respectively and a rainfall irrigation efficiency of 80%.

Table 5 shows the monthly irrigation requirements for Al-Mazra (Phase I) 2008 crops. As can be seen, the irrigation requirements vary substantially with the month of the year from a minimum of less than 0.019 MCM in January to a maximum of almost 1.84 MCM in October. The total irrigation requirement for 2008 crops of Phase I sums up to 11.135 MCM.

Currently, and as shown in Table 6, Phase I is irrigated with the base flows of Wadi Ibn Hammad and Wadi Al-Karak. The supply from Wadi Ibn Hammad base flow of 254 l/sec throughout the year amounts to 8.01 MCM per year. However, due to wide variation in monthly and seasonal irrigation requirements, only 6.185 MCM of this water is utilized for Phase I irrigation. The remaining 1.825 MCM is a surplus unutilized water of little value to the project. This surplus is due to supply in excess of irrigation requirements over the period from December to March and during July. Consequently, the deficit in irrigation requirements of Phase I of 4.95 MCM (11.135 MCM-6.185 MCM) has to come from the proposed Al-Karak dam.

Table 5. Total Irrigation Requirement of Phase I Area for 2008 crops

Open Filed Crops	Area	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Total
Tomato (Aut.)	9,739	1,636,152	995,715	290,222								1,178,419	1,061,551	5,162,060
Tomato (Spr.)	8,927	0	0	0	0	194,609	471,346	1,303,342	1,187,291	490,985	0	0	0	3,647,572
Jew's Mallow	50	0	0	0	0	4,040	5,840	9,300	7,500	0	0	0	0	26,680
Melon	350	0	0	0	0	7,630	14,280	36,050	61,250	73,150	60,550	0	0	252,910
Green Beans (Spr.)	301	0	0	0	0	542	15,291	42,140	7,224	0	0	0	0	65,197
Eggplants (Spr.)	493	0	0	0	0	11,733	30,960	72,471	89,726	61,625	0	0	0	266,516
Pepper (Spr.)	121	0	0	0	0	3,243	8,325	17,787	22,022	15,125	0	0	0	66,502
Banana	691	151,329	78,249	33,721	16,169	17,828	33,030	71,173	96,740	144,419	184,497	203,154	174,132	1,204,441
Other Fruit Trees	371	47,488	23,462	6,233	0	11,056	15,508	38,213	48,230	59,360	61,215	58,989	50,827	420,580
Total OF Crops		1,834,969	1,097,426	330,176	16,169	250,680	594,579	1,590,476	1,519,983	844,664	306,262	1,440,562	1,286,510	11,112,457
Greenhouse Crops	Area	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Total
GH Pepper	25.5	0	0	0	717	928	2,973	2,655	1,805	362	0	0	0	9,440
GH Tomato	3.0	0	0	0	0	42	123	276	441	396	159	0	0	1,437
GH Cucumber	15.0	915	1,245	795	930	1,095	1,170	510	0	0	0	0	0	6,660
GH Melon	0.5	0	0	0	5	20	45	90	120	95	15	0	0	390
GH Green Beans	6.0	243	85	74	184	327	485	465	0	0	0	0	0	1,863
GH Flowers	5.5	0	0	330	660	880	550	330	0	0	0	0	0	2,750
Total GH Crops	55.5	1,158	1,330	1,199	2,495	3,292	5,347	4,326	2,366	853	174	0	0	22,540
Total All Crops		1,836,127	1,098,756	331,375	18,665	253,972	599,926	1,594,802	1,522,349	845,517	306,436	1,440,562	1,286,510	11,134,997
M^3/du		131.2	78.5	23.7	1.3	18.1	42.9	113.9	108.7	60.4	21.9	102.9	91.9	795.4

Base flow of Wadi Al-Karak of 99 l/sec sums up to 3.122 MCM per year. Without the dam, and for the same reasons as in the case of Wadi Ibn Hammad base flow, only 1.722 MCM per year can be utilized for irrigation in Phase I. The remaining 1.4 MCM is a surplus unutilized water. With the dam and the control of flow from the dam to Phase I area, however, this water can be fully utilized. Therefore, a total of 3.228

MCM (4.95 MCM-1.722 MCM) is what can be considered as the contribution of the dam to the irrigation requirements of Phase I. Under this scenario, the dam contributes 29% (3.228 MCM of the 11.135 MCM per year) of the irrigation requirements of Phase I area.

Table 6. Analysis of Irrigation Requirements from Al-Karak Dam

	Unit	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	Jun.	July	Aug.	Sep.	Total
Demand for Phase I Area	MCM	1.836	1.099	0.331	0.019	0.254	0.600	1.595	1.522	0.846	0.306	1.441	1.287	11.135
Supply from Wadi Ibn Hammad (254 l/sec)	MCM	0.680	0.636	0.680	0.658	0.680	0.658	0.680	0.658	0.680	0.658	0.680	0.658	8.010
Surplus from Wadi Ibn Hammad Supplies	MCM	0.000	0.000	0.349	0.640	0.426	0.058	0.000	0.000	0.000	0.352	0.000	0.000	1.825
Utilized Base Flow of Wadi Ibn Hammad	MCM	0.680	0.636	0.331	0.019	0.254	0.600	0.680	0.658	0.680	0.306	0.680	0.658	6.185
Needed Water from Al-Karak Dam (m^3)	MCM	1.156	0.462	0.000	0.000	0.000	0.000	0.914	0.864	0.165	0.000	0.760	0.628	4.950
Base Flow of Wadi Al-Karak (99 l/sec)	MCM	0.265	0.248	0.265	0.257	0.265	0.257	0.265	0.257	0.265	0.257	0.265	0.257	3.122
Utilized Base Flow of Wadi Al-Karak	MCM	0.265	0.248	0.000	0.000	0.000	0.000	0.265	0.257	0.165	0.000	0.265	0.257	1.722
Unutilized Water from Base Flow	MCM	0.000	0.000	0.265	0.257	0.265	0.257	0.000	0.000	0.100	0.257	0.000	0.000	1.400
Net Additional Flow Requirement	MCM	**0.891**	**0.214**	**-0.265**	**-0.257**	**-0.265**	**-0.257**	**0.649**	**0.607**	**-0.100**	**-0.257**	**0.495**	**0.372**	**1.828**
Total Additional Flow Requirement	MCM	**0.891**	**0.214**	**0.000**	**0.000**	**0.000**	**0.000**	**0.649**	**0.607**	**0.000**	**0.000**	**0.495**	**0.372**	**3.228**

With the dam, the entire base flow of 3.122 MCM per year will be utilized for irrigation. The incremental flow of irrigation requirement of 1.828 (4.95 MCM – 3.122 MCM) will be supplemented from the dam storage. This incremental flow is equivalent to 70.5 l/sec over a period of 300 days per year.

Water for Industrial Use

Dam storage water in excess of irrigation requirements will be used to supply the Dead Sea industrial establishments. The main industrial users include:

- Arab Potash Company (APC), with a total estimated annual water consumption of around 30 MCM.
- Jordan Bromine Company (JB), with a total estimated annual water consumption of 1.2 MCM. JB is close to the APC plants.
- Jordan Magnesia (JM), with a total estimated demand of 3 MCM.
- Jordan Safi Salt Company, with a total estimated water consumption of 2 MCM.
- Other industries that are in operation at present and/or expansion of operating industries, as well as new industrial plants.

Currently, one source of water supply to these industries is Al-Mujib basin located north of the proposed Al-Karak dam. The water from Al-Mujib basin is being transported using existing facilities in two stages: 1) pumping from Al-Mujib weir to Al-Mazra water tank, and 2) gravity flow from Al-Mazra water tank to destination.

Water from the proposed Al-Karak dam will also be transported to destination in two stages: 1) Gravity flow from Al-Karak dam to Al-Mazra tank via a new 500 mm pipeline, and 2) Gravity flow from Al-Mazra tank to destination using the existing pipeline.

The quantity of water available for industrial use is the dam yield in excess of the irrigation requirements of Phase I. Yield will diminish with time as a result of sedimentation which is estimated at 35,000 m^3/year. As a result, yield starts at 1.9 MCM for the first year of operation and ends up at zero after 55 years of operation. Since irrigation has priority over industrial use, water for industrial use will only be available as long as there is sufficient water for irrigation.

Table 7. Years of Sufficient Yield after Considering Sedimentation

Scenario	Yield (MCM/year)	Irrigation water requirement (MCM/year)	Rate of sedimentation (m^3/year)	Years of operation of sufficient irrigation water only
A		1.218	35,000	19.5
B		1.828	35,000	2.0

Table 8. Scenario A Capital Cost Estimate Distribution over the Dam Construction Period

Cost component	Estimated capital cost	% of capital cost by year of construction		Distribution of capital cost by year of construction	
		year 1	year 2	year 1	year 2
Dam	6,000,000	60%	40%	3,600,000	2,400,000
Pipeline to tank	2,500,000	0%	100%	0	2500000
Pipeline to Phase I	500,000	0%	100%	0	500000
Total Construction	**9,000,000**			**3,600,000**	**5,400,000**
Engineering Cost (6%)	540,000	50%	50%	270,000	270,000
Sub-total	**9,540,000**			**3,870,000**	**5,670,000**
Contingencies (10%)	954,000			387,000	567,000
Total Capital Cost	**10,494,000**			**4,257,000**	**6,237,000**

The results shown in Table 7 indicate that, with the exception of high flood years, the dam yield can be utilized for industrial use for a period of 19.5 and 2 years from the start of dam operation for scenarios A and B, respectively. 2 years of operation life in scenario B do not justify the additional capital investment in the 500 mm pipeline from the dam to Al-Mazra tank. The analysis of this scenario will thus be limited to irrigation water only; i.e., no water for industrial use and consequently no capital investment in new pipelines and no energy saving as supply of Al-Mujib water to the Dead Sea industries will continue without the construction of Al-Karak dam.

Water for Domestic Use

The dam is not envisaged for the purpose of domestic use; however, the quantity of water used for industrial use is a replacement of that from Al-Mujib weir as the water for industrial use from Al-Karak dam will be used instead of the current supplies from Al-Mujib to the Dead Sea industries. This replaced quantity of water from Al-Mujib becomes available for other uses and most likely will be pumped to Amman for domestic uses via the existing pumping, pipeline and treatment facilities.

Cost Estimates

Project cost is divided into initial/capital investment costs and operations and maintenance costs.

Capital Investment Costs

The capital investment costs include the estimated cost of the dam, associated pipelines and engineering. The dam cost estimate includes the excavation/ trimming, spillway, supply of material and dumping of excess material, access road and construction site facilities. The land acquisition cost is excluded. Cost estimates are based on 2009 prevailing construction rates taking into consideration the project site and the socio-economic conditions in Jordan with 10% contingency.

Table 9. Scenario B Capital Cost Estimate Distribution over the Dam Construction Period

Cost component	Estimated capital cost	% of capital cost by year of construction		Distribution of capital cost by year of construction	
		year 1	year 2	year 1	year 2
Dam	6,000,000	60%	40%	3,600,000	2,400,000
Pipeline to Phase I	500,000	0%	100%	0	500000
Total Construction	**6,500,000**			**3,600,000**	**2,900,000**
Engineering Cost (6%)	390,000	50%	50%	195,000	195,000
Sub-total	**6,890,000**			**3,795,000**	**3,095,000**
Contingencies (10%)	689,000			379,500	309,500
Total Capital Cost	**7,579,000**			**4,174,500**	**3,404,500**

Table 10. Gross Revenues of 2008 Phase I Crops

Crop	Area	Income	
	(du)	(JD/du)	(JD)
Tomato (Aut.)	9,739	484.3	4,716,364
Tomato (Spr.)	8,927	485.1	4,330,530
Jew's Mallow	50	215.6	10,781
Melon	350	446.3	156,211
Green Beans (Spr.)	301	253.9	76,418
Eggplants (Spr.)	493	174.7	86,103
Pepper (Spr.)	121	76.6	9,273
Banana	691	921.0	636,389
Other Fruit Trees	371	846.0	313,870
GH Pepper	25.5	234.0	5,967
GH Tomato	3	221.9	666
GH Cucumber	15	1140.9	17,113
GH Melon	0.5	602.3	301
GH Green Beans	6	256.9	1,541
GH Flowers	5.5	500.0	2,750
Total Income	**21,099**		**10,364,277**

The dam project is expected to be completed over two years. The distribution of capital costs over the construction period is summarized in Tables 8 and 9 for scenarios A and B, respectively.

The useful life of the project is estimated at 55 years taking into consideration the loss of storage capacity due to sedimentation. However, the economic life of the project is limited to 50 years as the costs/revenues thereafter have little, if any, impact on the economical feasibility of the project.

Replacement investment costs are needed to replace the mechanical parts, which are assumed to amount to 5% of the capital investment costs; i.e., JD 525,000 and 379,000 for scenarios A and B, respectively. They are considered to be replaced after 25 years of operation.

Capital investment cost for Phase I plantation area is sunk cost as it has already been invested.

Operation and Maintenance Costs

Based on energy costs and manning data of Jordan Valley Authority (JVA) experience on similar projects, operation costs are estimated at 47,500 JD/year. Annual maintenance costs are estimated at 10,500 and 7,500 JD/year for scenarios A and B, respectively based on the practice gained from similar projects of 0.1% of the total capital investment costs. Accordingly, the operation and maintenance (O&M) costs of the project are estimated at 58,000 and 55,000 JD/year for scenarios A and B, respectively.

Project Benefits

The project will generate several direct and indirect benefits that will have positive impacts on the socio-economic conditions of the population as well as on the environment. On one hand, many of these benefits can be easily quantified in monetary terms and will be referred to herein as quantitative benefits. On the other hand, some cannot be easily expressed in monetary values, such as employment, and will thus be referred to as non- quantitative benefits.

Table 11. Economic Indicators for Quantifiable Benefits of Scenario A at 0% Inflation

Discount Rate	8%	10%	15%
B/C	1.23	1.04	0.74
NPV (Million JD)	2.247	0.355	-2.299
IRR	10.47%		

Table 12. Economic Indicators for Quantifiable Benefits of Scenario A at 3% Inflation

Discount Rate	8%	10%	15%
B/C	1.69	1.39	0.93
NPV (Million JD)	7.197	3.832	-0.607
IRR	14.00%		

Quantitative Benefits

Direct benefits include revenues from irrigation and industrial water usage as well as saving of energy for the transport of industrial water.

Agricultural returns (benefits) are based on the result of 2008 cropping pattern, production and farm-gate prices data from DOS and production cost data from Jordan University published research. All costs and prices are escalated to the 2009 base year using the appropriate DOS price indices.

Return on agricultural water is estimated by calculating the impact on agriculture (i.e., agriculture return), determined as follows:

- Apply cropping pattern in Phase I area.
- Apply yield per dunum for each crop.
- Determine production per dunum for each crop.
- Calculate benefits by multiplying farm-gate price by production.
- Calculate crop production cost.

The gross revenue for Phase I crops, as shown in

Table 10, is calculated by summing up the gross revenue of crops based on 2008 data. The gross revenue of each crop is the product of the gross revenue (JD/du and the crop area planted in du.). The resulting gross revenue of all Phase I crops is 10.364 million JD; i.e., 491 JD/du for 21,099 dunums of crops.

The gross revenue of the dam project is taken in proportion of the dam contribution of irrigation water to the total irrigation requirements of all Phase I crops.

Returns on industrial water and energy savings are limited to scenario A. Return on industrial water is calculated by applying the selling price rate of industrial water of 0.53 JD/m^3. The energy savings of scenario A result from gravity flow from Al-Karak dam instead of pumped flow from Al-Mujib weir to Al-Mazra tank. JVA data show that the average cost of pumping from Al-Mujib to Al-Mazra tank is 0.026 JD/m^3.

Table 13. Economic Indicators for Quantitative Benefits of Scenario B at 0% Inflation

Discount Rate	8%	10%	15%
B/C	1.97	1.67	1.20
NPV (Million JD)	7.171	4.779	1.268
IRR	18.21%		

Table 14. Economic Indicators for Quantitative Benefits of Scenario B at 3% Inflation

Discount Rate	8%	10%	15%
B/C	2.64	2.19	1.48
NPV (Million JD)	12.925	8.820	3.225
IRR	21.76%		

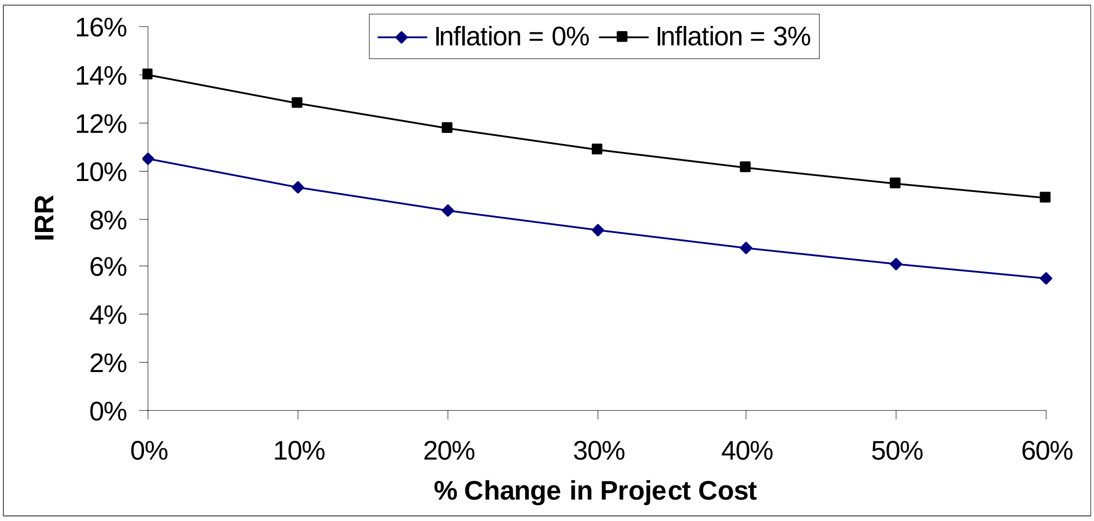

Figure 1: Sensitivity of Scenario A to Variation in Cost

Non-quantitative Benefits

Employment is a major benefit of the dam project, particularly generated by agricultural, industrial and tourism sectors and their social and economical impacts. It also creates more job opportunities in other sectors having backward or forward linkage with agricultural, industrial and tourism sectors such as transportation, trade, storage and export to outside markets.

The estimation of the work opportunities in the agricultural sector averages 1 per 10 dunums. On one hand, the agricultural area in Phase I is already planted and hence the project does not increase the cropping area. On the other hand, the dam project contribute at least 10% (1.22 MCM of the 11.135 MCM annual irrigation requirement) of Phase I. Considering the contribution of the dam to the irrigation requirements of Phase I and reflecting that on the irrigated area of Phase I and the contribution of the dam to the irrigation requirement and to the irrigation area, up to 140 work opportunities will be created by the dam. This is in addition to the manpower required to operate and maintain the dam project.

Furthermore, industrial water available permanently will allow expanding existing industries as well as establishing new industries in the area, hence creating more work opportunities in the industrial sector and other related activities. Detailed data and information are not available to estimate the number of work opportunities in the industrial and tourism sectors.

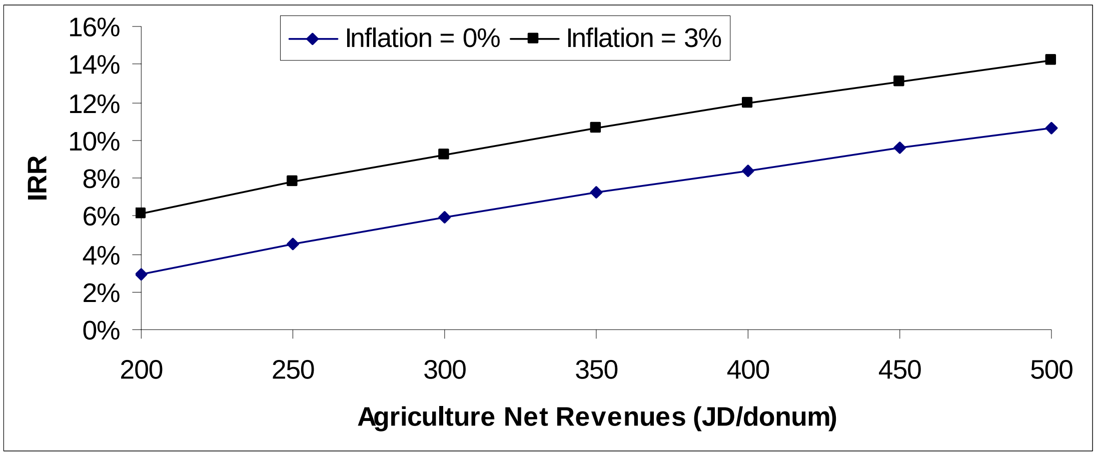

Figure 2: Sensitivity of Scenario A to Variation in Revenues from Agriculture

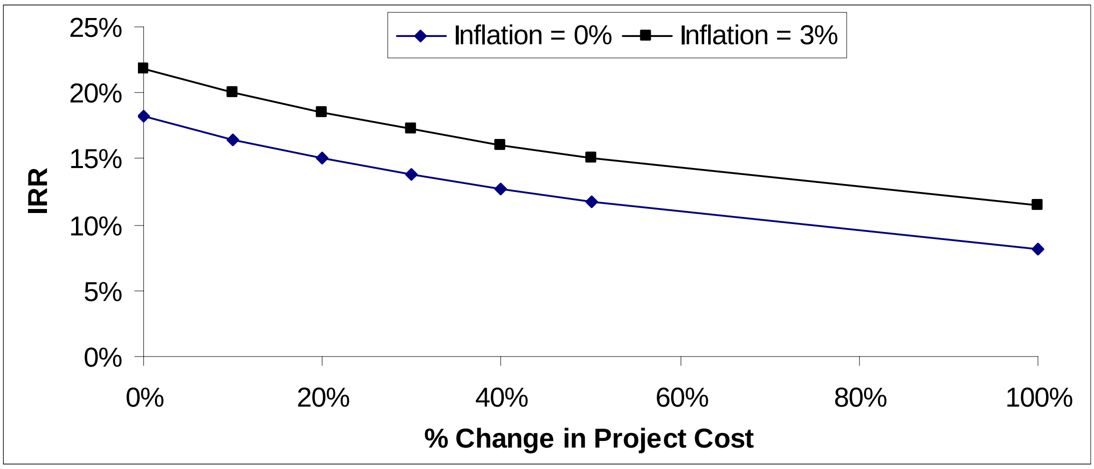

Figure 3: Sensitivity of Scenario B to Variation in Cost

In addition to the new jobs that can be created in the agricultural and industrial sectors, the project will create more job opportunities in other related sectors and activities such as transportation, trade of crops and inputs, storage, packing and packaging, storage and export to other markets.

As it is rather difficult at this stage to quantify all of the above benefits, it is usually assumed as a percentage of quantitative benefits. This percentage varies from 0% to 200% depending on an assessment of the magnitude of contribution of the project on the economy. Considering the contribution of this project to the overall economic activities, JVA believes that non-quantitative benefits will be in the order of 50 percent of the quantitative benefits.

Economic Assessment of the Project

The economic analysis and assessment of the project is based on cost-benefit analysis of all the streams of quantitative costs and benefits over the project life span from inception till termination. The analysis is carried out on the basis of current estimates of prices and costs for the 2009 base year. The analysis is conducted using fixed prices and costs over the project life span (i.e., without impact of inflation), as well as on a variable basis considering inflation rates of 3% over the project life span.

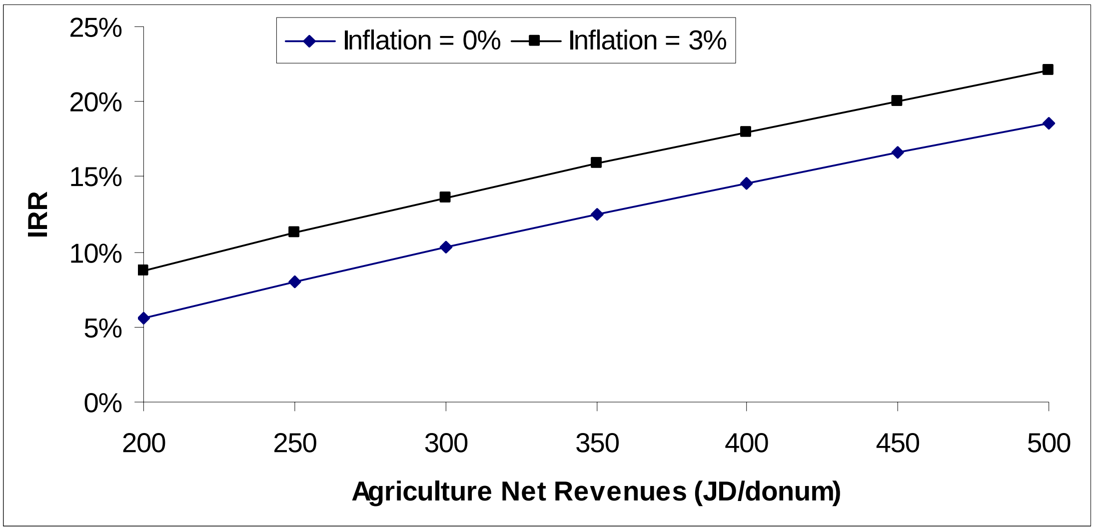

Figure 4: Sensitivity of Scenario B to Variation of Revenues from Agriculture

Estimated yearly costs and benefits are compared and three economic parameters are calculated:

1) The project Internal Rate of Return (IRR);
2) The Net Present Value (NPV) of the project at certain discount rate;
3) The Benefit to Cost ratio (B/C) at a certain discount rate.

The last two parameters, NPV and B/C ratio, are calculated for a base discount rate of 8%, being the threshold for project finance decision, as well as for discount rates of 10% and 15%.

Sensitivity analysis tests are also carried out by varying the values and/or amounts of project inputs (capital costs) and project outputs (revenues).

Economic Analysis for Scenario A

This scenario is based on JVA officials' estimate of irrigation requirement from the dam of 47 l/sec for a period of 300 days (1.218 MCM) in addition to the already provided base flow from Wadi Al-Karak of 99 l/sec (3.122 MCM) and 254 l/s base flow of Wadi Ibn Hammad (8.01 MCM). Accordingly, the dam contributes 9.9% of the total irrigation requirement of 12.351 MCM. This translates to a contribution of 1.022 million JD of annual revenues of 10.364 million JD.

Tables 11 and 12 summarize the economic indicators at a 0% and 3% inflation, respectively. The results indicate that the project is feasible with a B/C value greater than one and positive NPV at all considered discount rates, and the project becomes more attractive with increasing rate of inflation.

Figure 1 shows the sensitivity of IRR to the variation in cost for inflation rates of 0% and 3%. The results indicate that the project remains feasible (IRR > 8%) with increasing costs up to 20% in case of 0% inflation and to over 60% in case of 3% inflation. For this scenario, the economic feasibility is insensitive to variation in project costs.

Figure 2 shows the sensitivity of IRR to the variation in revenues from agricultural water use for inflation rates of 0% and 3%. As can be seen, the project is economically feasible (IRR > 8%) for all agricultural revenues in excess of 375 JD/du at 0% inflation and in excess of 250 JD/du at 3% inflation. At IRR of 6%, the project is feasible at all agricultural revenues in excess of 300 JD/du at 0% inflation and in excess of 200 JD/du at 3% inflation.

Economic Analysis for Scenario B

When considering the additional irrigation requirement from the dam of 1.828 MCM (70.53 m^3/sec over a period of 300 days) as the only contribution of the dam to irrigation requirement, the dam contributes 16.42% of the total irrigation requirement of 11.135 MCM per year. This translates to a contribution of 1.702 million JD of the annual income of Phase I of 10.364 million JD.

Tables 13 and 14 summarize the calculated economic indicators at 0% (fixed prices) and 3% inflation, respectively. The results indicate that the project is very feasible with a B/C value greater than one and positive NPV at all considered discount rates, and the project becomes more attractive with increasing rate of inflation.

Figure 3 shows the sensitivity of IRR to the variation in cost at 0% and 3% inflation. For this scenario, the project remains economically feasible even when costs are doubled.

Figure 4 shows the sensitivity of IRR to the variation in revenues from agricultural water use at 0% and 3% inflation. Revenues are expressed in terms of net income from agriculture (JD/du). The project is feasible (IRR > 8%) if revenues exceed 280 JD/du at 0% inflation and for revenues above 200 JD/du at 3% inflation.

CONCLUSIONS

Based on the presented economic feasibility of Al-Karak Dam, the following conclusions can be drawn:

The project is economically feasible for all considered scenarios of irrigation requirement and of the contribution of the dam to the irrigation requirement. This conclusion is valid even when not considering the non-quantifiable benefits of the project.

a) When considering an additional irrigation requirement of 47 l/sec as suggested by JVA officials, the project achieves IRR values of 10.5% and 14.0% for inflation rates of 0% and 3%, respectively.

b) When considering an additional irrigation requirement of 70.5 l/sec as determined from the analysis, the project achieves IRR values of 18.2% and 21.8% for inflation rates of 0% and 3%, respectively.

The economic feasibility of using the dam water for industrial and touristic establishments at the Dead Sea depends on the irrigation requirement of Phase I. The cost of the proposed 500 mm pipeline from the dam to Al-Mazra tank is justified in the case of irrigation requirement of 47 l/sec as suggested by JVA officials. However, this cost is unjustifiable if the irrigation requirement of Phase I is in the order of 70.5 l/sec as suggested by the presented analysis of the irrigation requirement. This is mainly due to the limited and diminishing yield of the dam.

Sensitivity analysis proves that the economic feasibility is insensitive to the increase in estimated project costs and to the decrease in project revenues. This is true with and without consideration of non-qualitative benefits. The dam remains economically feasible with an increase of cost up to 50% and with a decrease of revenues to as low as 250 JD/du when considering quantifiable benefits only. When considering non-quantifiable benefits as well, the project remains economically feasible for revenues as low as 200 JD/du and for cost increase up to 100%.

Acknowledgement

This research is authorized and funded by JVA and submitted in partial fulfilment of Al-Karak Dam feasibility report prepared by the author on behalf of Engineering Consultants (EngiCon), Amman, Jordan. The author would like to express his appreciation to Engineers Khairy Ammary and Fuad Ejailat from JVA and to Mr. Issa Abu Taha from EngiCon for their cooperation.

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