THE HASHEMITE KINGDOM OF JORDAN

MINISTRY OF PLANNING

IN ASSOCIATION WITH

WATER AUTHORITY OF JORDAN

HYDROGEOLOGICAL AND WATER USE STUDY OF THE MUJIB WATERSHED

FINAL REPORT

APPENDIX (II)

JULY 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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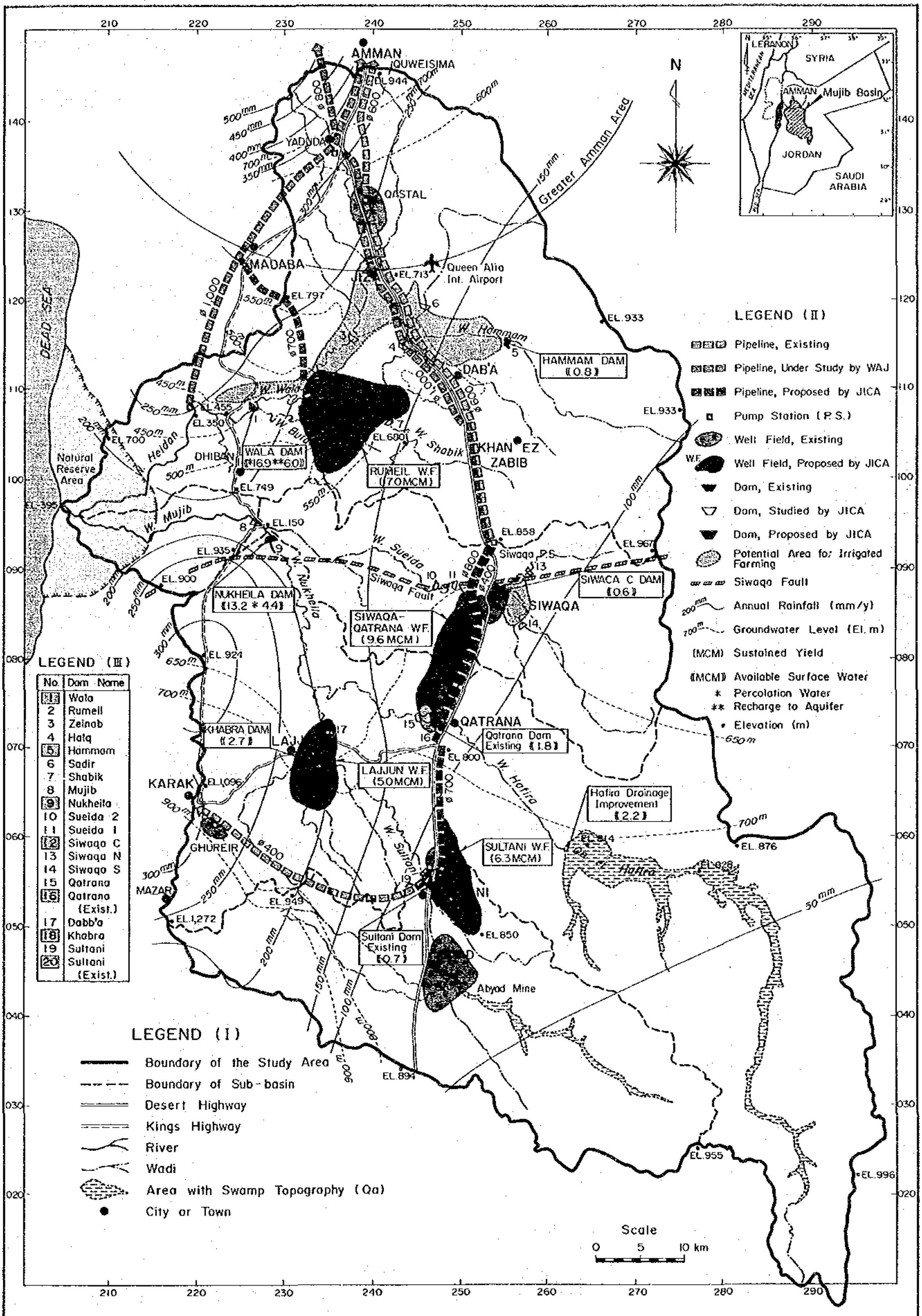

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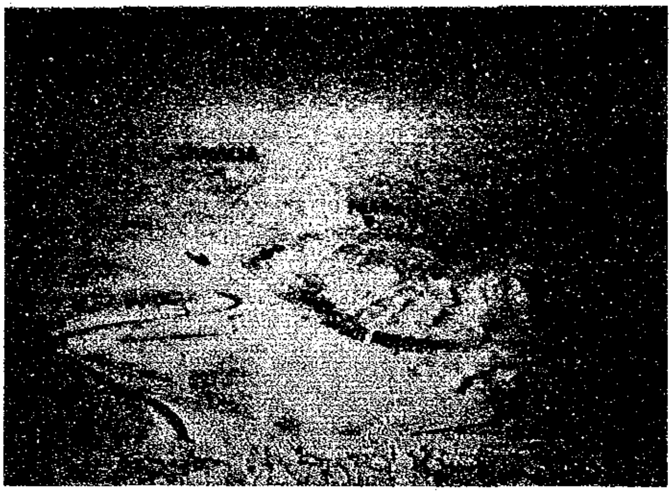
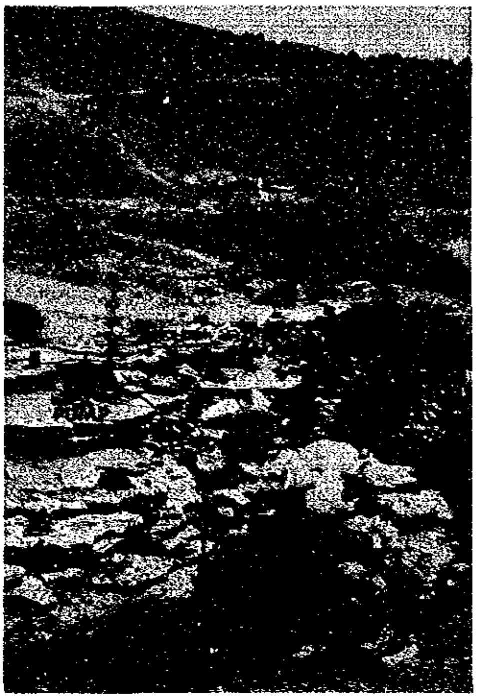


Wadi Mujib (View from Dhiban)



Small Spring in Wadi Heidan
(200m eastward from Wala bridge)

Flush Flood in Wadi Sueida (at Siwaqa bridge)
Date : 8 Nov. 1986

Qatrana Existing Dam

APPENDIX (II)

STUDY ON TWO WATER PIPELINE PROJECTS

ON

FEASIBILITY STUDY LEVEL

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LIST OF ABBREVIATIONS

JICA	=	Japan International Cooperation Agency
Government	=	Government of Jordan
MOP	=	Ministry of Planning
WAJ	=	Water Authority of Jordan
JVA	=	Jordan Valley Authority
MOA	=	Ministry of Agriculture
NRA	=	Natural Resources of Authority
RSS	=	Royal Scientific Society
JNGC	=	Jordan National Geographic Center
JEA	=	Jordan Electricity Authority
JEPCO	=	Jordan Electric Power Company
S/W	=	Scope of Work
C/P	=	Counterpart Personnel
M/P	=	Master Plan
Pre-F/S	=	Pre-feasibility Study
F/S	=	Feasibility Study
KV	=	Kilo Voltage
KW	=	Kilo Watt
KVA	=	Kilo Voltage Ampere
sq.km or km^2	=	Square Kilo Meter
lit/s	=	Liter per Second
cu.h or m^3/h	=	Cubic Meter per Hour
cu.s or m^3/s	=	Cubic Meter per Second
cu.d or m^3/d	=	Cubic Meter per Day
bs/ft	=	Pound per Foot
MCM	=	Million Cubic Meter
MCM/y	=	Million Cubic Meter per Year
MCM/m	=	Million Cubic Meter per Month
O & M	=	Operation and Maintenance
M & I	=	Municipal and Industrial
API	=	American Petroleum Industry
ha	=	Hectare

F1 THE PROJECTS

F1.1 Description of the Projects

F1101 As described in the Main Report of the Master Plan Level Study, the water demand in the Greater Amman area in the year 1985 exceeded the supply capacity and more volume was pumped up from the wells than the safe yield. As the results, water extraction was made over the sustained yields (refer to Para M4316, Annex M4316).

F1102 Meanwhile, the Master Plan envisages that the study area will demand water of 192 MCM/y for the municipal pourpose in the target year 2005 including 188 MCM/y for the Greater Amman area and 4 MCM/y for the Mujib basin. By that year, however, the existing supply capacity for the Greater Amman area will reach only 91 MCM/y, 50 MCM by the existing system (normal supply capacity) and 41 MCM/y by the planned system (refer to Paras M5361 to M5365).

F1103 Thus it is evident that if things remain as they are, the water demand will continue to exceed the existing supply capacity. To cope with this foreseeable result, WAJ plans to exploit the ground water of the Mujib basin (neighboring on the south Amman) for the exclusive use in the Greater Amman area. The pipeline project for this purpose has been already implemented (refer to Para M4321).

F1104 The outline of WAJ's pipeline project from the Mujib basin to the Greater Amman area is as follows (refer to Annex M4321):

(1) Madaba-Yaduda-Suweilih Pipe Line Project
(constituting a part of the Amman Ring Line)

Water source : Wala Water Conveyance Project &
New Siwaqa Water Conveyance Project

Pump station : Yaduda Pump Station

Pipeline : From Madaba through Yaduda to the Dabuq Terminal Reservoir (250,000 m^3) of the Deir Alla System
Madaba to Yaduda, pipe diamater 1,000 mm, length 15.2km
Yaduda to Suweilih, pipe diameter 800 mm, length 23.0km
Total length 38.2 km

Completion : 1987

Fund : Saudi Arabian loan

Present stage: Under construction

(2) Yaduda-Abu Alanda-Azraq Pipeline Project
(constituting a part of the Amman Ring Line)

Water source : Wala Water Conveyance Project &
New Siwaqa Water Conveyance Project

Pump station : Yaduda Pump Station

Pipe line : From Yaduda to the Azraq
Pipeline via Abu Alanda, diameter 600 mm
Total length 28.7 km

Completion : 1987

Fund : Saudi Arabian loan

Present stage: Under construction

(3) Wala Water Conveyance Project

Water source : The well field in the vicinity of the Kings Highway Wala Bridge & the base flow in Heidan

Intake quantity: 15 MCM/y

Pump station : Pump station at Wala & a booster pump station

Pipeline : Pipeline from Madaba to Yaduda being already under construction. This project has to place a pipe line only between Wala and Madaba
Diameter : 1,000 mm
Total length : approx. 19 km

Completion : 1987 (target)

Fund : Yet to be decided

Present stage: Designing

(4) New Siwaqa Water Conveyance Project

Water source : Siwaqa & Qatrana well fields

Intake quantity: Yet to be decided

Pump station : Siwaqa pump station

Pipeline : From Siwaqa to the Yaduda pump station via Qastal
Diameter : 1,000 mm
Total length : 52.1 km

Completion : Yet to be decided

Fund : Yet to be decided

Present stage: Designing

F1105 This Master Plan level study intends to supply the Greater Amman area with water from the Sultani (6.3 MCM/y), Siwaqa-Qatrana (9.6 MCM/y) and Rumeil (7 MCM/y) well fields. Consequently, taking account of the WAJ's plan mentioned in Para F1104, the following pipeline Projects are independent with each other to supply water to the Greater Amman area, and are studied under the condition of the feasibility study level.

(1) Sultani-Siwaqa Pipeline Project: Pipeline from the Sultani well field to the Siwaqa pump station via the Siwaqa-Qatrana well field

(2) Rumeil-Madaba Pipeline Project: Pipeline from the Rumeil well field to the Madaba point of the pipe line of Wala Water Conveyance Project.

F1.2 Sultani-Siwaqa Pipeline Project

F1201 General: The Sultani-Siwaqa pipeline is planned to convey water from the Sultani and Siwaqa-Qatrana well fields to the Siwaqa pump station. The Siwaqa pump station has been planned by WAJ. Both well fields are located along the Desert Highway in the Mujib basin. Put together, their sustained yield amounts to 15.9 MCM/y, 6.3 MCM/y for the Sultani and 9.6 MCM/y for the Siwaqa-Qatrana well field. The general layout of the project is shown on Drawing Nos.1 and 2.

F1202 Although this pipeline will run parallel to the National Conveyer planned by the Jordan Government to cut through from the south to north, they are to be constructed separately.

F1203 Along the pipeline, there are already two dams in Sultani and Qatrana and another one is planned in Siwaqa. The Main Report of the Master Plan Level Study recommends that further study be carried out to establish a recharge water plan using these dams. The planned pipeline has enough capacity to take in recharge water from the dams.

F1204 The following is the outline of facilities for the pipeline.

(1) Average pumped water volume (i.e. sustained yield) and peak pumped water volume (mainly in July and August) are as follows:

	Average (MCM/y)	Peak (MCM/y)
Sultani	6.3	6.3 x 1.3 = 8.2
Siwaqa-Qatrana	9.6	9.6 x 1.3 = 12.5
Total	15.9	20.7

(2) The Sultani well field will have 18 wells (about 270m deep), each of which will be equipped with a pump of 60 m^3/h pumping rate. The Siwaqa-Qatrana well field, on the other hand, will have 21 wells (about 270m deep), each of which will be equipped with a pump of $70m^3/h$ and $90m^3/h$ pumping rates.

(3) The pumps will average 16 hours operation a day, while at the peak time the operation will increase to 20.8 hours (16 hours x 1.3).

(4) The pipeline will have two reservoirs, one at Sultani and the other at Siwaqa. The capacity of the reservoirs shall be equal to average flow volume during five hours.

Sultani reservoir	3,600 m^3
Siwaqa reservoir	9,100 m^3

(5) The diameter and length of each part of the pipeline is as follows:

	Diameter (mm)	Length (m)
Sultani well field - Sultani reservoir	500-600	11,700
Sultani reservoir - Siwaqa reservoir	600-700	23,100
Siwaqa reservoir - Siwaqa pump station	600-800	5,900
Total		40,700

(refer to Annex F1204)

F1205 Well field and well arrangement: Water source is dependent on the potential well fields of "Siwaqa-Qatrana" and "Sultani" which are located along the Desert Highway in the Mujib basin. The Siwaqa-Qatrana well field is situated in the desert highland with elevation between 750 and 790 m and location between existing well field of Siwaqa and Qatrana. The Sultani well field is located in the southern part of the Mujib basin between Qatrana and Abiad near the Mahattal El Manzil with higher elevation of 820 to 850 m.

F1206 On the bais of the result of groundwater model simulation which is shown in Appendix C, the potential yield of the proposed well field is estimated to be 15.9 MCM/y in total, which includes the yield of 9.6 MCM/y from Siwaqa-Qatrana well field and 6.3 MCM/y from Sultani well field. Deep wells of 39 in number, which include 21 wells in Siwaqa-Qatrana well field and 18 wells in Sultani well field, are located with interval at 1 to 2 km each as shown in Annex F1206. The pumping rate of these wlles are estimated in the range between 60 and 90 m^3/h.

F1207 Design concept of the pipe line system: The design concept for the pipeline system is as follows:

(1) The diameter of pipeline is designed to accommodate a peak flow.

(2) Water is pumped up from the well fields to a high-level reservoir. To be specific, water from the Sultani well field and the Siwaqa-Qatrana well field will be sent to the Sultani reservoir and the Siwaqa reservoir respectively.

(3) The Sultani reservoir is located at the highest point of the pipe line, so that water should flow from there to the Siwaqa pump station by means of gravity.

The pipeline plan and its profile are shown on Drawing Nos.3 to 5.

F1208 Peak flow: The water demand in the Greater Amman area increases considerably in summer. When present water systems were designed, the peak/average water supply ratio is estimated between 1.25 and 1.3. This estimate has been confirmed by the actual records, which have been between 1.2 and 1.3 (refer to Paras M4318 & M4319). The peak flow of the pipeline also sets the ratio at 1.3.

F1209 Even if an average annual pumping volume is kept under a sustained yield, excess pumping in a peak season may cause over-extraction. That is why water should be pumped up cautiously by always keeping an eye on ground water levels.

F1210 Setting the peak/average water supply ratio at 1.3 allows the pipeline to have the following spare capacities.

Sultani well field - Siwaqa-Qatrana well field
6.3 x 0.3 = 1.9 MCM/y

Siwaqa-Qatrana well field - Siwaqa pump station
(6.3 + 9.6) x 0.3 = 4.8 MCM/y

These spare capacities can be used for the conveyance of recharge water as described in the following paragraphs.

F1211 Recharge water: The Main Report (refer to Appendix C) of Master Plan Level Study envisages to make further study on the following recharge water plan using three dams.

Dam	Recharge Water (MCM/y)
Sultani	0.7
Qatrana	3.2
Siwaqa C	0.6
Total	4.5

The recharge water will be taken by the existing well fields in Mujib basin, namely Siwaqa, Qatrana and Sultani well fields.

F1212 In consideration of the water demands in the Greater Amman area in the target year 2005 and a capacity of existing water conveyance facilities in the Mujib basin, it will be necessary to send all the recharge water to the Greater Amman area by using the Sultani-Siwaqa pipeline. On the other hand, a diameter of its pipeline is determined on condition that a ratio of peak flow against an average flow is 1.3. Therefore, the pipeline has a capacity to convey all the recharge water without the alteration of pipe diameter, even though all the recharge water would be developed.

F1213 Basis for pipeline planning: When the shortest route is taken, it becomes necessary to lay considerable length of construction roads. So, the route is selected to run mostly along the Desert Highway.

F1214 Inside a well field, a pipeline is placed close to the center line of the field as much as possible, so that it can be also used as a collecting pipe line from each well. The construction cost can be cut in this way.

F1215 Arrangement of reservoirs, selection of optimum pipe diameter and utilization of gravity flow are determined to make the energy consumption optimum by the profile.

F1216 The purposes of reservoirs are as follows:

(1) To reserve pumped water and regulate the discharge to keep water flow suitable for downstream facilities

(2) To prevent the rapid change of hydraulic level in pipes and keep the operation stable

(3) To supply contingent water in an emergency

To achieve these purposes, reservoirs should be constructed in the vicinity of a well field or at a high point for gravity flow.

F1217 Pipeline Alignment: On the basis of Para F1213, the pipeline route is determined under the following condition (Sultani well field lies on the east side of the Desert Highway, and the Siwaqa-Qastal well field on the west side).

(1) From the Sultani well field and Qatrana town, the pipe is aligned on the east side of the Highway.

(2) Then the pipe crosses the Highway through a box culvert at the Karak Road interchange.

(3) From the Qatrana town through Siwaqa-Qatrana well field to Wadi Siwaqa, the pipe is aligned on the west side of the Highway.

(4) Then the pipe crosses the Highway through the Wadi Siwaqa Bridge.

(5) From Wadi Siwaqa to the Siwaqa pump station, the pipe is aligned on the east of the Highway.

As shown on Drawing Nos.1 and 2, this pipeline route is the shortest possible way to connect each well field with the Siwaqa pump station, which, together with the general downward slope, makes it optimum.

F1218 Pipeline system: As shown on Drawing Nos. 3 to 10, the pipeline on the whole makes a downward slope. The highest point being Sultani (11.7 km from a starting point in the Sultani well field), the slope is gentle between Sultani and Siwaqa (34.9 km) and steep between Siwaqa and the Siwaqa pump station.

F1219 To make the most of this profile feature, a water will be pumped up to the Sultani reservoir, and from there it will be sent down by means of gravity. Two reservoirs will be constructed, one near the Sultani well field and the other near the Siwaqa-Qatrana well field. They will be located at relatively high point and designed to keep a free water surface, so that stable gravity flow can be secured.

F1220 The alternative to this system is either to set up a reservoir in the middle of the Sultani well field to collect water and pump it up to the Sultani reservoir or to send the Sultani well water directly to the Siwaqa reservoir. Having compared these two alternatives with the aforementioned system, we have decided to adopt the latter from economic and operational points of view (refer to Annex F1220).

F1.3 Rumeil-Madaba Pipeline Project

F1301 General: The project aims to connect the Rumeil well field which has sustained yield 7 MCM/y with the Yaduda pumping station planned by WAJ. Since a pipeline (diameter: 1,000 mm) will run from Wala to Madaba and further to Yaduda is to be constructed by WAJ, the Rumeil-Madaba pipeline runs from the Rumeil well field to Madaba point of the Madaba-Yaduda pipeline by WAJ. The general layout of the project is shown on Drawing No. 8.

F1302 The Rumeil well field lies between the Kings Highway and the Desert Highway, in the middle reaches of the Wadi Wala basin. It consists of the Wadi Shabik and the Wadi el Butum basins, both being branches of the Wadi Wala. The sustained yields of the Wadi Shabik and Wadi el Butum areas are 3.85 MCM/y and 3.15 MCM/y respectively, the total being 7 MCM/y.

F1303 The following is the outline of facilities for the pipeline.

(1) Annual average pumped water volume and peak pumped water volume of the Rumeil well field are as below.

	Average (MCM/y)	Peak (MCM/y)
Wadi el Butum	3.15	3.15 x 1.3 = 4.10
Wadi Shabik	3.85	3.85 x 1.3 = 5.00
Total	7.00	9.10

(2) For the Wadi el Butum well field, 9 wells of the depth of about 270m will be drilled down. The Wadi Shabik well field have 11 wells of the depth of about 300m. Thus the Rumeil well field have altogether 20 wells, each of which will be equipped with a pump of 60 m^3/h pumping rate.

(3) The pumps will average 16 hours operation a day, while at the peak time the operation will increase up to 20.8 hours (16 hours x 1.3).

(4) The following two reservoirs will be constructed for the pipeline. The capacity of the reservoirs shall be equal to average flow volume during five hours.

Abu Haliefa reservoir	1,800 m^3
Rumeil reservoir	4,000 m^3

(5) A booster pump station will be installed right below the Rumeil reservoir.

Rumeil booster pump station

Total pump discharge	1,040m^3/h
Pump head	160m
Nos. of pump	4 units

(6) The diameter and length of each part of the pipeline is as follows:

	Diameter(mm)	Length(m)
Wadi el Butum - Abu Haliefa well field reservoir	300-400	4,100
Abu Haliefa reservoir - Branch point	400	5,400
Branch point - Rumeil booster pump station	700	3,400
Rumeil booster - Madaba connection pump station point	700	14,500
Total		27,400

	Diameter(mm)	Length(m)
Branch pipe line		
Wadi Shabik - Branch point	300-500	13,900

(refer to Annex F1303)

F1304 Well field and well arrangement: Water source is dependent on the well field of Rumeil which is situated in the middle reaches of southern Wadi Wala between Kings Highway and Desert Highway including tributaries of Wadi Shabik and Wadi el Butum. The Rumeil well fields is located in the valleys of the two Wadis of Shabik and el Butum where the ground elevation is in the range between 560 and 700 m.

F1305 On the basis of the result of groundwater model simulation the potential yield of the proposed well field is estimated to be 7 MCM/y in total. Deep wells of 21 in number, which include 9 wells in the Wadi el Butum and 11 wells in the Wadi Shabik, are located with interval at 1 to 2 km each as shown in Annex F1206. The pumping rate of these wells are estimated to be 60 m^3/h.

F1306 Design concept of the pipeline system: The design concept for pipeline system is as follows:

(1) The diameter of pipeline is designed to accommodate a peak flow.

(2) Water will be pumped up from the well fields to a high-level reservoir. To be specific, water from the Wadi el Butum well field and the Wadi Shabik well field will be sent to the Abu Haliefa reservoir and the Rumeil reservoir respectively.

(3) Water will be carried from the Abu Haliefa reservoir to the Rumeil reservoir by means of gravity.

(4) From the Remeil reservoir, water will be sent to the Yaduda pump station by using the Rumeil booster pump station.

The pipeline plan and its profile are shown on Drawing Nos. 9 and 10.

F1307 "Peak flow" and "Basis for pipe line planning" are the same as stated in Paras F1208 and F1213.

F1308 Pipeline alignment: There are two routes connecting the Rumeil well field with the Yaduda pump station. One is the Kings Highway through Madaba, and the other is the Desert Highway through Jiza (refer to Annex M4321). Having compared these two routes, we have chosen the Kings Highway route. Accordingly, the proposed pipeline is connected with the WAJ's Madaba-Yaduda pipeline at the Madaba point. Alternative study for selecting the pipeline route is described in Annex F1308.

F1309 As described in Para F1302, the Rumeil well field consists of the Wadi el Butum and the Wadi Shabik well fields. The Wadi el Butum well field is located on the highland across the Wadi Wala whereas the Wadi Shabik well field lies in the low land of the reaches of the Wadi Wala. Taking these geographical conditions into account, a main pipeline will be set between Wadi el Butum and Madaba, while a branch pipeline will link the Wadi Shabik well field with the main line.

F1310 The main pipeline will be constructed from Madaba to the Wadi el Butum well field along the regional paved road through Nitil, Rumeil, Muzeir Alya and Aba Haliefa. It will be placed along the center line of the Wadi el Butum well field which is now being used as farmland.

F1311 As shown on Drawing No.8, a branch pipeline will start from the main line at the Wadi Wala point and reach the Wadi Shabik well field, which is now mostly desert.

F1312 Pipeline system: As shown in the profile of Drawing No.9, the main pipeline will cross the low land along the Wadi Wala, where the ground is about 100 m lower than the surroundings. Abu Haliefa lies on the hill of the highland, which is 30-40 m higher than the Wadi el Butum well field.

F1313 The pipeline system is planned to minimize the water pressure on the main pipe at the low land crossing point of the Wadi Wala and the branch pipe. By this means, the designing of pipes and Wadi Shabik well pumps will be made easy.

F1314 To minimize the water pressure on the pipe at the river crossing point, water will be conveyed from Abu Haliefa to the other side of the Wadi by means of gravity. To be more exact, water from the Wadi el Butum will be pumped up to the Abu Haliefa reservoir and from there conveyed to the Rumeil reservoir on the other side of the Wadi Wala (Madaba side) by gravity. From the Rumeil reservoir, the booster pump will send the water directly to the Yaduda pump station.

F1315 The branch pipeline from the Wadi Shabik well field will join the main pipe line at the Wadi Wala point. Water from the Wadi Shabik field will be pumped up to the Rumeil reservoir through leteral pipes, the branch pipe and the main pipe.

F1316 Alternatives to this system is either (1) to set up a reservoir and a pump station around the end of the branch pipeline and pump up the water to the Rumeil reservoir through the main pipe, or (2) to set up a pump station at the Abu Haliefa in addition to a reservoir and a pump station as above side around the end of the branch pipe, and send the water directly to the Yaduda pump station by two pump stations. Having compared these two alternatives with the aforementioned system, we have adopted the latter from economic and operational points of view. (refer to Annex F1316)

F2 PRELIMINARY DESIGN OF SULTANI-SIWAQA PIPELINE PROJECT

F2.1 Design Criteria

F2101 Basis for designing: The design of major facilities for the pipeline are prepared, based on the Design Criteria of Water Works Facilities which have been published by the Japan Water Works Association.

F2102 Design flow (qmax.): Design flow is the basis of the hydraulic design of a pipeline. For the planned pipe line, two design flows are set in the following formulas:

Well pump -- reservoir

$$q_{max.}(m^3/s) = \frac{\text{Total pumping volume of wells}(m^3/h)}{3600}$$

Downstream of reservoir

(On the assumption of 24-hour/day operation of pumps)

$$q_{max.}(m^3/s) = \frac{\text{Peak flow (MCM/y)}}{365 \times 24 \times 3600}$$

The peak/average flow ratio of the pipeline is set at 1.3 (refer to F1208).

F2103 Hydraulic design: The following Hazen William's formula is to be applied for the hydraulic design of the pipeline.

$$I = 10.666 \times C^{-1.85} \times D^{-4.87} \times q_{max.}^{1.85}$$

where, I : hydraulic gradient

C : velocity coefficient

cement mortar lining = 130

D : diameter of pipe (m)

qmax. : design flow (m^3/s)

The value of C reflects the internal deterioration of the pipe after 30 years. To allow for the losses caused by valves or fittings, the above I-value should be increased by approximately 10%.

F2104 <u>Optimum pipeline diameter</u>: The increase of a pipe diameter entails the increase of construction cost and the decrease of pumping up cost. Inversely, the decrease of a pipe diameter results in the decrease of construction cost and the increase of pumping up cost. An optimum diameter, therefore, is such one that makes the sum of annual interest amortization cost and pumping up cost minimum (refer to Annex F2104).

F2105 <u>Capacity of reservoir</u>: The purpose of reservoirs is two-fold; to control the volume of water flow and to supply water at the time of emergency. In the peak flow, well field pumps operate 20.8 hours/day, whereas pump stations at downstream work 24 hours/day. Thus, the function of reservoirs is to store pumped water and regulate the discharge to keep water flow suitable for downstream facilities. Also, in case of accident at upstream, reservoirs provide emergency water. The calculation shows that the reservoir capacity equivalent to 4.2-hour average flow volume is sufficient for this regulating purpose. In the proposed pipeline, however, each reservoir capacity is set at 5-hour average flow volume on the safe side.

F2106 <u>Disinfection facilities</u>: The groundwater from the Mujib basin has so high quality that no treatment is needed. The result of the water quality analysis is shown in clause 2.9 and 2.9 in Appendix C. From the point of view of domestic water use, it is essential that the chlorination facilities must be equipped with the pipeline to keep the water quality. *However, in consideration of the condition on the pipeline* Projects on this study, the chlorination facilities will be equipped with the on-going Projects of WAJ to function effectively the chlorination. Therefore, no chlorination facilities are provided in the pipeline Projects on this study.

F2107 Type of pipe: Ductile iron pipes will be used for the all pipeline Projects taking account into technical, economic and constructive aspect (refer to Annex F2107).

F2108 The determination of the pipeline route and reservoir/pump locations is based on the topographic map of 1/50,000 scale and field surveys such as traverse survey, profile survey and topographic survey.

F2.2 Preliminary Design

F2.2.1 Production Well

F2211 The production well is designed to penetrate the main aquifer of the B21A7 formation to the depth of 265 to 285 m. The well drilling is performed by two stages in depth, that is drilling (1) by diameter of 17-1/2 inches to the depth of 175 to 200 m and then (2) by diameter of 12-1/4 inches to the bottom as shown in typical well design of Annex F2211-1. The casing program consists of installing i) pump chamber pipe with diameter of 13-3/8 inches and ii) screen pipe with diameter of 9-5/8 inches, which is installed in accordance with the drilling program as mentioned above. The drilling and casing program for each production well is shown in Annex F2211-2.

F2212 Casing pipes are seamless carbon steel type with thread coupling. The unit weight is 54.5 lbs/ft. for the pipe with 13-3/8 inches diameter and 36.0 lbs/ft. for the pipe of 9-5/8 inches, in accordance with the specification of API standard. The screen pipe is slotted type with open ratio of 5%. Total length of the screen pipe is assumed to be 70% of the saturated zone. However, the details of the arrangement of the slotting sections will be decided after performing the geophysical logging in each boreholes.

F2213 Design pumping rate of the production well is estimated to be 60 to 90 m^3/h, depending on the operation schedule of 16 hours per day, that is decided by taking account of the regional aquifer parameters and (2) the recovery factor of the wells, in order to sustain the B2/A7 aquifer system for the perennial use.

F2.2.2 PipeLine System

F2221 Pipe diameter: The diameters of the pipes from the Sultani well field to the Sultani reservoir are determined referring to the "optimum pipeline diameter" as described in Para F2104. From the Sultani reservoir to the Siwaqa pump station via the Siwaqa reservoir, where water will be carried by gravity, the "optimum pipeline diameter" would produce redundant water head because of small friction loss and be uneconomical. For that part of the pipeline, therefore, diameters which are one or two scales smaller than the optimum ones should be employed in order to reduce the construction cost. The pipe diameters are as follows:

	Diameter (mm)	qmax. (m^3/s)	Velocity (m^3/s)
Sultani well field (0 km) - 4.3 km	500	0.183	0.86
4.3 km - Sultani reservoir (11.7 km)	600	0.300	0.99
11.7 km - 26.9 km	600	0.260	0.85
Siwaqa-Sultani -- Siwaqa reservoir(26.9 km) reservoir(24.9 km)	700	0.718	1.73
34.9 km - 35.0 km	800	0.657	1.31
35.0 km - Siwaqa pump station(40.8 km)	600	0.657	2.34

F2222 Hydraulic design of the pipeline is shown in Annex F2222.

F2.2.3 Reservoir

F2231 As mentioned in Para F2105, each reservoir capacity is set at 5-hour average flow volume. Its draw down is to be 4.0 m in Sultani, 5.0m in Siwaqa.

	Average flow (MCM/y)	Volume (m^3)
Sultani reservoir	6.3	3,600
Siwaqa reservoir	16.0	9,100
Total		12,700

The total capacity amounts to approximately 7-hour average flow volume.

F2232 The layout of the reservoirs is shown on Drawing Nos. 6 and 7. A reservoir is to be divided into two sections. While one is being used, the other is drained for cleaning and maintenance. Each section will be equipped with training wall in order to prevent the formation of dead water zone. The reservoir will be of reinforced concrete structure, its roof being covered with gravel to shield it from direct sunshine. A simple control house will be built in each reservoir site for the surveillance of water level in the reservoir, and flow volume and valve operation in the pipeline.

F2233 The Siwaqa reservoir is located in the west side of the 132 KV transmission line stretching along the Desert Highway. Hence there is a steel transmission tower near the reservoir site. Though not by the regulation, JEA demand that the reservoir be built at least 41.0 m apart from the tower. To meet this condition, the location of the reservoir had to be chosen on the low ground. So raft foundation is used to raise the bottom of the reservoir.

F2.2.4 Control System of Pipeline

F2241 The well pumps are provided at the Siwaqa-Qatrana and Sultani well fields. These pumps are operated by the one-man control system. According to the adoption of this control system, each well pump is independently started and stopped by the manual operation of a operator. The remote control panel for well pumps will be provided in the control house which will be located at near reservoir for each well field.

F2242 The water flow in the pipeline is controlled by the flow control valves equipped at the appropriate position in the pipeline. The opening ratio of flow-control valves will be adjusted by the water level gauge detector in each reservoir and electromagnetic flow meter in the pipeline.

F2.2.5 Electric Supply Plan

F2251 The electric supply for the major facilities will be carried out from the existing distribution line along the Desert Highway which have been installed by JEA. The location of existing distribution lines is shown in Annex F2251.

F2252 The method of electric supply will be planned as follows:

(1) The new 33 KV distribution lines will be branched and extended from the existing 33 KV distribution lines to the major facilities in each well field.

(2) The voltage of 33 KV will be reduced to 400 KV at near major facilities by the 33/0.4 KV pole mounting transformer.

F2.2.6 Other Appurtenant Equipment

F2261 Flow-control valves: Flow-control valves with a flow meter are installed at the end of a pipeline through which water comes into a reservoir by gravity. Since each pipeline is very long, a flow-control valve is liable to cause a big water hammer due to sudden closing operation of valve. For this reason, sleeve type valves will be installed for controlling the flow in the pipeline.

F2262 Air valves, blow-off and stop valves: To facilitate water flow, air valves are installed on a convent parts of the pipeline. Blow-offs leading to a drainage or the Wadi are installed on a concave parts of the pipeline. At the starting points, ending points, branching points and main blow-off points of the pipe line, sluice valves or butterfly valves are installed. The butterfly valve chamber and blow-off are shown on Drawing Nos. 14 to 16.

F2.3 Construction Plan

F2.3.1 General

F2310 The construction plan and implementation schedule on the Sultani-Siwaqa pipeline are prepared by the assumption that the works will be performed by contractors selected through local and international competitive tenders. The main works are planned to be constructed in the form of a package system. The contract includes preparatory works such as the improvement of existing roads construction of a temporary buildings for construction use.

F2.3.2 Implementation Schedule

F2321 From the preparatory work to the final tests, construction work is planned to be completed in 28 months, starting in July 1990 and ending in October, 1992. The detail of implementation schedule is shown on the Annex F2321. Main components of schedule are as follows:

Financial arrangement	: January-December, 1988, 12 months
Selection of consultant	: January-March, 1989, 3 months
Tender and detailed design	: April, 1988-March, 1990, 12 months
Tendering and contract award including prequalification	: January-June, 1998, 6 months
Construction work including preparatory work and final test	: July, 1990-October, 1992, 28 months

F2322 The implementation schedule is planned based on the required work quantities. The work quantities for the pipeline are summarized in Annex F2322.

F2323 Depending on domestic and overseas condition, the import of equipment and materials is expected to take three months including shipping, customs clearance and inland transportation.

F2.3.3 Construction Plan

F2331 Preparatory works: Before starting the major work, preparatory works are to be provided at respective site. The preparatory works consist of the improvement of existing roads and construction of storage yards and temporary buildings for construction use. Areas of major storage yards and buildings are estimated as follows and will be located near in Sultani and Siwaqa reservoirs, respectively.

	Estimated Area (m^2)	
Item	Lane	Building
Goverment office	800	160
Contractor's office	1,300	250
Contractor's quarter	3,000	1,000
Storage yard	1,500	150

F2332 The electric power required for the storage yards and buildings will be supplied from the existing 33 KV distribution line of JEA. The water supply for the above facilities will be supplied from the existing water distribution system along the Desert Highway.

F2333 Production wells: The construction of production wells includes drilling of 39 boreholes with total depth of 10,680 m. It is expected to take 18 months to complete the work. The drilling will be carried out by using four units of rotary rigs with installing the function of chemical foam and air hammer. The rate of drilling depth is estimated to be lump sum rate of 5 m per day per rig which includes drilling geophysical logging, casing installation, well development, pumping test and site transportation.

F2334 Pipeline system: The pipeline is altogether 40.7 km long, for which ductile iron pipes having 500 to 800 mm diameters are to be used. The pipeline construction is planned to be completed in 18 months. The earth of the construction site seems to be fairly hard, characterized by weathered lime stones at hilly area or clay material with gravels at flat area under a soil surface. Pipes will be burried under the ground with earth coverage of 1.0 m. For the trench excavation in the site, the combination of a breaker and backhoe will be needed. To lay the pipes, trench excavation will be carried out by a team equipped with the following machines.

Machine	Capacity	Quantity
Braker	1,300 kg	1 set
Back hoe	0.6 m	2 set
Hydraulic crane	4.8 - 4.9 t	1 set
Hand rammer	60 - 80 kg	5 set
Bulldozer	8 t	1 set

F2335 It is estimated to take 43 days in calendar day to lay ø 500 mm pipes for 1,000 m, and 54 days for 700ø mm pipes. The whole work will be performed by four teams for main pipeline and three teams for lateral pipeline in the well field. This plan, however, may have to be changed by more detailed geological survey.

F2336 Reservoirs: The quantity of major works for the Sultani and the Siwaqa reservoirs are as follows:

	Sultani	Siwaqa
Open excavation (m^3)	2,400	2,600
Backfilling (m^3)	1,500	2,200
Reinforced concrete (m^3)	1,620	7,240

F2337 It is estimated to take 12 months and 14 months to complete the Sultani and the Siwaqa reservoirs, respectively. Open excavation will be carried out with a braker and a bulldozer. A concrete mixing plant of the capacity of 1 m^3 will be installed, and concrete will be placed by using a concrete pump.

F2.3.4 Required Major Construction Equipment and Plants

F2341 The major plants and equipment for the construction of the project are as listed Annex F2341.

F2.3.5 Estimated Land Expropriation

F2351 The extent of land expropriation was provisionally estimated to be 43 ha, constituting of 41 ha for pipeline and 2 ha for two reservoirs.

F2.4 Cost Estimate

F2.4.1 Basic Condition

F2411 The investment cost of the Project and its operation and maintenance costs are estimated on the basis of the preliminary design and the proposed construction plan and implementation schedule. All the cost estimates are made at the price level of 1986 using exchange rates 0.342 JD or 155 Yen to 1 U.S. dollar.

F2412 The basic conditions applied for the cost estimate are as follows:

(1) Unit cost is estimated on the basis of the current similar projects.

(2) Costs of engineering services and administration are estimated at 10% of total direct construction cost.

(3) For unforeseeable change in physical conditions, 15% of total direct construction cost with engineering services and administration cost is added as physical contingency cost.

(4) Contingency cost resulting from currency fluctuation is derived from the estimated annual inflation rate of average 3% for foreign and local currency. This inflation rate is forecasted by using the following indexes.

- Foreign currency portion : Unit value index of manufactured exports from developed to developing countries forecasted by IBRD.

  Source : Half-yearly Revisions of Commodity Price Forecasts, IBRD, December 1983

- Local currency portion : Amman wholesale price index

  Source : Central Bank of Jordan, Monthly Statistical Bulletin

(5) Land acquisition costs for pipeline are estimated to be 1,000 JD/ha for the fertile farmland, and 500 JD/ha for the ordinary farmland.

F2.4.2 Total Investment Cost

F2421 The total investment cost including contingency cost is estimated at JD 19,262 thousand as shown on Annex 2421.

F2422 The local and foreign currency components of the investment cost are estimated. Most of the construction materials for civil work such as cement, reinforcement steel bar, fuel, oil, etc. will be supplied by the contractor from local market. Such materials and labour wages are estimated as the local currency portion. Equipment and materials such as pumps, ductile iron pipes, valves, electrical facilities and distribution line are assumed to be procured from abroad. These belong to the foreign portion.

F2.4.3 Disbursement Schedule

F2431 The Project is recommended to be executed over four years for selection of consultant, detailed design, contracting work and construction work including preparatory works. The disbursement schedule of investment cost is to be made in accordance with the work progressed and is shown on Annex F2431.

F2.4.4 Operation and Maintenance Cost

F2441 Judging from the past records, the operation and maintenance cost of the pipeline is assumed to be 0.5% of its investment cost. For pump stations and well field facilities, it is about 4% of the investment cost.

F2442 Of the total investment cost of the project, the pipeline occupies 60%, and the pump stations/well field facilities take up 40%. Consequently total operation and maintenance cost is calculated to be 2% of the total investment cost.

F3 PRELIMINARY DESIGN OF RUMEIL-MADABA PIPELINE PROJECT

F3.1 Design Criteria

The principal items of design criteria are prepared as described in Paras F2101 to F2108.

F3.2 Preliminary Design

F3.2.1 Production Well

F3211 The production well is designed to penetrate the main aquifer of the B2/A7 Formation to the depth of 250 to 335 m. The drilling is performed by two stages in depth, that is drilling (1) by diameter of 17-1/2 inches to the depth of 150 to 230 m and then (2) by diameter of 12-1/4 inches to the bottom as shown in typical well design of Annex F2211-1. The casing program consists of installing i) pump chamber pipe with diameter of 13-3/8 inches and ii) screen pipe with diameter of 9-5/8 inches, which is installed in accordance with drilling program as mentioned above. The drilling and casing program for each production well is shown in Annex F3211.

F3212 Design condition of the casing and screen pipe is described in the previous Para F2212.

F3213 Design pumping rate of the production well is estimated to be 60 m^3/h, depending on the operation schedule of 16 hours per day, that is decided by taking account of (1) the regional aquifer parameters and (2) the recovery factor the wells, in order to sustain the B2/A7 aquifer system for the perennial use.

F3.2.2 Pipeline System

F3221 Pipe diameter: The pipe diameters are determined referring to the "optimum pipeline diameter" in Para F2104. The following is the outline of pipe diameters.

	Diameter (mm)	qmax. (m^3/s)	velocity (m^3/s)
Wadi el Butum well field (0 km) - 3.1 km	300	0.067	0.95
3.1 km - Abu Haliefa reservoir (4.1 km)	400	0.150	1.21
4.1 km - Branch point (9.5 km)	400	0.130	1.04
9.5 km - Rumeil booster pump station (13.0 km)	700	0.313	0.82
13.0 km - Madaba connection point (27.1 km)	700	0.289	0.76

F3222 Hydraulic design of the pipeline is shown on Annex F3222.

F3223 As shown on Annex F3222, the profile of the Wala-Yaduda pipeline have a point, which will comes above the hydraulic-grade line for Rumeil booster pump. This point is located at 3.3km upstream side from the Yadudak pump station. Such profile will occur the obstruction to pump operation. Therefore, it is presumed that the route profile of Madaba-Yaduda pipeline would be reviewed by WAJ.

F3.2.3 Reservoir

F3231 The reservoir capacity and its draw down are derived from the same principle as described in Para F2105.

	Average flow (MCM/y)	Volume (m^3)
Abu Haliefa reservoir	3.15	1,800
Rumeil reservoir	7.0	4,000
Total		5,800

The total capacity amounts to approximately 7-hour for average flow volume.

F3232 Principle of layout and the structure of reservoirs are the same as in the case of the Sultani-Siwaqa pipeline. The layout of reservoirs is shown on drawing Nos.12 and 13.

F3.2.4 Rumeil Booster Pump Station

F3241 Rumeil booster pump station will be installed in T.34 point as shown on Drawing No. 9. The number of booster pumps is decided so as to meet the peak flow requirement as defined in Para F2102. The pumping installation comprises four electrically operate pumps, three duty units and one standby. The pumping is normally continuous operation. Type of pump is of the double suction volute pump. No provision for standby generator has been made, because as it is considered that the future electrification of the project area is sufficiently advanced to ensure reliable supplies of power at the pump station.

F3242 The water hammar, which will be occurred in the pipeline due to pump trip, is not analyzed in this report, because the design condition of Madaba-Yaduda pipeline to be connected with this pipeline are not yet decided in detail. Besides, it is essential that the water hammer analysis in this pipeline must be made under the combined operation of both this pipeline and Madaba-Yaduda pipeline. Accordingly, it is recommended that the water hammer analysis should be carried out on the detailed design stage for this pipeline.

F3.2.5 Control System of Pipeline

F3251 The well pumps are provided at the Rumeil well field. These pumps will be operated by applying of the one-man control system, which is described in Para F2241.

F3252 The discharge of booster pumps will be controlled due to the number of pump. For the realization of the reliable control system for booster pumps, the control system of the booster pump station will be integrated into the control system of the Amman ring pipeline. Accordingly, the booster pump station will be provided with the telemetering equipment to transmit the operational condition of the booster pump to the master control station for the Amman ring pipeline.

F3253 The water flow in the pipeline will be controlled by the flow-control valves equipped at the appropriate position in the pipeline. The opening ratio of flow-control valves will be adjusted by the water level gauge detection in each reservoir and the electromagnetic flow meter in the pipeline.

F.3.2.6 Electric Supply Plan

F3261 At the present condition, no existing distribution line is provided at the Rumeil well field. The location of existing distribution lines is shown in Annex F2251.

F3262 For supplying the stable electricity to major facilities, the new 33 KV distribution line will be installed from the Queen Alia Air Port substation at Jiza to the Rumeil well field. The method of electric supply will be planned as follows:

(1) The new 33 KV distribution line will be installed from the Queen Alia Air Port substation to the Rumeil well field through Nitel.

(2) The voltage of 33 KV will be reduced to 400 V at near major facilities by the 33/0.4 KV pole mounting transformer.

F.3.2.7 Other Appurtenant Equipment

F3271 Surge arrester tanks: Two number of surge arrester tanks will be required at near booster pumping station to solve water hammer which will be occurred due to pump trip. A capacity of one surge arrester tank is assumed to be $100m^3$.

F3272 Flow-control valves: Flow-control valves with a flow meter are installed at the end of a pipeline through which water comes into a reservoir by gravity. Since each pipeline is very long, the flow-control valve is liable to cause a big water hammer due to the sudden closing operation of valve. For this reason, sleeve type valve will be installed for controlling the flow in the pipeline.

F3273 <u>Air valve, blow-off and stop valve</u>: To facilitate water flow, air valves are installed on convet parts of the pipeline. Blow-offs leading to a drainage or the Wadi are installed on a concave parts of the pipeline. At the starting points, ending points, brancheing points and main blow-off points of the pipe line, sluice valves or butterfly valves are installed. The butterfly valve chamber and blow-off are shown on Drawing Nos.14 to 16.

F3.3 Construction Plan

F3.3.1 General

F3311 The condition of making construction plan is the same as previous Para F2311.

F3.3.2 Implementation Schedule

F3321 From the preparatory work to the final test, construction work is planned to be completed in 28 months starting in July 1990 and ending in October, 1992. The detail of implementation schedule is shown in the Annex 3321. Main components of schedule are as follows:

Final arrangement	: January - December, 1988, 12 months
Selection of consultant	: January - March, 1989, 3 months
Tender and detailed design	: April, 1989 - March, 1990, 12 months

Tendering and contract award including prequalification	:	January - June, 1990, 6 months
Construction work including preparatory work and final test	:	July, 1990 - October, 1992, 28 months

F3322 The implementation schedule is planned based on the required work quantities. The work quantities for the pipeline are summarized in Annex F3322.

F3323 The import of equipment and materials is expected to take three months as shown in Para F2323.

F3.3.3 Construction Plan

F3331 Preparatory works: The component of preparatory works are almost same as said Para F2331. Area of major storage yards and buildings are estimated as below, and the location is supposed near planning Rumeil booster pump station site.

Item	Estimated Area (m^2)	
	Land	Building
Government office	600	160
Contractor's office	1,000	250
Contractor's quarter	2,400	1,000
Storage yard	1,200	150

F3332 Electric power required for the construction use will be supplied from the distribution line conducting temporarily from Nitil before starting of construction.

F3333 Production wells: The construction of production wells includes drilling of 21 boreholes with total depth of 6,050 m. It is expected to take 10 months to complete the work. The drilling will be carried out by using four units of rotary rigs with installing the function of chemical foam and air hammer. The rate of drilling depth is estimated to be lump sum rate of 5m per day per rig which includes drilling geophysical logging, casing installation, well development, pumping test and site transportation.

F3334 Pipeline system: The length of the main and branch pipelines are 27.4 km and 13.9 km respectively, for which ductile iron pipes having 300 mm to 700 mm in diameter are to be used. The total length to a main line and a branch line comes to 41.3 km and this length is nearly same as the case of Sultani-Siwaqa pipeline. The pipeline construction is planned to be completed in 18 months. Condition of the earth in the construction site is not so different from the one in Desert Highway area. Therefore same construction method in Paras F2334 and F2335 will be applied to this construction site. Construction of the main pipeline will be done by three teams and two teams for branch pipeline including latoral pipeline in the well field. This plan, however, may have to be changed by more detail geological survey.

F3335 Reservoirs: The quantities of major works for Abu Haliefa and Rumeil reservoirs are as follows:

	Abu Haliefa	Rumeil
Open excavation (m^3)	1,900	2,300
Back filling (m^3)	1,250	2,400
Reinforced concrete (m^3)	920	1,860

F3336 It is estimated to take 8 months and 11.5 months to complete the Abu Haliefa and the Rumeil reservoirs respectively. The installation of Rumeil booster pump station is estimated at 5 months and will be carried out at the same time together with the construction of Rumeil reservoirs. Open excavation will be carried out with a braker and a bulldozer. A concrete mixing plant of the capacity 1 m^3 will be provided, and concrete will be placed using a concrete pump.

F3.3.4 Required Major Construction Equipment and Plants

F3341 The major plant and equipment for the construction of the Project are listed in Annex F3341.

F3.3.5 Estimated Land Expropriation

F3352 The extent of land expropriation is provisionally estimated to be 27 ha consisting of 25.5 ha for the pipeline and 1.5 ha for the reservoir and pump stations.

F3.4 Cost Estimate

F3.4.1 Basic Condition

F3411 Basic condition of cost estimate is the same as previous Paras F2411 and F2412.

F3.4.2 Total Investment Cost

F3421 The total investment cost including contingency cost is estimated at JD 14,621 thousand as shown on Annex F3421.

F3422 The definition of local and foreign currency portion are same as Para F2422.

F3.4.3 Disbursement Schedule

F3431 The project is recommended to be executed over four years from the selection of consultant to the final test of pipeline. The disbursement schedule of investment cost is to be made with the work progressed and is shown on Annex F3431.

F3.4.4 Operation and Maintenance Cost

F3441 Operation and maintenance cost is estimated at 2% of investment cost in the same manner as shown in Paras F2441 and F2442.

F4 ECONOMIC EVALUATION

F4.1 General

F4101 The municipal water supply project is in general evaluated technically and financially, exclusive of economic evaluation, because it is very difficult to find out the real water value. In the present study, an attempt is nevertheless made on the economic evaluation by assuming an appropriate value of water. The economic evaluation is made by economic internal rate of return (EIRR), benefit-cost ratio (B/C) and net present value (B-C), and a sensitivity test is carried out in terms of EIRR to ascertain the economic viability of the project.

F4102 The evaluation is made as to three cases; (1) Sultani-Siwaqa pipeline project, (2) Rumeil-Madaba pipeline project and (3) combined project of (1) and (2). The project life is taken as 30 years from the commencement of these projects.

F4.2 Economic Cost

F4201 The economic cost of the project is given by applying the transfer and opportunity costs and the standard conversion factor assumed in Annex F4201-1 against the financial cost (see Paras F2421 and F3421). The economic construction cost is estimated at JD 16,486 x 10^3 for the Sultani-Siwaqa pipeline project, JD 12,510 x 10^3 for the Rumeil-Madaba pipeline project and JD 28,986 x 10^3 in total. The annual flow of the economic construction cost is shown in Annex F4201-2, and is summarized below:

Economic Construction Cost

	Project	Total	1989	1990	1991	1992
(1)	Sultani-Siwaqa	16,486	528	1,927	10,304	3,727
(2)	Rumeil-Madaba	12,510	376	1,353	6,480	4,301
(3)	Combined	28,996	904	3,280	16,784	8,028

F4202 The economic operating and maintenance cost (OM cost) is estimated to be JD 230 x 10^3 for the Sultani-Siwaqa project and JD 174 x 10^3 for the Rumeil-Madaba project, and these annual flows together with the economic replacement cost are shown in Annexes F4202-1 and F4202-2. The economic OM cost of the combined project comes to JD404 x 10^3 and its cost flow is given in Annex F4202-3.

F4.3 Economic Benefit

F4301 The economic benefit of the pipeline construction project would be given as a product of the water value and the volume of water supplied. However, it is in general very difficult to find out the real water value. An assumed value is therefore introduced in the present study. According to the result of questionnaire to 47 cities (25 countries) in the world in 1982 by the Japan Water Works Association, the ratio of water tariff to income per household is distributed as follows:

Ratio of water tariff to income per household (%)	Distribution (%)
< 0.5	29.8
0.5 - 0.8	17.0
0.8 - 1.0	17.0
1.0 - 1.5	23.3
> 1.5	12.9

An average ratio is estimated at about 0.9% from the above distribution. In general, it appears that the water tariff reflects economic, financial, political and social conditions in respective objective areas, and in a society matured economically, it is supposed that the water tariff would be in the economic balance in the society, namely, such water tariff is expected to be close to the economic value of water based on result of the said questionnaire. From such a viewpoint, in the present study the water value per household is assumed to correspond to approximately 1% of income per household based on result of the said questionnaire. The effect to the economic evaluation of variation in the water value assumed will be discussed by a sensitivity test later on.

F4302 The water value per cu.m in the Study Area in 1985 is estimated at JD 0.231 under the following conditions:

(1) The per capita income adopts the figures given in Para M.3.1.5, for example, JD 738 per annum for the Amman Governorate and JD 689 per annum for the national level.

(2) Household size is set at 6.7 persons (see Table A-23, Appendix A).

(3) The per capita water consumption in the Study Area is assumed to be 90 lit/c/d for the Amman and Zarqa Governorates, 45 lit/c/d for Irbid Governorate, 65 lit/c/d for the Balqa Governorate and 80 lit/c/d for Karak Governorate, based on figures in 1985 shown in Annex M5311.

Further, assuming that the real growth rate of per capita income will be 3% on average per annum during the period from 1985 to the end year of the project life, the water value is estimated at JD 0.293/m^3 in 1993.

F4303 The water volume supplied to the Study Area is designed to be 16 MCM per annum through the Sultani-Siwaqa pipeline and 7 MCM per annum through the Rumeil-Madaba pipeline in and after 1993. The economic benefits brought by these water supplies are estimated under the following assumption:

(1) The rate of lost and unaccounted water is assumed to be 32% of the supplied water on average during the period from 1985 to the end year of the project life, in accordance with the projection of VBB

Report.

(2) The range of construction of two pipelines, Sultani-Siwaqa and Sultani-Madaba pipelines, is a part of the whole line to the Greater Amman area. Accordingly, the economic benefit of the project seems to be given by dividing the whole benefit expected in the Greater Amman area between the present project and the other construction project of pipeline to be connected, for example, in ratio of the construction cost. This ratio is supposed as some 65% as to the Sultani-Siwaqa project and some 80% as to the Rumeil-Madaba project.

F4304 Under the said assumption, the economic annual benefit in 1993 is estimated at JD 2,072 x 10^3 for the Sultani-Siwaqa project, JD 1,116 x 10^3 for the Rumeil-Madaba project and JD 3,188 x 10^3 for the combined project. These benefits would accrue during the period of project life increasing at the rate of 3%. The economic benefit flow together with the flows of construction cost and OMR cost are shown in Annexes 4202-1, 4202-2 and 4202-3.

F4.4 Economic Analysis

F4401 Using the annual flows of the economic cost and benefit, EIRR together with the benefit-cost ratio (B/C) and the net present value (B-C) are calculated, and the results are summarized below:

	Project	EIRR (%)	B/C Discount Rate 5%	B/C Discount Rate 10%	B-C (JD1,000) Discount Rate 5%	B-C (JD1,000) Discount Rate 10%
(1)	Sultani-Siwaqa	11.6	1.82	1.14	14.417	1,879
(2)	Rumeil-Madaba	7.6	1.28	0.81	3,797	-1,852
(3)	Combined	10.0	1.59	1.00	18,214	27

EIRR of the project is estimated at 11.6% for the Sultani-Siwaqa project and 7.6% for the Rumeil-Madaba project, and further 10.0% for the combined project. As for the Rumeil-Madaba project, EIRR is somewhat low compared with that of the Sultani-Siwaqa project, but it seems to be fairly high judging from an average level of municipal water supply project.

Accordingly, it indicates that both projects are economically viable.

F4.5 Sensitivity Test

F4501 The sensitivity of EIRR is tested for increase in the project cost and decrease in the project benefit by 5% and 10% either of the cost and benefit, and the result is summarized below:

(1) EIRR of Sultani-Siwaqa Project

Unit : %

	Decrease in Benefit		
	0%	5%	10%
Increase in Cost			
0%	11.6	11.0	10.3
5%	11.0	10.4	9.8
10%	10.4	9.8	9.2

(2) EIRR of Rumeil-Madaba Project

Unit : %

	Decrease in Benefit		
	0%	5%	10%
Increase in Cost			
0%	7.6	7.1	6.5
5%	7.1	6.6	6.0
10%	6.6	6.1	5.5

(3) EIRR of the Combined

Unit : %

	Decrease in Benefit		
	0%	5%	10%
Increase in Cost			
0%	10.0	9.4	8.8
5%	9.4	8.9	8.3
10%	8.9	8.3	7.7

In common to all of the above three cases, EIRR decreases by about 1% due to the 10% decrease in benefit, for example, EIRR of the Rumeil-Madaba project decreases from 7.6% of the original to 5.5% in case of the 10% increase in cost and the 10% decrease in benefit, but it is still higher than the average level of municipal water supply project. Accordingly, the result of sensitivity test indicates that the project is economically viable. For example, the benefit would decrease by 20% in case of the 20% decrease in the water value or the 20% increase in distribution losses of water, and as the result EIRR would decrease by about 2%, but the project is still economically viable.

F4.6 Social and Economic Impacts

F4601 Aside from the direct benefit discussed in Para F4.3, various indirect and/or intangible effects would be produced from the implementation and completion of the project. Among them, major effects are mentioned below:

(1) Completion of the project would relieve water shortage in the Greater Amman area after 1993. As a result, it would be to give a basic security for the stabilization of people's livelihood and for the development of socio-economic activities of inhabitants.

(2) Implementation of the project would give a stimulative effect for promoting the socio-economic development in and around the Study Area.

(3) The greater employment opportunities would be created for inhabitants, especially for unemployment laborers, in and around the Study Area during the construction period of four years.

F5. FINANCIAL EVALUATION

F5.1 Financial Cost

F5101 The financial cost is provided as to two cases with and without loans for the construction fund. The financial construction cost is estimated at JD 19,263 x 10^3 for the Sultani-Siwaqa pipeline project, JD 14,621 x 10^3 for the Rumeil-Madaba pipeline project and JD 33,885 x 10^3 in total (see Para F3.4.1). The annual disbursement schedule of these costs is summarized below:

Annual Construction Cost

Unit: JD 1,000

Project	Total	1989	1990	1991	1992
(1) Sultani-Siwaqa	19,263	601	2,216	11,979	4,467
(2) Rumeil-Madaba	14,621	427	1,541	7,525	5,128
(3) Combined	33,884	1,028	3,757	19,504	9,595

F5102 The loan conditions for construction fund are assumed as follows:

(1) International loan is financed for the foreign currency portion (F.C.) of construction cost under the following conditions:

- Annual interest rate: 4.5 %
- Grace period: 7 years
- Repayment period: 25 years (including grace period)

(2) Domestic loan is financed for the local currency portion (L.C.) of construction cost under the following conditions:

- Annual interest rate: 6%
- Grace period: 4 years
- Repayment period: 20 years (including grace period)

The annual flows of these interests together with the capital are given in Annexes F5102-1, F5102-2 and F5102-3.

F5103 The financial operating and maintenance cost (OM cost) is estimated at JD 271 x 10^3 per annum for the Sultani-Siwaqa project and JD 205 x 10^3 per annum for the Rumeil-Madaba project, and the annual flows of OM cost together with the replacement cost are shown in Annexes F5102-1 and F5102-2. The OM cost of the combined project comes to JD 476 x 10^3 per annum, and its annual flow is given in Annex F5102-3.

F5.2 Financial benefit

F5201 The financial benefit (or revenue) is given as a product of the water tariff and the volume of water supplied. The average monthly volume of water consumption per household in the Study Area is estimated to be 18 m^3 for the Amman and Zarqa Governorates, 9 m^3 for the Irbid Governorate, 13 m^3 for the Balqa Governorate and 15 m^3 for the Karak Governorate, using the assumptions in terms of the household size and the per capita water consumption shown in (2) and (3) of Para F4302. By applying these results to the water tariff of Jordan as of June 1986 (see Annex F5201) and the population distribution by governorate (see Annex M5231), an average tariff of water supplied in the Study Area is estimated to be JD 0.117/m^3 in 1986. Further, it is estimated at JD 0.144/m^3 in 1993 assuming that the average growth rate of water tariff would be 3% per annum during the period from 1986 to the end year of the project life.

F5202 In and after 1993, the annual water volume to be supplied to the Study Area through the Sultani-Siwaqa pipeline and the Rumeil-Madaba pipeline is 16 MCM and 7 MCM, respectively, as mentioned previously. In 1993, the annual revenue from these water supplies is estimated at JD 1,567 for the Sultani-Siwaqa project and JD 685 x 10^3 for the Rumeil-Madaba project, by applying the said supply volume to the water tariff mentioned in the preceding paragraph, and further taking into account the rate of 32% in terms of the lost and unaccounted water. The revenue flows of three cases are given in Annexes F5102-1, F5102-2 and F5102-3, respectively.

F5.3 Financial Viability

F5301 Using the annual flows of the financial cost and benefit (see Annexes F5102-1, F5102-2 and F5102-3), the financial internal rate of return (FIRR) together with the benefit-cost ratio (B/C) and the net present value (B-C) are computed, and the results are summarized below:

Case 1: without loan

	FIRR (%)	B/C Discount Rate: 2%	B-C (JD 1,000) Discount Rate: 2%
(1) Sultani-Siwaqa	6.6	1.60	15,492
(2) Rumeil-Madaba	1.3	0.92	-1,491
(3) Combined	4.7	1.64	33,912

Case 2: with loan

	FIRR (%)	B/C Discount Rate: 2%	B-C (JD 1,000) Discount Rate: 2%
(1) Sultani-Siwaqa	3.8	1.20	6,837
(2) Rumeil-Madaba	-	0.68	-8,474
(3) Combined	1.7	0.97	-1,637

(1) Case without loan:

FIRR is estimated at 6.6% which is financially viable for the Sultani-Siwaqa project. Regarding the Rumeil-Madaba project, although FIRR shows the low figure, it seems to be viable financially from the stand of public utilities corporation.

(2) Case with loan:

Under the Loan conditions mentioned in Para F5102, FIRR is estimated as shown above. It indicates that the Sultani-Siwaqa project and the combined project are financially viable and the Rumeil-Madaba project is inviable financially.

F5302 The annual flows of the revenue and expenditure of the project are given in Annexes F5102-1, F5102-2 and F5102-3. In case of the Sultani-Siwaqa project, the annual revenue from water sold could cover the annual expenditure in the fourteenth year (the year 2002) after the start of project, and the accumulated deficit would be eliminated in the twentieth year (the year 2008). On the other hand, in case of the Rumeil-Madaba project, the annual revenue could cover the annual expenditure in the twenty-third year (the year 2011), but the accumulated deficit would not be eliminated within the period of project life. In case of the combined project, the accumulated deficit could be eliminated within the period of 30 years. It appears that the Remeil-Madaba project is attended with financial difficulty. As a measure to relieve such difficulty, it is considered to be implemented as one package financially by combining the Remeil-Madaba project with the Sultani-Siwaqa project.

F6 INSTITUTIONAL STUDY

F6.1 Executive Agency for Construction

F6101 In Jordan, the Jordan Valley Authority (JVA) and the Water Authority of Jordan (WAJ) are in charge of every project relating to water resources and water supply. Both organizations are directly accountable for the Prime Minister of Jordan.

F6102 JVA is mainly engaged in agro-related projects in the low land (below sea level) facing the Jordan Valley and the Dead Sea.

F6103 WAJ conducts the development and management of water supply/ sewerage systems outside the domain of JVA. Its main activities include:

- Water supply & sewerage service
- Monitering of water resources & water quality
- Planning, designing, construction, operation and maintenance of facilities for water resources, water supply & sewerage

The organization chart of WAJ is shown on the Annex F6103.

F6104 The current project aims to construct water supply systems from the Mujib basin to the Greater Amman area. The contents and location of the project indicate that WAJ shall be in charge of it.

F6105 WAJ takes full responsibility for the whole process of the project, including survey, plan, design and construction.

F6106 WAJ is currently engaged in the construction of the Sueilie-Madaba pipeline and Yaduda-Abu Alanda-Azraq pipeline. Also, the Wala water conveyance project and New Siwaqa water conveyance project are now at the stage of planning and designing. All these projects are carried out in cooperation with appropriate consulting firms, which design, construction works to be executed by contractors selected through international competitive tenders. WAJ supervises the whole process of projects.

F6107 Under the general management of WAJ, appropriate consulting firms take part in the pipeline project proposed in this study, too.

F6.2 Executive Agency for Operation and Maintenance

F6201 The pipeline systems constructed by this project will belong to WAJ. The operation of these systems would be fully in tune with that of WAJ's other water supply systems for the Greater Amman area. Therefore, the operation and maintenance of the planned pipeline systems would be also performed by WAJ.

F6202 In order to carry out Sultani-Siwaqa and Rumeil-Madaba pipeline projects successfully and operate the completed facilities for these pipelines in a sound manner, a special task unit would be desirable to be established in WAJ. The line of authority of the task unit will be led by the president of WAJ. All staff of the task unit will be taken from among the staff of WAJ.

F7 CONCLUSION AND RECOMMENDATION

F7001 Water supply to the Greater Amman area: In 1985, the supply of water to the Greater Amman area and the Mujib watershed was 61.5 MCM against the demand of 70 MCM. In the target year 2005, this demand will grow to 192 MCM with average annual growth rate of 5.2%. WAJ is undertaking many projects to increase the supply capacity. However, with all of the capacities of such projects added, the total capacity will become 114 MCM leaving a deficiency of 78 MCM. Thus, further reinforcement of supply capacity is definitely needed.

F7002 Advantage of the Mujib groundwater: The groundwater potential clarified under the present study, about 23 MCM, is the only water source of which quantitative character is known at present. Mujib groundwater is located nearest to the Greater Amman area among all the conceivable water sources. And, the entire Mujib watershed is located in the Kingdom leaving no international problems to develop. These conditions indicate that the Mujib groundwater is highly suitable for the source of water supply in the Greater Amman area.

F7003 Allotment of groundwater: Under the Study, it is clarified that the sustained yields of the well fields are 6.3 MCM of Sultani, 9.6 MCM of Siwaqa-Qatrana, 7.0 MCM of Rumeil and 5.0 MCM of Lajjun. Of them, the Lajjun well field is to be preserved for the future development of the oil shale by the Government policy. Total of the remainder makes some 23 MCM. This amount corresponds to about 30% of the afore-mentioned deficiency of 78 MCM and to reduce the deficiency down to 53 MCM. Moreover the extraction of the full amount does not give essential influence on the amount of the base flow on the lower reaches. Hence, it is planned to take this amount for the water supply of the Greater Amman area.

F7004 Formulation of pipeline projects: Currently, WAJ is undertaking the implementation of many pipeline projects. The outcomes of these projects are to be used fully for the development of water source under the present study. Water from the proposed Sultani and Siwaqa-Qatrana well fields located to the south of Siwaqa is to be sent through pipeline to Siwaqa from which place the Yadudah-Siwaqa pipeline is to be constructed by WAJ. This pipeline with the Sultani and Siwaqa-Qatrana well fields are to formulate a pipeline project referred tentatively to as the Sultani-Siwaqa pipeline Project. Water from the Rumeil well field is to be sent through pipeline to Madaba from which place the Yadudah-Madaba pipeline is to be constructed by WAJ. This pipeline with the Rumeil well field are to formulate a pipeline project referred tentatively to as the Rumeil-Madaba pipeline Project. For these two pipeline projects, studies on the feasibility study level are made, and the results are stated later.

F7005 Sultani Siwaqa Pipeline Project: Four years will be necessary for construction. The total financial cost is estimated at JD 19.262 million (equivalent to US$ 6.7 million at JD 1 = US$ 2.92 rate). Of the amount, JD 14.425 milliom is for foreign currency portion and JD 4,837 million is for local currency portion. The economic cost of the Project is estimated at JD 16.480 million against the total investment cost. Economic benefit is calculated at JD 2.1 million a year, and financial benefit at JD 1.5 million a year. Then the economic internal rate of return (EIRR) is evaluated at 11.6% and the financial internal rate of return (FIRR) at 6.6%. The total financial cost is summarized on the following table.

(Unit: JD 1,000)

Item No.	Description	Total	Foreign Currency	Local Currency
(1)	Land Acquisition	43	0	43
(2)	Direct Cost	13,561	10,658	2,903
(3)	Engineering Services and Administration	1,356	664	694
(4)	Physical Contingency	2,238	1,698	540
(5)	Price Escalation	2,064	1,405	659
	Grand Total	19,262	14,425	4,837

F7006 Rumeil-Madaba Pipeline Project: Four years will be necessary for construction. The financial cost is estimated at JD 14.621 million (equivalent to US$ 42.7 million at JD 1 = US$ 2.92 rate). Of the amount, JD 11.143 million is for foreign currency portion and JD 3,478 million is for local currency portion. The economic cost of the Project is estimated at JD 12.510 million against the total investment cost. Economic benefit is calculated at JD 1.1 million a year, and financial benefit at JD 0.7 million. Then EIRR is evaluated at 7.6% and FIRR at 1.3%. The total investment cost is summarized on the following table.

(Unit: JD 1,000)

Item No.	Description	Total	Foreign Currency	Local Currency
(1)	Land Acquisition	27	0	27
(2)	Direct Cost	10,263	8,205	2,058
(3)	Engineering Services and Administration	1,026	503	523
(4)	Physical Contingency	1,693	1,306	387
(5)	Price Escalation	1,612	1,129	483
	Grand Total	14,621	11,143	3,478

F7007 Combined consideration: As mentioned above, two pipeline projects are formulated because of the intention to utilize fully the on-going pipeline projects undertaken by WAJ. However, these two projects are to be considered to be the integral parts of the comprehensive plan to develop the groundwater potential of the whole Mujib watershed. In this context, the fund procurement of two projects is desirably to be made in a package. Combined EIRR is calculated at 10% and FIRR at 7%.

F7008 Sensitivity tests: The sensitivity of EIRR is tested for increase in the economic cost and decrease in the economic benefit by 5% and 10% either of the cost and benefit. In common to all of the above three cases, EIRR decreases by about 1% due to the 10% increase in cost or the 10% decrease in benefit, for example, EIRR of the Rumeil-Madaba project decreases from 7.6% of the original to 5.5% in case of the 10% increase in cost and the 10% decrease in benefit, but it is still higher than the average level of municipal water supply project. Accordingly, the result of sensitivity test indicates that the project is economically viable.

F7009 Recommendation: Both projects are technically feasible. Both projects are economically and financially viable. In view of the necessity of urgent reinforcement of city water supply, it is recommended to commence to take necessary step for implementation of the both projects at the earliest possible time.