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

MAIN REPORT

JULY 1987

JAPAN INTERNATIONAL COOPERATION AGENCY

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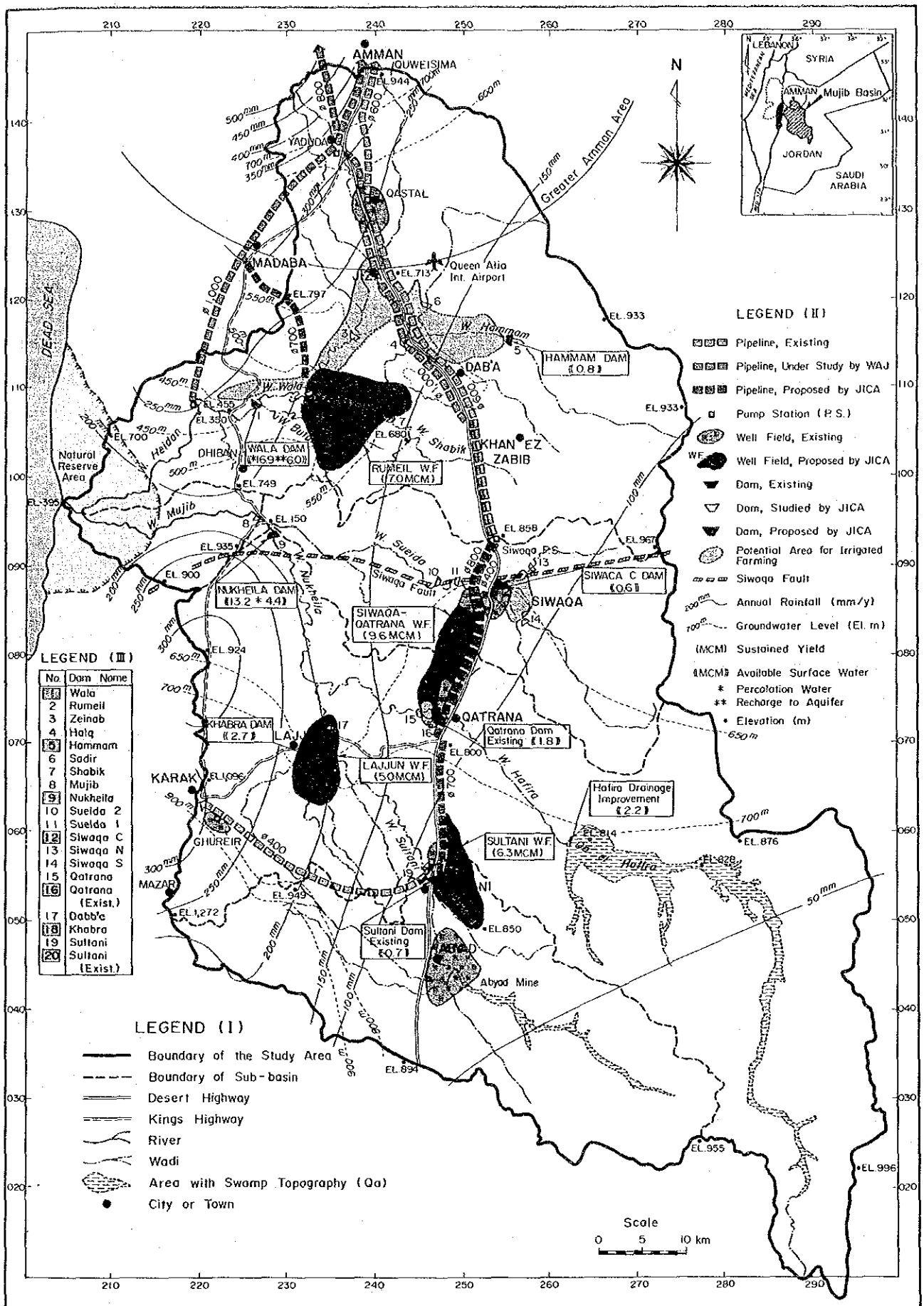

LEGEND (I)

- Boundary of the Study Area
- Boundary of Sub-basin
- Desert Highway
- Kings Highway
- River
- Wadi
- Area with Swamp Topography (Qa)
- City or Town

LEGEND (II)

- Pipeline, Existing
- Pipeline, Under Study by WAJ
- Pipeline, Proposed by JICA
- Pump Station (P.S.)
- Well Field, Existing
- Well Field, Proposed by JICA
- Dam, Existing
- Dam, Studied by JICA
- Dam, Proposed by JICA
- Potential Area for Irrigated Farming
- Siwaqa Fault
- Annual Rainfall (mm/y)
- Groundwater Level (El. m)
- (MCM) Sustained Yield
- (MCM) Available Surface Water
- * Percolation Water
- ** Recharge to Aquifer
- Elevation (m)

LEGEND (III)

No.	Dam Name
1	Wala
2	Rumeil
3	Zeinab
4	Halq
5	Hammam
6	Sadir
7	Shabik
8	Mujib
9	Nukheila
10	Sueida 2
11	Sueida 1
12	Siwaqa C
13	Siwaqa N
14	Siwaqa S
15	Qatrana
16	Qatrana (Exist.)
17	Qabb'e
18	Khabra
19	Sultani
20	Sultani (Exist.)

THE MUJIB WATERSHED

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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

HYDROGEOLOGICAL AND WATER USE STUDY

OF

THE MUJIB WATERSHED

LIST OF VOLUMES

1. MAIN REPORT

2. APPENDIX (I)
   - A. SOCIO-ECONOMY
   - B. HYDROLOGY
   - C. GROUNDWATER RESOURCES
   - D. MUNICIPAL WATER SUPPLY PLANNING
   - E. ENGINEERING GEOLOGY
   - F. DAM PLANNING
   - G. AGRICULTURE

3. APPENDIX (II) STUDY ON TWO WATER PIPELINE PROJECTS ON FEASIBILTY LEVEL

PREFACE

It is with great pleasure that I present this report entitled "HYDROGEOLOGICAL AND WATER USE STUDY OF THE MUJIB WATERSHED" to the Government of the Hashemite Kingdom of Jordan.

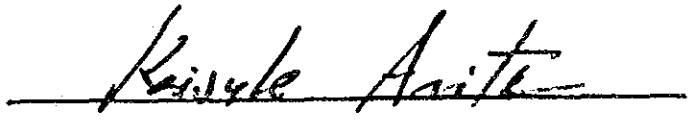
The report embodies the result of the study which was carried out from October 1985 to July 1987 by a Japanese study team commissioned by the Japan International Cooperation Agency following the request of the Government of the Hashemite Kingdom of Jordan to the Government of Japan.

The Study Team, headed by Mr. Takao Ichimiya of the Nippon Koei Co., Ltd., had a series of discussions on the Study with the officials concerned of the Government of Jordan, conducted a wide-ranging field survey and has prepared the present report.

I hope that this report will be useful as a basic reference for development of the Project and contribute to the promotion of friendly relations between our two countries.

I wish to express my deep appreciation to the officials concerned of the Government of the Hashemite Kingdom of Jordan for their close cooperation extended to the team.

July, 1987



Keisuke Arita
President
Japan International
Cooperation Agency

July, 1987

Mr.Keisuke Arita
President
Japan International
Cooperation Agency
Tokyo

Dear Sir,

LETTER OF TRANSMITTAL

We have the pleasure of submitting to you a Final Report of Hydrogeological and Water Use Study of the Mujib Watershed prepared for the consideration by the Government of Jordan in implementing water resources development in nation's socio-economic development objective.

This report consists of three volumes. The Main Report contains the results of the master plan level study of the future water resources development in the Mujib watershed based on the national development policy. The plan indicates that it is the time to expedite water resources development to a great deal to attain the declared goal of the socio-economic development in the country. Appendix-I contains preliminary analyses and discussions in seven sectors to support the master plan presented in the Main Report. Appendix-II contains a study on two water pipeline projects on feasibility study level.

All members of the Study Team wish to express grateful acknowledgement to the personnel of the Advisory Committee, Ministry of Foreign Affairs, Embassy to Jordan as well as officials and individuals of Jordan for their assistance extended to the Study Team.

In conclusion, the Study Team sincerely hopes that the study results would contribute to socio-sconomic development and well-being in general and to the future water resources development in the country.

Yours sincerely,

T. Ichimiya

Takao Ichimiya
Team Leader
Hydrogeological and Water Use Study
of the Mujib Watershed

SUMMARY

A Background

1 In the Hashemite Kingdom of Jordan, the most important and vital area is the capital area (the Greater Amman area), and the watershed of the Mujib River system is located adjacent to the south of the capital area. The water resources in the watershed has been developed to a considerable extent, but an overall study has not been made yet, and the potential of the water resources has not been evaluated. Thus, the Government of Jordan decided to implement the hydrogeological and water use study of the Mujib watershed (the Study), and requested the Government of Japan to provide a necessary technical assistance. The executive agency of the Study is the Water Authority of Jordan (WAJ).

2 In response to this request the Government of Japan organized a Study Team through Japan International Cooperation Agency (JICA). The study works were commenced in October 1985. Until July 1987, the Study Team was dispatched to Jordan for four times and carried out the field works in close cooperation with WAJ, as well as the home works in Japan. Four reports such as the Inception, Progress, Interim and Draft Final Reports were prepared, and discussions were made with WAJ and other concerning agencies of Jordan. This is a Final Report of the Study with the comments from the Jordanian side are duly incorporated in.

B Present Condition

3 Geography: The Mujib watershed is situated adjacent to the south of Amman having a drainage area of 6,600 km^2 which occupies 7% of the territory of Jordan, 98,000 km^2. The Mujib River consists of two tributaries, the Wadi Wala (alias Heidan) and the Wadi Mujib, which join into the Wadi Mujib immediately upstream from the estuary. Many tributaries run with gentle slopes on the flat highlands, 700-900 m high above sea level, flow down in gorges with steep slopes joining neighbouring tributaries, and the main stream finally debouches to the Dead Sea of which salt content is 25%, being the highest in the world, at about 400 m below the sea level which is the lowest water level in the

world. The Desert Highway and the King's Highway run in the north-south direction crossing the tributaries on the highland and on the escarpment respectively. Northern half of the watershed belongs administratively to the governorate of Amman and southern half to the governorate of Karak. The Queen Alia airport is located in the north of the watershed. Population in the watershed is about 80,000 (1985) or 12 head/km^2 which is forecast to grow 110,000 (17 head per 1 km^2) in 2005.

4 Greater Amman area: Under the present study, an area encircled by 30 km radius from Amman is referred to as the metropolis area. Southern part of this area is included in the Mujib watershed. This area which occupies 3% of the area of the Kingdom includes such cities as Amman, Zarqa, Salt and Madaba and is populated by about 1.62 million (1985) of population (573 head/km^2). It is estimated that the population in this area will grow to 3.37 million (1,192 head/km^2) in the target year 2005 when the national population will reach 5.06 million (52 head/km^2).

5 Geology of the Mujib watershed is not complicated. The surface of the watershed is covered by a thick horizontal layer. This layer is referred to as the Balqa/Ajlun (B/A) layer composed mainly of limestone layers of the upper to middle cretaceous periods, and is about 900 m thick. Surface of the highland is the upper surface of B/A. This B/A is underlain by the Kurnub (K) layer composed of sandstone layers of lower cretaceous period, which crops out on the riverbed below about El. 0 m. The main aquifer is the pervious layers called B2/A7 of which water is sustained by precipitation and has good quality. A long fault called the Siwaqa Fault is running in the east-west direction. The B/A is bisected by the fault, but the aquifers in the both portions are continuous.

6 Precipitation is very small. The highest precipitation is seen in the northern and western fringes being 300 m a year. The precipitation descends towards the south-east, and finally becomes 50 mm or less in the south-eastern corner. Yearly average precipitation over the Wala basin is 189 mm, over the Mujib basin 128 mm and over the whole basin 154 mm. Precipitation is concentrated in the rainy season from October to April, but quantity and timing fluctuate very much by year. In the present

study, the most frequent value (50% frequency) is used.

7 Hydrology: The tributaries (wadi) are dry except for short periods after the rainfalls. Perennial base flow is seen only on the lowest reaches downstream from the King's Highway bridges. The base flow is constant being 1.1 m^3/sec or 35 MCM a year. The outflow in the rainy season which is referred to as the flood flow is 29 MCM and 36 MCM from the Wadi Wala and the Wadi Mujib respectively, totalling 65 MCM. Coefficient of runoff is 4.2% for the base flow and 5.3% for the flood flow, totalling 9.5%. Because of high concentration of outflow, very little flood flow has been used.

8 Hydrogeology: Groundwater potential of the basin is relatively rich because of the geological characteristics. Main sustained aquifer is B2/A7. The whole basin is bisected by the Siwaqa fault. In the northern portion, the groundwater is B2/A7 flows in the similar directions to the surface flow of the Wala river system, and appears to the surface in a river stretch of 5 km downstream from the King's Highway bridge. Although the groundwater in the both portions are hydraulically continuous, the groundwater in the southern portion is dammed up by the impermeability of the fault by 50 m to 100 m. In the southern portion, there is an indistinct ridge of the groundwater contour approximately underneath the Desert Highway. The groundwater flows towards the estuary in the western part of the ridge, whereas it flows in the north-east direction towards the Azraq Oasis in the eastern part of the ridge, and hence, this flow does not join the outflow towards the estuary.

9 Soil: Because of the dry condition, the soils in the Mujib watershed are generally poor both in quantity and quality. Soils of relatively good quality for agriculture are distributed on areas with more precipitation or flood flow, particularly in the northern part, on the western escarpment, and on the spots around the crossing points of the Desert Highway and tributaries. Natural vegetation is extremely scarce especially in the poorly precipitated areas.

10 Agriculture: Non-irrigated and irrigated farms are existing in the basin. In the northern part, plastic house or drip irrigation from private wells are distributed (about 3,500 ha) mainly for vegetables. In the western part where the precipitation is more than 150 mm a year, rainfed fields are existing, but the area planted varies very much with the yearly variation of rainfall. On such rainfed area, wheat and barley are grown in the traditional method without giving much inputs. Hence, the harvest is very low, for example 0.6-0.8 tons/ha for wheat. Along the lower reaches of the Wadi Wala, there are vegetable growing area irrigated by pumped water from the base flow. It is said that almost all of the areas in the basin suited for agriculture under the present condition have been developed, remaining no room unless new water source is given.

11 Present water use: The groundwater in the Mujib watershed has been used to a considerable extent. There are 223 existing wells (1985) in the northern part and along the Desert Highway. Among them, 155 wells are privately owned by farmers for growing vegetables, and 68 wells are Government owned for supplying water to Amman, Karak and many villages in the watershed. In 1985, 15.1 MCM were sent to Amman bearing one quarter of the Amman's consumption. Besides, base flow on the lower reaches of the Wadi Wala is used for irrigated farming. The flood flow is left unused.

C Study Works

12 Fieldworks: Since the start of the present study in October 1985, works of many items are carried out. These works are made through four batches of fieldworks in Jordan and four batches of homeworks in Japan. Main items of fieldworks achieved are;

- Hydrologic observation and analysis.
- Excavation of four test wells with two observation wells; as existing 223 wells are not distributed uniformly, positions of these wells are selected to supplement the distibution so that uniform

constants for simulation can be obtained, 260 to 305 m deep totalling 1,684 m with 4 inches to 13 inches diameter.

- Mapping of twenty sites of dam and reservoir from air-photo, 1/7,500 or 1/15,000 in scale with 5 m contour intervals.
- Engineering boring at five damsites and soil mechanical tests.
- Soil and land use survey.
- Topographic survey mainly for preliminary design of pipelines.
- Preparation of Inception, Progress and Interim Reports.

13 Homeworks: Of many items of the homeworks achieved, the main items are;

- Simulation of groundwater potential on natural condition, using the finite element method (FEM) on two dimensional groundwater model simulation.
- Dam study on each of 20 topographically selected sites putting use of all the results of fieldworks. Finally, several promising dam plans are selected out.
- Simulation of groundwater on condition that flood flow is caught by dams and added into aquifers.
- Master planning works. Using all the results of aforementioned studies, some plans worthy of future development are selected.
- Study on two pipeline (P/L) plans (projects) on a feasibility study level. Projects studied are the Sultani-Siwaqa P/L project and the Rumeil-Madaba P/L project.

14 Simulation of groundwater potential: After careful study on the hydrogeological structure and characteristics of the Mujib basin, three well fields such as the Sultani, Siwaqa-Qatrana and Rumeil well fields are selected. The future development plans of these well fields are obtained by means of two dimensional model simulation applying the finite element method (FEM). Total potential is estimated at 23 MCM/y. This value can be obstructed safely without giving much influence to the base flow of the lower reaches for a long period of time.

15 Water Quality Quality of groundwater in the main aquifer, B2/A7, is good to fair with salinity (TDS) in a range between 500 and 1,500 ppm. Both existing and proposed well fields are located in the area with TDS less than 1,200 ppm. The hydrochemical structure of the B2/A7 aquifer is non-uniform. By a long term pumping up to 20 to 100 years, the TDS will be increased by 50 to 80% respectively at the maximum. The TDS of the base flow in the Wadi Wala (Heidan) is in a range between 400 and 900 ppm, while the TDS is 1,000 to 1,300 ppm in the base flow in the Wadi Mujib. The TDS at the confluence of Wadi Wala and Wadi Mujib is measured at 1,056 ppm, but the TDS at the confluence will be increased by 40% at the maximum, if the base flow is withdrawn at the upper Wadi Heidan. However, the provision of the proposed Wala Dam will mitigate such increase.

16 Dam planning: As the flood flow occurs only for a short time after rain in the rainy season, dams are indispensable to put the flood flows into use. By thorough study on the general topographic map (1/50,000 scale with 25 m contour intervals), all of the possible sites for dam and reservoir are selected. Reservoir capacity of each site is measured and the elevation-capacity (H-V) curves are drawn. From the results of the engineering borings, preliminary geological profiles of each dam site are drawn. On the other hand, the values of inflow and flood discharges with different probabilities to each dam site are estimated on the basis of all of the past precipitation data as well as on the hydrologic data. All of these works are made on 20 sites which are selected preliminarily.

17 Putting use of the said materials, the simulation of the reservoir operation are made taking into account the seepage from the reservoir, evaporation from the reservoir water surface, and the decrease in the reservoir capacity owing to sedimentation. As the results, the available flow of each dam is estimated. (These works are made on each site except those which are obviously unfavourable in view of geology or in case of comparison in group of similar nature.) Then, provisional design of dam is made in consideration of the type and optimum scale of dam, and the usable flow and cost are estimated. Finally, seven sites which are considered worthy of further study are selected out; they are, Qatrana

(existing), Sultani (existing), Siwaqa C, Wala, Hammam, Khabra and Nukheila sites.

18 Irrigation planning: Firstly, the soil distribution is mapped considering the relative location to the water source. Next, several cropping patterns for the basin are designed in consideration of the present status of agriculture in the whole country and new Governmental policy on agriculture. Then, irrigation schemes are planned taking into account the land and water source. In general, precipitation over the basin is extremely poor, and the soil distribution is limited for the irrigation schemes. Therefore, it is hardly possible to formulate the irrigated agriculture schemes of large scale but only a few schemes of small sizes scattered in the basin are planned.

D Water Use Plans

19 Strategy: Basing upon the results of the aforementioned studies and the elemental schemes, the overall water use plan of the Mujib watershed on master planning level is elaborated. As to the water source, the groundwater of B2/A7 which is dependable and sustained by precipitation is to be used in the main. As to the surface flow, the dams are to be used. However, the main function of the dam is for the recharge of the B2/A7 groundwater and sub-function is for the surface storage in view of the nature of the surface geology which consists mainly of limestone. As for the use of the water, main use is for the city water supply which is the most important water demand in the country, but the supply thereto is chronically deficient. Especially the water supply to the metropolitan area is attached by the highest importance. Irrigation water is considered next to the city water supply. Dam schemes by which storage or supply to the groundwater is possible, but of which present demand is not yet definite at present, are raised with conceivable uses of water.

20 In line with the abovementioned strategy, the water use plan of the Mujib watershed is made. Firstly, the development of well fields and pipelines are planned with due consideration of the on-going projects by WAJ. Next, dams are planned which have main function to catch flood flow and turn the caught flow into the groundwater or base flow. Irrigated agriculture schemes are planned as far as the given condition allows. Possible available flow by other dams are estimated for the water use in the future when such water becomes required. Pipeline (P/L) projects are studied on the feasibility study (F/S) level, and other schemes are studied on the master plan level.

21 Planned schemes: As the results of planning works, the following schemes are planned. (Refer to the location map on flyleaf).

Purpose and name of scheme	Priority
1. City water supply	
Sultani-Siwaqa P/L project	A
Rumeil-Madaba P/L project	A
2. Reinforcement of base flow or groundwater	
Wala dam scheme	A'
Qatrana dam scheme	B
Sultani dam scheme	B
Siwaqa C dam scheme	C
3. Irrigated agriculture	
Hammam irrigation scheme	C
Qatrana irrigation scheme	C
4. Storage	
Nukheila dam scheme	C
Khabra dam scheme	C
5. Others	
Green belt	C

Note; A : scheme on which F/S level study is already made
A' : scheme of which F/S study is to be made urgently
B : scheme of which F/S study is to be made soon
C : schemes of which F/S study is to be made when needed

E Water Supply Projects

22 Water demand to the Greater Amman area: In 1985, the supply of water to the municipal area and the Mujib watershed was 61.5 MCM against the demand of 70 MCM. This value is a sum of the supply for domestic, public and small industrial uses, but the supply for large industries are not included because the demand is supplied from the wells owned by respective factories. This water demand is projected to grow in the target year 2005 to 198 MCM/y with the mean annual growing rate of 5.2%. This value consists of 190 MCM/y of the Greater Amman area, 2 MCM/y of the Mujib basin and 6 MCM/y of a part of Karak which is already connected with the Sultani wells by pipeline. WAJ is undertaking the implementation of some other projects to increase the supply capacity. However, with all these capacities of such projects added, the total capacity will become 114 MCM/y leaving a deficiency of 84 MCM. Then, the groundwater source left in the Mujib basin is raised to fill the deficiency. The Mujib groundwater source is located nearer to the municipal area than any other water sources. Water quality is good and suited for water supply without being purified. Thus, the available groundwater in the Mujib watershed is to be developed for the municipal area as much as possible.

23 Allotment of Groundwater: It is clarified under the Study 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 about 23 MCM. This amount corresponds to 27% of the aforementioned deficiency of 84 MCM and to reduce the deficiency down to 61 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 municipal area.

24 Formulation of pipeline projects: Currently, WAJ is undertaking the implementation of many pipeline (P/L) 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 P/L to Siwaqa from which place the Yadudah-Siwaqa P/L is to be constructed by WAJ. This P/L with the Sultani and Siwaqa-Qatrana well fields is to formulate a P/L project referred tentatively to as the Sultani-Siwaqa P/L Project. While, the water from the Rumeil well field is to be sent through P/L to Madaba from which place the Yadudah-Madaba P/L is being constructed by WAJ. This P/L with the Rumeil well field is to formulate a P/L project referred tentatively to as the Rumeil-Madaba P/L Project. For these two P/L projects, studies on the feasibility study level are made.

25 Sultani-Siwaqa pipeline project: Scope of this project is to develop the Sultani well field, 6.3 MCM/y in sustained yield, and the Siwaqa-Qatrana well field, 9.6 MCM/y, and to transmit the total amount of water 15.9 MCM up to Siwaqa. WAJ is planning the construction of the Yadudah-Siwaqa P/L. Hence, the water transmission from Siwaqa to the Amman area is to be made through this pipeline.

26 The project consists of such components as, 18 production wells in the Sultani well field, 21 production wells in the Siwaqa-Qatrana well field, two reservoirs and P/L. This pipeline consists of a portion from Sultani well field to Sultani reservoir (500-600 mm in diameter, 11.7 km long), a portion from Sultani reservoir to Siwaqa reservoir (66-700 mm in diameter, 23.1 km long), and a portion from Siwaqa reservoir to Siwaqa pumping station to be constructed by WAJ (600-800 mm in diameter, 5.9 km long). Total length of the pipe is 40.7 km. No purification plant is required.

27 Four years will be necessary for construction. The cost is estimated at JD million 19.26 (equivalent to US$ million 6.7 at 1 JD = 2.92 US$ rate). Of the amount, JD million 14.43 or 74% is for foreign exchange and JD million 4.84 or 26% for domestic currency. Economic benefit is estimated at JD million 2.1 a year, and financial benefit at JD million 1.5 a year. Then, the economic internal rate of return (EIRR) is calculated at 11% and the financial internal rate of return (FIRR) at 7%.

28 Rumeil-Madaba pipeline project: Scope of this project is to develop the Rumeil well field, 7.0 MCM in sustained yield, and to transmit the produced water to Madaba. WAJ is undertaking the construction of the Yadudah-Madaba pipeline (1,000 mm in diameter). Hence, the water transmission from Madaba to the Amman area is to be made through this pipeline.

29 The project consists of such components as 20 production wells, two reservoirs, one booster pump station, a main P/L and a branch pipeline. The main pipeline collects water from 9 wells and the branch pipeline 11 wells. The main pipe is 300-700 mm in diameter and 27.4 km long. The branch pipe is 300-500 mm in diameter and 13.9 km. Total length of the pipes is 41.3 km. The booster pump station is for pumping head of 160 m of maximum discharge of 1.04 m^3/s for a distance of 17.9 km. Purification plant is not required.

30 Four years will be necessary for construction. The cost is estimated at JD million 14.62 (equivalent to US$ million 42.7 at 1 JD = 2.92 US$ rate). Of the amount, JD million 11.14 or 76% is for foreign exchange and JD million 3.48 or 24% is for domestic currency. Economic benefit is estimated at JD million 1.1 a year, and financial benefit at JD million 0.7. Then, EIRR is calculated at 7% and FIRR at 1%.

31 Combined consideration: As mentioned above, two pipeline projects are formulated because of the intention to utilize fully the on-going and planned 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 can be made in a package. Combined EIRR is calculated at 10%, and FIRR at 7%.

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

F Recharging of Groundwater or Base Flow

33 General: It is studied to retain the flood flow by dam and thereby recharge the groundwater or base flow. This principle is applicable in two parts of the whole basin. One is the lower reaches of Wadi Wala and the other is the upper reaches of the tributaries of Wadi Mujib. Former is to retain flood flow by the proposed Wala dam for recharging the base flow and groundwater. The latter is to retain flood flow by the Qatrana dam, the Sultani dam (both existing) and the Siwaqa C dam (newly proposed) for recharging the groundwater along the Desert Highway of both existing and proposed well fields.

34 Wala dam scheme: There exists a group of farms on the lower reaches of the Wadi Wala downstream from the King's Highway bridge. These farms depend on the base flow of the Wadi Wala for irrigation. Area measures 350 ha of existing and 250 ha of registered farms totalling 600 ha. This group is the largest irrigated area in the Mujib basin. While, WAJ has a plan (Wala P/L project) to take 15 MCM of base flow for the water supply of highland, and the survey has been started. If this plan is put to commission, such farms will lose the irrigation water source. Hence, a compensating water for irrigation by some 6 MCM is needed.

35 The Wala dam scheme is proposed first for the compensation purpose. The damsite and reservoir areas are composed of pervious B2a layer, about 15 m thick, and an impervious B1 layer underlay. When a dam, of central core rockfill type, 65 m high, 350 m long and 0.92 MCM of fill volume is constructed, then 19.3 MCM of effective reservoir capacity is available. Water stored in the reservoir will leak into B2a layer by 16.9 MCM, and 2/3 of the same or 11 MCM/y will reappear on the downstream river channel. Of this flow, 5 MCM/y will be injected from 11 injection wells, 200 m deep each, into A7 layer so that the potential of the WAJ's Heidan well field will be increased. The remainder 1/3 or 6 MCM/y will join the base flow from the points about 3 km downstream from the dam. This flow can be used for compensation of irrigation water for the said 600 ha. Unified irrigation facilities will not be necessary because most of the existing farms are already equipped with pumps and pipes. On the other hand, the proposed Rumeil well field will be benefited because the seepage from the Wala reservoir will raise the groundwater level of the Rumeil well field by about 10 m.

36 Recharge of groundwater on upstream part: The most important area of groundwater source is the belt along the Desert Highway to the south of Siwaqa. In this belt, there are three existing well fields (Siwaqa, Qatrana and Sultani) and two proposed well fields (Siwaqa-Qatrana and Sultani). In 1986, excessive abstraction of water which might lead to a devastation of aquifer was made from the existing wells. Hence, it is better to recharge positively the existing well fields as well as to increase the potential of the proposed well fields. There are tributaries of the Mujib river nearby each of these well fields and also two existing retention dams. Such existing beings are to be utilized for the recharging purposes.

37 Qatrana dam scheme: Near the existing Qatrana well field, there exists the Qatrana retention dam on the tributary Wadi Hafira. Flood flow retained in the reservoir is to be used for reinforcement of the existing well field and a part of the proposed well field. By providing a desilting basin and three wells for injection and production, 1.8 MCM a year can be injected in the rainy season and 1.4 MCM can be pumped up

again in the dry season. Such injection is also good for curing the existing wells from which over-extraction was sometimes made.

38 On the upper reaches of the Wadi Hafira, there is a vast area where the topography is very flat. This area turns to a swamp after the rainfall. This phenomenon incurs less inflow to the Qatrana dam, more evaporation loss and more seepage which joins the groundwater flow towards Azraq. It is estimated that the outflow of the Wadi will increase by 2.2 MCM by the full drainage improvement. By adding four wells, 1.8 MCM will be pumped up again in the dry season. By combining the natural inflow and the increased outflow by the drainage improvement, 3.2 MCM by seven additional wells will become available in the dry season.

39 Sedimentation took place to some extent in the existing reservoir, and present storage capacity is 4 MCM. Hence, some additional works on the dam are required. The crest of the dam is to be heightened by 3 m to increase the capacity. Existing spillway is to be extended to 136 m and the spillway crest is to be heightened by 1.25 m high at maximum, and the dykes of 2 km are required to protect the Desert Highway from occasional floodings.

40 Near the existing Sultani well field, there exists the Sultani retention dam. Same idea as the Qatrana dam is applicable in smaller scale. The Sultani reservoir has been almost filled up by the residue from the Abyad Phosphate Mine located upstream. Hence, it is necessary to excavate the filled materials and to take countermeasures to prevent the residue to flow into the upstream part of the Wadi. Removal of 0.9 MCM is required to obtain the storage capacity of 1.1 MCM. Also, future precaution not to allow the sedimentation inflow is necessary. Then 0.6 MCM by two additional wells will become available in the dry season. This scheme as a whole will be rather costly.

41 Siwaqa C dam scheme: Near the existing Siwaqa well field, the Wadi Siwaqa flows. By constructing a dam on the Siwaqa-C site, 0.6 MCM by one or two additional wells will become available in the dry season. The dam

will be of central core rockfill type, 16.5 m high, 124 m long, and 28,000 m^3 in fill to obtain 1.1 MCM of effective capacity. This scheme will be rather costly.

G Other Schemes

42 Irrigated agriculture: Study is made covering the entire basin to find the possibilities of developing the irrigated agriculture. However, the distribution of soils suited for agriculture are limited, and water source is scanty. Hence, it is found difficult to formulate the irrigated agriculture schemes of large to middle sizes. Only two small schemes are planned. They are Hamman scheme and Qatrana scheme.

43 Hammam irrigation scheme: This scheme is to store the flow of the Wadi Hammam by a dam and to irrigate the downstream areas. The irrigation area consists of two blocks. One is 100 ha composed of 50 ha for plastic house and 50 ha for normal upland field both of which are covered by existing farms. The other area is 75 ha, which is uncultivated at present, only for the winter irrigation. Three existing wells in the area will be kept in use. Hence, this area receives the conjunctive use of well water and stored water in the Hammam reservoir. Crops will be vegetables such as strawberry, cucumber, tomato, carrot and potato which are suited for the highland agriculture. Governmental management of the scheme is desirable. IRR is estimated at 0.5%.

44 The Hammam dam is of center core rockfill type, 16 m high, 2,670 m long (very long) and 0.6 MCM in fill volume. Effective storage capacity is 1.5 MCM. As the dam site and reservoir area are located on the clay sediment layer, there is no leakage problem, but the evaporation loss is considerable. In view of the loss and length of the dam, the storage efficiency is not favourable and the irrigation water becomes costly.

45 Qatrana irrigation scheme: There is an area of 75 ha which is suitable for the irrigated farming on the downstream area from the Qatrana existing dam. Crops will be potato, carrot and onion to be grown

in the winter season. Irrigation water can be taken from the Qatrana dam. Required irrigation water is 0.6 MCM which corresponds to one well. Governmental management is desirable.

46 Storage of flood flow: There are possibilities of flood water storage on the Nukheila site and the Khabra site. At present, it is difficult to confine the use of stored water, but these schemes will be useful when such water is demanded.

47 Nukheila dam scheme: The Nukheila dam site is located on the middle reaches of the Wala River at about El. 180 m. Many tributaries join on the upstream points from the reservoir. The dam will be of center core rockfill type, 61 m high, 350 m long and 0.94 MCM in fill volume to obtain an effective storage capacity of 20.8 MCM. The left bank is covered by thick layer of uncemented alluvial material, and it is necessary to make further geological investigation in future. Available water will be 8.8 MCM/y of storage and 4.4 MCM/y of seepage which increase the downstream base flow, totalling 13.2 MCM/y. Conceivable use of water would be, the city water supply and irrigation water on highlands, or industrial and irrigation uses on the downstream areas.

48 Khabra dam scheme: Damsite is found on the Albit river which drains the eastern escarpment of Karak. Precipitation is relatively rich in the whole Mujib basin, but the catchment area is rather small. The damsite is located at El. 690 m adjacent to the Lajjun oilshale deposit. The dam will be of center core rockfill type, 29.5 m high, 455 m long, and 0.29 MCM in fill volume. Available storage capacity will be 6.1 MCM from which 2.7 MCM/y of water can be used. As aforementioned, the groundwater potential of 5 MCM/y is reserved for the future development of the oilshale by the Government policy. The Khabra water can replace part of this requirement, and it will be possible to use the saved groundwater for the city water supply for Amman or Karak. Also the irrigation use in the Karak region or on the low lands are conceivable.

49 Combination of two dams: As mentioned above, the available water from storage reservoir will be 8.8 and 2.7 MCM/y from the Nukheila and Khabra reservoirs respectively if one of them is constructed. However, in case of two of them are constructed, the total availability of water from the storages will become 10.0 MCM/y which is some 10% less than the simple sum of two.

50 Green belt: Realization of green belt along the Desert Highway from Jiza to the south onward and from Qatrana to Karak, totalling some 100 km, will be possible. Required water for three rows of trees on both sides of the road is estimated provisionally at some 0.1 MCM. Irrigation can be made with tank lorry, and water can be taken from the nearest reservoirs. In case of the driest time, some amount of well water will be required.

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LIST OF ANNEXES

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

M1. INTRODUCTION

M1.1 Background

M1101 For the economic development of the Hashemite Kingdom of Jordan, the limited availability of water which is one of the rarest resources in the country has at all times been the obstacle. Great efforts have been made for the sector of water resources development making investments of about one sixth of the national budget. These efforts will be continued also in the years to come.

M1102 Among the several measures taken for this sector by the Government, the Water Authority of Jordan (WAJ) was established in 1983 mainly for the purpose to cope with the rationalization of water allocation in entire Jordan.

M1103 Of various water uses in the country, the most important and deficient category is the municipal water supply. Especially, the metropolis area is suffering from chronic deficiency of water supply. This area within a circle of 30 km radius centering about Amman, has a population equivalent to two thirds of the whole nation. To fill the growing water demand in this area is one of the most important measures of Jordan.

M1104 The Wadi Mujib basin is located adjacent to the south of the metropolis area. It is already known that this watershed has a fairly rich groundwater resources together with a flood flow water source which appears only in short period in the rainy season. In fact, the groundwater has been developed since more than 20 years ago. In the northern part of the basin, many wells have been dug by the private sector for irrigated farming of vegetables, and in the southern part some wells have been dug by the Government for the water supply of Amman and Karak.

M1105 Despite the present states are as such, the water resources in the Mujib watershed have not been surveyed and assessed as yet. And the water from Mujib watershed has not been incorporated in the water master plan of nation-wide scale.

M1106 Thus, the Government of Jordan decided to implement the hydrogeological and water use study of the Mujib watershed (the Study), and requested the Government of Japan to provide a necessary technical assistance. In response to this request, the Government of Japan through the Japan International Cooperation Agency (JICA), the sole official agency for the implementation of the technical cooperation programs of the Government of Japan, commenced to undertake the Study in close cooperation with the Government of Jordan through WAJ as an executive agency of the Study.

M1107 JICA organized a Preliminary Study Team and dispatched it to Jordan in June 1985. The Scope of Works (the S/W) was agreed upon by the both sides in July 1985. Then, JICA further organized a team for the Study (the Study Team) and dispatched it to Jordan in late October 1985. The Team commenced the works in no time after the arrival, and the works have been continued until the completion of the Study.

M1.2 Concept and Objectives

M1201 Concept: The water resources contained in the Mujib watershed consist of the groundwater which is already developed partly and the surface flow which is mostly not developed yet. However, the potentials of such water resources are not yet studied. Hence, the basic concept of the Study is firstly to survey and clarify the potential so that the results could be useful for the Government in planning the water allocation on the national basis, and to plan the promising facilities to use such water for the most urgent purposes.

M1202 Objectives: The objectives of the Study are;

- To assess the potential of the groundwater and to work out the practical sustained yield of the groundwater,
- To assess the potential of the surface water which consists of the perennial base flow and seasonal flood flow, and to work out the available amount of water mostly by dams,
- To study the conjunctive use of the groundwater and the surface water,
- To assess the future demand for water,
- To formulate a Master Plan (the M/P) for the water resources development, and
- To study the plans (projects) which have the top priority in the M/P on the feasibility study level.

M1203 The Study area and target year: The areas to be studied under the Study are the Mujib watershed as a water source area and the metropolis area as a main area of water demand. The former includes the entire topographic catchment area of the Wadi Mujib (or the Mujib River) system which covers 6,600 km^2 and located in the governorates of Amman and Karak. The latter is defined in the Study as an area within a circle with 30 km radius centering on the downtown of the Amman city. This area is located adjacent to the north of the Mujib watershed with a southern part included in the Mujib watershed. The metropolis area is located in the governorate of Amman, Zarqa and Balqa and includes such cities as Amman, Zarqa, Salt and Madaba. The target year of the master plan is the year 2005.

M1.3 Study Works

M1301 The Study has been made since the commencement in September 1985 in accordance with the S/W in which the whole works are divided by category into Parts A, B, C and D. Part A is for the data collection, analysis and review; Part B is for the field survey; Part C is for the analysis and alternative study; and Part D is for the formulation of project and master plan.

M1302 As the time schedule for the Study is long being more than 21 months in total, the whole works are also broken down by time period into four batches of field works to be made in Jordan and of homeworks to be made in Japan which follow each batch of the field works. By the time when this final report is prepared, the works are accomplished up to the fourth batch of the homeworks.

M1303 The first batch works are for the collection of data, records and information, reconnaissance on the Study Area and finding of facts and the preparation of an Inception Report in which work plan for the Study is described. This report was submitted to the Jordanian side in November 1985.

M1304 The second and third batches of the works are mainly for the survey works. Four test wells were drilled at the expense of JICA. There are already many existing wells in the Mujib watershed but their locations are not distributed uniformly, hence these four test wells are located to supplement the uniformity of location of wells for the purpose to level up the accuracy of the simulation analysis.

M1305 As for the surface water, four new gauging stations were built (one station was built separately by WAJ) and observation was initiated under the Study. All of the conceivable damsites (20 in number) were found in view solely of topography on the map in 1/50,000 scale for further screening. Boring works for the dam engineering and construction materials were made on five selected damsites at the expense of WAJ.

Air-photo mapping of the damsites and reservoir areas were made in the National Geographic Center (NGC) at the expense of WAJ. Additional topographic survey works necessary for supplementing the said mapping as well as for the study of the planned facilities were made jointly by the experts of the Study Team and WAJ. The progress of these works was reported in the Progress Report submitted in May 1986.

M1306 The fourth batch of the field works was made mainly for formulating the possible schemes of the water resources development, provisional formulation of the master plan, and necessary field works for the pipeline project which will have the highest priority among the schemes formulated. As the results, the Interim Report was prepared and submitted to WAJ in November 1986.

M1307 Draft Final Report was prepared in March 1987. This report deals with the results of all the foregoing studies since the commencement of the Study. The study results consist of those of the hydrogeological studies for the groundwater development, those of the surface water uses with number of dams, and those of the master planning of total water resources development. This report consists of two volumes. One is the main volume to deal with the study on the master plan on the water resources development, together with the study on the possible two pipeline (P/L) projects such as the Sultani-Siwaqa P/L Project and the Rumeil-Madaba P/L Project on the feasibility study level. The second volume is the Appendix in which study results of each work category are compiled.

M1308 In March 1987, the discussions on the reported matters on the Draft Final Report were held by the members of Jordanian and Japanese sides in Amman. Opinions were exchanged, and the comments on the text were prepared by MOP and WAJ and delivered to the Japanese side.

M1309 This is a Final Report on the Study prepared based mainly upon the Draft Final Report with the said comments from the Jordanian side are duly incorporated in. This Report consists of three volumes. The first volume is the main report which deals with the master plan on the water

resources development of both of the groundwater and the surface water of the Mujib basin. In the second volume, the results of each study category are compiled. The third volume deals with two P/L projects to convey the groundwater such as the Sultani-Siwaqa P/L Project and the Rumeil-Madaba P/L Project studied on a feasibility study level.

M1.4 Personnel

M1401 The Study Team organized by JICA is composed of 14 members. The members with assignment schedule is shown on Annex 1401.

M1402 The Study Team received the counterparts services from the Jordanian side through the Department of Study, Water Resources and Dams of WAJ. The counterpart personnels were assigned from the members of the said Department including the senior members. List of the counterpart personnel is shown on Annex 1402.

M1403 Sufficient office spaces with necessary furnitures were allotted to the Study Team during its stay in Jordan mainly in the said Department of WAJ. Necessary vehicles were procured by the Study Team by rental, and the drivers and fuel were provided by WAJ.

M1.5 Acknowledgment

M1501 In undertaking the Study, the Study Team has attached great importance to the incorporation of the views of WAJ. The contribution to the Study by the officials of the Government of Jordan who have provided information and data, participated in meetings and discussions, given valuable advices and provided other forms of assistance to the Study are gratefully acknowledged.

M1502 Special gratitude is expressed to all the members of the Department of Study, Water Resources and Dams including those who worked as counterpart personnel, to the Department of Water Resources Development and Services of WAJ for providing data and records, and to other Departments of WAJ for giving the information.

M1503 A heartfelt gratitude is also given to the following:

- Department of Study and Planning, WAJ,
- Department of Irrigation, WAJ,
- Ministry of Energy,
- Ministry of Planning,
- Ministry of Public Works,
- Ministry of Transport,
- Department of Statistics,
- Department of Customs, Ministry of Finance,
- Central Bank of Jordan,
- Jordan Electric Authority (JEA),
- Jordan Valley Authority (JVA) and
- Jordan Electric Power Company (JEPCO).

M2. ECONOMIC BACKGROUND

M2.1 National Economic Background

A. General

M2101 The Hashemite Kingdom of Jordan is one of countries in the Middle East Arab and extends from 29 degrees to 33 degrees of north latitude and from 35 degrees to 39 degrees of east longitude. The country which covers an area of about 89,000 sq. km is bounded by Syria on the North, by Iraq on the East, by Saudi Arabia on the Southeast and by Israel on the West.

M2102 More than 80% of the country land is covered by a desert land which has a little utility value. Majority of Jordanian population (about 2.7 million in 1985) inhabits in the remaining area which has a high growth in population including the forced migration from the West Bank and the Gaza Strip due to Israeli occupation.

M2103 In Jordan, the fertile land for agricultural use is the area by the Jordan River and the Dead Sea, and it corresponds to an area of 7% of the country. Therefore, major crops of wheat, barley, potato, etc. has to rely on import, except export goods such as tomato, cucumber and other some fruits.

M2104 Jordan, which has a relatively high growth in population and a little suitable land for agricultural use and is not a oil-producing country, is in financial difficulties. To relieve such difficulties, the Government has made strenuous efforts toward increase in export commodities by promoting the development of industry, improving the agricultural technology and rising the education level.

M2105 While, water which is essential for the development of industry and agriculture is so scarce resource in Jordan as to be insufficient even water supply for domestic purpose. Therefore, the development of water resources is an important measure by which Jordan is confronted not only to ensure the domestic water, but also to promote the development of industry and agriculture.

M2106 In Jordan, a situation of external trade deficits occurred every year during the recent five years ,but a great part of the deficits has been covered by the remittances of Jordanians working abroad and by financial aid from abroad, especially from Saudi Arabia. In view of such fact, the greater cooperation and a further strengthening of economic relations between Jordan and other Arab countries will be needed through the provision of skilled Jordanian workers and the proper use of Arab financial aid in order to achieve the desired economic stability and development of Jordan.

B. GDP and GNP

M2107 In 1985, Gross Domestic Product (GDP) and Gross National Product (GNP) amounted to JD 1,581 million and JD 1,856 million at current market prices, respectively (refer to Annex M2107). As seen in figures of GDP and GNP, although the Jordanian economy since 1980 has realized a high growth at average annual rate of about 10% at current market prices, the real growth rate was only 4% on average for the same period and fell into negative growth in 1985. Such negative trends were mainly due to economic recession of the world, especially the Gulf states.

M2108 The per capita GNP of Jordan in 1985 amounted to about JD 689 at current market prices, rising by JD 155 compared with JD 534 in 1980, maintaining the average annual growth rate of 5.2%, while the real growth rate was -0.2% per annum on average during the same period. In 1985 the growth rate recorded a negative figure, namely, -3.0% at current market prices and -5.9% at the 1980 constant market prices.

M2109 The contribution of each economic sector to GDP at factor cost showed a little change during the period from 1980 to 1985, namely, the contributions of productive and services sectors changed from 39.0% and 61.0% in 1980 to 36.5% and 63.5% in 1985, respectively. The share of productive (or services) sectors trended downward (or upward) every year since 1981. The contribution of mining and manufacturing industrial sector, the most conspicuous among the productive sectors, fell from 20.0% in 1981 to 16.4% in 1985. The services sectors were led by both sectors of trade and government services which had the share of 18% or more either of them. A detailed description on GDP and GNP is given in Paragraph 1.1.2 of Appendix A.

C. Agricultural Production

M2110 Agricultural crops of Jordan are represented by tomatoes, cucumbers, eggplant, wheat, olive and citrus fruits. Among them, tomatoes are the most important crops as the export goods and their production in 1985 amounted to about 410 thousand tons, corresponding to increase in about 100% against the average annual production of about 200 thousand tons during the period from 1980 to 1984.

M2111 Besides tomatoes, production of vegetables such as cucumbers, eggplant, melons, cauliflower and cabbage showed also remarkable increases in 1985 owing to the good harvest on the one hand and due to increases in acreage and in the productivity of land brought by advanced cultivation techniques on the other.

M2112 The production of wheat, which is the staple food for Jordanian people, ranged between 50 thousand tons and 140 thousand tons per annum for the period from 1980 to 1985, depending upon the amount of precipitation in those years. For example, the domestic production of wheat was 50 thousand tons in 1984 and 63 tons in 1985. Quantity of the wheat production had influence on imports of wheat in the same and next years.

M2113 In general, most of the agricultural productions of Jordan varied considerably every year, that is, there was not a regularity in terms of the growth in production. Accordingly, it is hereupon required to promote a stabilized growth in production by developing water resources and by introducing advanced cultivation techniques. A detailed breakdown on the agricultural production is given in Paragraph M3.3.1, Chapter M3.

D. Industrial Production

M2114 During six years from 1980 to 1985, the industrial sector (including mining) achieved a remarkable growth which rose by 73% (at average annual rate of about 10%) in the overall index number of the production, while in 1985 the industrial production index number rose by only 0.3% due to the stagnation of domestic and foreign demand. Notwithstanding such unfavorable circumstances, it is expected that the Jordanian industry will maintain a fairly high growth on the whole for the time being, being supported with phosphate industry and newly-developed industries such as potash, fertilizers and chemical acids, even if there is a decline in production of some industries such as iron and leather.

M2115 Phosphate which is one of the most important products achieved the production of 6,200 thousand tons in 1984 and 6,100 thousand tons in 1985 and played a great role for earning the foreign currency. The detailed description on phosphate together with other industrial products is given in Paragraph M3.1.4, Chapter M3.

E. Price Index

M2116 Jordan has kept the stability of prices for the last few years, reducing gradually the rate of price escalation, namely, the rise in consumer price was by only 3.0% in 1985 against 7.7% in 1981, and the average annual increase rate was 5.4% during five years from 1981 to 1985. The wholesale price has also continued the stability since 1981; its index recorded a slight increase of 1.5% in 1985 and 3.9% at the

average annual increase rate during the same period. Judging from trends of consumer and wholesale prices in the last five years, it is expected that Jordan will maintain the price stability for the time being. The detailed description on price index is given in Paragraph 1.1.5, Appendix A.

F. External Trade

M2117 In 1985, the external trade of Jordan amounted to JD 1,385 million, composed of exports of JD 311 million (including re-exports) and imports of JD 1,074 million. The imports maintained around JD 1,100 million per annum with a little difference every year since 1981, on the other hand the exports showed a great increase since 1984; JD 291 million in 1984 against JD 211 million in 1983.

M2118 Such a remarkable improvement in export performance was mainly due to the increase in exports to Iraq and the rise in both the prices and quantity of exports of phosphates, fertilizers and potash. Nevertheless, the imports exceeded the exports by JD 780 million in 1984 and JD 760 million in 1985, namely, the imports accounted for approximately 80% of all the external trade in both years.

M2119 In 1985, domestic exports (except re-exports) amounted to JD 255 million which consisted of the industrial production (including the mining production) of JD 212 million (or 83%), the agricultural production of JD 44 million (or 17%). Of the industrial products, exports of phosphate rock, fertilizers and potash reached JD 66 million, JD 31 million and JD 31 million, respectively. The exports of the above three products accounted for about 60% of the total exports of industrial and mining products.

M2120 During six years since 1980, Arab countries maintained their position as the leading market for the Jordanian external trade. In particular, Arab Common Market countries took usually the first place in exports and accounted for 29% of the total exports in 1985. In terms of individual countries, Iraq ranked first and the exports for Iraq in 1985

reached JD 65.8 million or 26% of the total exports. The second and the third were India and Saudi Arabia which formed 18% and 15% of the total exports, respectively.

M2121 As for imports, in 1985, E.E.C., Arab countries and U.S.A. formed 29%, 24% and 12% of the total imports, respectively. Among Arab countries, Saudi Arabia which was a main supplier of crude oil for Jordan maintained the position as the leading supplier of Jordan's imports and provided commodities of JD 159 million or 15% of the 1985 imports. The detailed breakdown on the external trade is given in Paragraph 1.1.6 of Appendix A.

G. International Balance of Payments

M2122 The international payments of Jordan have been confined to a little unfavorable balance every year since 1980, despite a great deficit in the external trade, owing to remittances from Jordanians working abroad and foreign aid receipts (see Annex M2107).

M2123 The remittances from Jordanians working abroad in 1985 amounted to JD 403 million corresponding to 53% of the trade deficit (JD 762 million). On the other hand, the foreign aid receipts in the same year reached JD 318 million covering 77% of the unfavorable balance of goods and services (JD 415 million), and overwhelming portion of the aid receipts was the transfers received from Saudi Arabia. Accordingly, it will not be too much to say that the international payments of Jordan have been mainly constituted by three items; trade, remittances and foreign aid receipts. The detailed breakdown on international payments is given in Table A-14 of Appendix A.

H. Government Budget

M2124 In 1985, the Government budget of Jordan amounted to JD 842 million for the public revenues and JD 819 million for the public expenditures. The average annual growth rate for five years from 1980 to 1985 was 10.7% for the former and 7.8% for the latter at current prices (See Annex 2108). The detailed breakdown of the Government budget is given in Paragraph 1.1.8, appendix A.

I. Economic Development Plan

M2125 The previous Second Five-Year Plan(1981-1985) was formulated in an optimistic atmosphere, assuming that Jordanian economy would continue such a high growth as indicated during the period 1975-1980. While, the economic performance fell below plan's projections leading to a decline in domestic and external demand due to negative trends in the economies of the Gulf states and the recession in the world economies since 1982. With regard to the average annual growth rate of each economic sector during the plan period(1981-1985), for example, GDP at factor cost in real terms was 11.1% for the planned figure but 4.2% for the actual one. The planned and actual rates of exports' growth were 21.7% and 3.4% respectively, and further concerning the investment, the former was 12.2%, but the latter was by only 0.8%.

M2126 Taking into account the actual growth rates for the period 1981-1985 and prospects of long-term economic development by the year 2000, the Government envisages the following growth rates for the third plan period(1986-1990):

Average Annual Growth Rates in Real Terms
(1986-1990)

	%
1. GDP(at factor cost)	5.1
2. Imports	2.7
3. Exports	6.1
4. Consumption	3.2
5. Investment	5.3

M2127 According to the above growth rates, the real GDP at factor cost will reach JD 1,739 at the 1985 constant prices by the end of 1990. As a result, the real GDP per capita will be increased from JD 509 in 1985 to JD 543 in 1990 at a growth rate of 1.3% per annum.

M2128 The Third Five-Year Plan is instituted with the following overall targets for the purposes of sound development and stability of the national economy;

1. Creation of new employment opportunities,
2. Proportionality of consumption and income,
3. Increase in domestic revenues and rationalization of current government expenditures,
4. Reducing the deficit in the balance of goods and services,
5. Fostering joint Arab economic action, and
6. Ensuring regional distribution of development benefits.

The detailed description on The Third Plan is given in Paragraph 1.1.9, Appendix A.

M2.2 Greater Amman Area

M2201 General : The Study Area is composed of the Greater Amman area and the Wadi Mujib watershed. The Greater Amman area which is defined as an area within 30 km with centre in the Amman city stretches administratively over four governorates; Amman, Zarqa, Balqa and Irbid Governorates. It includes industrial and commercial cities such as Zarqa, Ruseifah, Salt and Madaba and had a population of 1.6 million in 1985, corresponding to nearly 60% of the whole population of Jordan.

M2202 The Amman city, which became a capital of Jordan in 1923, is situated at the junction of important trade route linking Egypt and the Middle-East countries, and in 1985 had a population of about 800,000. It is, in common with capital cities in the world, a centre of government of the country as a whole and of all the diplomatic and commercial activities.

M2203 Industry : Except potash industry, most of Jordan's industries including middle and small scale industries mass in the Greater Amman area, especially Amman-Reseifah-Zarqa zone, and this area is particularly expected to achieve the more development of various industries during the Third Plan period (1986-1990). As a measure for encouraging the development of industry, the Government established industrial estates with suitable infrastructures and service facilities for light and medium industries in such regions as Amman, Salt, Irbid and Aqaba. Of these estates, the Amman industrial estate finished the first stage of its construction in 1984 and the remainder is planned to be completed by the end of 1987. As for the Salt industrial estate, the construction is planned to start at the beginning of 1988.

M2204 Urbanization : The urbanization in this area will be further promoted as a result of encouraging the establishment of industries and the great growth in population supported by high birthrate and migration. It is expected that the Great Amman area will have a population of about 3.4 million or 67% of the total population of Jordan by the year of 2005. Such rapid urbanization, on the other hand, will cause the more serious

problems in terms of water supply, transportation, etc.

M2205 Water Supply : At present, municipal water supply in this area depends chiefly upon groundwater in the Amman-Zarqa zone and water supplied by pipelines from Azraq oasis and from Questal, Siwaqa and Qatrana well fields in the Mujib basin. Among them, the groundwater in the Amman-Zarqa zone already is nearing a limit in terms of both quantity and quality. In addition, water consumption in this area is expected to increase fairly in the future due to the rapid growth in urbanization as mentioned above. In view of such situation it is urgently required to secure the suitable water sources to meet the future demand in this area.

M2206 Transportation : The transportation in Jordan depends exclusively on road and its main network is centred in the Greater Amman area, especially Amman-Zarqa conurbation. Traffic volume on primary roads in this area is expected to reach from about 10,000 vehicles per day in 1985 to 15,000 or more vehicles per day in 1990 as a result of the aforementioned rapid urbanization. To cope with such increased traffic volume, the Third Five-Year Plan envisages some road improvement and construction projects of the Amman outer ring-road construction project, the terminal construction project for overland transport in the eastern region of Amman, etc.

M2207 Labor Force and Unemployment : The size of labor force in Jordan rose from 218,000 in 1961 to 405,000 in 1979 and further to 502,000 in 1985. The Greater Amman area had more than 80% of the whole labor force of Jordan in 1985. During the period from 1961 to 1985, the average annual growth rate of labor farce in Jordan was 3.5% which lows fairly compared with that of population (4.6%). This was mainly due to a rise in the ratio of population under 15 years of age and an increased enrollment at all educational levels. The rate of participation in the labor force also declined from 24% in 1961 to 22% in 1979 and then to 21% in 1985. While the unemployment rate rose during the last decade, namely, 2% in 1976, 6.7% in 1982 and 8% in 1985. Such increase in unemployment would be chiefly owing to the economic recession during the above period. It is serious to Jordanian people, especially to

inhabitants in the Amman municipality. To relieving such high unemployment, the Third Five-Year Plan aims at increasing the employment opportunities for workers as a priority policy of the Government, through creating the new jobs, encouraging the increase in industrial production and other various programs.

M2.3 Mujib Watershed

M2301 General : The Mujib watershed (Wadi Mujib basin) extends to the south of the Amman city and a part of its northern region is included in the Greater Amman area. The Mujib river system consists of both the Wadi Wala and the Wadi Mujib which have the catchment area of about 6,800 sq.km. Administratively, the Mujib basin stretches over three governorates; Amman, Karak and Ma'an Governorates, and it has the advantage of transportation owing to both primary roads; Desert Highway and Kings Highway which run through this basin from north to south.

M2302 In the basin, the desert land covers more than 80% of the total area and the remainder is used as agricultural and residential areas, forest and others. In 1985, the population in the basin was only 80,000, and although the basin has some communities such as Na'oor, Jiza, Dieban, Qasr and Mazar, the population of each community was below 10,000 in the same year. Such a depopulation in the basin resulted from that there are no striking industries, except phosphate industry, and most of industries have hesitated extending their business to the basin due to a little rain.

M2303 Industry : In the basin which has a few industry, Abiad phosphate mine located in the southern region of the basin is among the most important industries of Jordan, together with Hassa phosphate mine which lies outside the basin baundary at about 30 km to the south of the Abiad mine. In 1985, they produced the phosphates of 150 million tons and 300 million tons, respectively. The Jordan Phosphate Mines Co., Ltd. operating them envisages the increase in phosphate production by about 300 million tons per annum furthermore in total at the both mines by the

end of 1990.

M2304 Agriculture : Agriculture in the basin is characterized by a highland agriculture which depends on rainfed, except a little irrigation. Major crops planted in the rainfed area are wheat, barley and tobacco. Among them, wheat field covers more than 90% of the rainfed area, but its productivity is very low, or less than 0.1 tons/ha. Majority of vegetables such as tomato, eggplant, cucumber, and cauliflower are planted in the irrigated area, and tomato plantation covers an area of about 60% of the vegetables land.

M2305 Besides, olives and grapes are representative of tree fruits in the basin, and they have unit yield of 1 ton/ha and 4 tons/ha respectively, or near the national level. In the northern part which is much rain relatively in the basin, they are mainly produced in the rainfed areas, while in the southern part, they are planted in the irrigated areas.

M2306 About 80% of agricultural land in the basin is cultivated by landowners and the remaining 20% is used by tenants. Farm size per family is about 10 ha on average, but more than 50% of landowners holds an area of below 2 ha.

M2307 Regional development : The Third Five-Year Plan is designed to achieve a more socio-economic development of Jordan through an overall regional development plan which takes into account the special socio-economic conditions of the different regions. In the light of such target of the Plan, development of the Mujib basin, taking into account the existing conditions of the basin, would be to give priority to the developments of mining industry and highland agriculture, and to the expansion of infrastructure.

M2308 As for the mining industry, the increase in production of phosphates which have made a great contribution to the obtain foreign currebncies, is regarded as the most important. In addition, development of the highland agriculture is essential for developing the basin, and it

will be attained by developing the agricultural systems and by enhancing the productivity in the rainfed areas through introduction of the advanced techniques.

M2309 To increase the production of phosphates and agricultural crops, more water is an essential resource. Water in the basin, at present, is used for municipal purposes to Amman and Karak as well as for domestic and irrigation purposes in the basin and for industrial purpose of Abiad Phosphate Mine. The water demand for the said purposes is expected to increase in the future, while water in the basin has a limit. Therefore, it is required as a pressing matter to formulate a rational water distribution plan so as to make the balanced socio-economic development for industrial sectors and regions concerned.

M3. STUDY AREA

M3.1 Socio-Economy

M3.1.1 Administration

M3111 The country, except West Bank, was administratively divided into five governorates (before 1985); Amman, Irbid, Balqa, Karak and Ma'an. Each governorate was further subdivided in order of districts, sub-districts and nahias, and these sub-divisions were under the control of their immediate superior administrations (see Table A-17(1), Appendix-(I)A).

M3112 In 1985 the Government made a change in administration divisions. As a result, number of governorates was increased from 5 units to 8 units. Amman governorate was divided into two governorates; Amman and Zarqa, and further Mafraq and Tafielah Governorates were born of Irbid and Karak Governorates, respectively. Number of divisions came to 10 units for "city and localities", 12 units for districts, 16 units for sub-districts, 15 units for nahias and 4 units for "town and localities". All of districts and "city and localities", except "Madaba city and localities" and "Aqaba city and localities", are connected directly with governorates concerned administratively. Some of sub-districts and nahias also are under the direct control of governorates concerned. The details of new administration divisions are shown in Table A-17(2), Appendix-(I)A.

M3113 The Study Area, as forementioned, consists of the Greater Amman area and the Mujib watershed. The former stretches four governorates; Amman, Zarqa, Irbid and Balqa, and the latter expands three governorates; Amman, Karak and Ma'an. Both areas overlap each other in the southern part of the Amman Governorate. The Study Area includes major cities such as Amman, Zarqa, Ruseifa, Salt and Madaba, and it covers all or a part of 5 districts, 5 sub-districts and 5 nahias.

M3114 Each of district, sub-district and nahia contains some localities such as cities, towns and villages. According to the 1979 Census, Jordan had localities of about 1,020 in number consisting of 20 cities, 70 towns and 930 villages. Among them, the Study Area contained 12 cities, 13 towns and about 780 villages (see Table A-18, Appendix-(I)A).

M3.1.2 Population Statistics

M3121 Since the establishment of the Hashemite Kingdom of Jordan, the comprehensive population censuses in Jordan were conducted three times; Oct. 1952, Nov. 1961 and Nov. 1979. These censuses showed population of 586 thousand in 1952, 901 thousand in 1961 and 2,133 thousand in 1979 in the East Bank. During the two periods from 1952 to 1961 and from 1961 to 1979, the average annual rate of population growth was 4.89% and 4.91%, respectively. Such a great growth in population was mainly due to the increased migration and the high birthrate. Especially, Amman Governorate had the remarkable growth at an average rate of 5.69% per annum during the period from 1961 to 1979 (see Annex M3121). While, the population density of Jordan was very low or about 90 persons per sq. km in 1979, because that more than 80% of the country land are covered by the desert land which has a little utility value.

M3122 According to the 1979 Census, population in the Study Area amounted to about 1,322 thousand corresponding to 62% of the total population of Jordan. It consists of 1,253 thousand in the Greater Amman area and 69 thousand in the Mujib basin, and more than 70% of population in the Greater Amman area inhabits in Amman, Zarqa and Ruseifa cities and their surrounding areas (see Annex M3122). Breakdowns of population by governorate, by kind of localities and by nahia are given in Table A-22, Appendix-(I)A.

M3123 The ratio of female to male of population in 1979 was 48 to 52 in the Study Area as well as the whole country, and it had a little difference among governorates except the Ma'an Governorate. In the Ma'an Governorate, this ratio was 44 to 56, namely, male was the fairly larger population than female. This was mainly due to population of the Aqaba city which had the ratio of 39 to 61.

M3.1.3 Labor Force

A. Manpower

M3131 In 1979, the population of 15 years or more of age in Jordan was about 1,030 thousand. It corresponds to about 49% of the total population. The population of the said age group in the Study Area was about 650 thousand corresponding to 63% of that in the whole country. According to estimation by the Department of Statistics, in 1985 a share of the population of more than 15 years of age to the total population came to 52% which rose by 3% compared with that in 1979 in the Study Area as well as the whole country.

B. Employment

M3132 Out of population more than 15 years of age in Jordan in 1979, number of the employed amounted to some 406 thousand comprising male of 376 thousand and female of 30 thousand. A rate of the employed in the above age group showed about 70% for male, 6% for female and 40% as a whole. More than 90% of female of these ages was engaged in the housework without economic activity. These figures had a little difference among governorates. Unemployment in Jordan was about 4% in 1979. However, it is on the increase since 1982 due to the recession in the world economies. In 1985, the unemployment was estimated at about 8%.

M3133 Number of the employed in services and productive sectors in 1979 was 255 thousand (63% share) and 151 thousand (37% share), respectively. The former was considerably many compared with the latter. Particularly, number of the employed in the public administration and defense sectors accounted for more than one-third of the total employed, and in case of female it amounted to about two-thirds. Such a large number of the employed in services sectors is obviously abnormal. The Third Five Year Plan(1986-1990) then envisages encouraging the growth in productive sectors to GDP to improve such a unfavorable situation to the national economy. As a result, it is expected that a ratio of productive sectors to services sectors in terms of contribution to GDP would be 60 to 40 by the end of the Plan period. Details on the labor force are given in Tables A-24, A-25 and A-26, Appendix A.

M3.1.4 Industry

A. Mining Industry

M3141 In Jordan, phosphate and potash are the typical products in the mining sector. Phosphate has been produced at three mines; Ruseifa, El-Abiad and El-Hasa. The total production increased from 3,900 thousand tons in 1980 to 6,000 thousand tons in 1985 at the increase rate of 9.2% per annum. Majority of phosphate products was exported and has greatly contributed to the Jordan economy. While, it is programmed that both mines of El-Hasa and EL-Abiad will be closed in 1990 and 1992 respectively because of decrease in phosphate reserves remained. On the other hand, instead of these mines, it is planned that the El-Shiddiyya mine located in the southern part of the El-Hasa mine will start the operation in 1988. The phosphate reserves of this mine are estimated at about 250 million tons.

M3142 Potash which follows phosphate among mining products in Jordan started its production in 1982 at the southern end of the Dead Seacost. The yearly output increased from 15 thousand tons in 1982 to 900 thousand tons in 1985. Potash also is an important export product in Jordan and its exports amounted to JD 31 million in 1985. Statistical data on productions and exports of the mining products are given in Tables A-8 and A-12, Appendix-(I)A.

M3143 Besides, Jordan has some mineral resources such as plaster stone, silica sand, copper, manganese and oilshale. Among them, plaster stone and silica sand were respectively produced 120 thousand tons and 25 thousand cu. m in 1984 for the domestic uses. The deposit of copper accompanying with manganese is distributed in Feinan and Petra regions and further the oilshale deposit is found in El-Lajjun of the Karak District and in other two regions. The oilshale reserves in the El-Lajjun region are estimated at about 1,200 million tons. All of these minerals do not reach the stage of production yet from the viewpoint of commercial basis.

B. Manufacturing Industry

M3144 In Jordan, the major industries such as cement, fertilizer, oil refinery and glass are operated as the Government enterprise, and the light industrial products of textiles, leathers, etc. are produced by the private enterprises. A large portion of industries is located in the Greater Amman area, especially in Amman-Ruseifah-Zarqa area.

M3145 Cement is among the most important products for export. The production reached about 2,000 thousand tons in each year of 1984 and 1985 increasing every year. As of 1986, there are two cement plants in Jordan; one is located in Fuheis (the north of Amman) and the other lies Rashadiya in the Tafiela Governorate. In 1984, each factory produced 1,600 thousand tons and 400 thousand tons of cement, and number of employees was 1,200 and 700 respectively.

M3146 Phosphate produced at Hasa and Abiad is sent to Aqaba by trucks and trains for the purposes of export and production of fertilizers. Jordan Chemical Fertilizers Co. was established in 1982 in Aqaba and commenced the production of fertilizers such as di-aminonium phosphate (DAP), phosphoric acid and sulphuric acid. Breakdown of productions and exports of fertilizers is described in Paragraph 4.2, Appendix-(I)A.

M3147 Jordan is scarce of petroleum-resource as well as water. The refinery has therefore been made using crude oil carried from Saudi Arabia and Iraq, and it has been operated at Zarqa by Jordan Refinery Co. The production of refined petroleum increased from 1,760 thousand tons in 1980 to 2,420 thousand tons in 1985 at an average growth rate of 6.6% per annum. Despite such a relatively high growth, the above amount of the production in 1985 was only about 67% of the design capacity. However, in view of increase in petroleum demand in the future, the Company has construction plan of an oil refinery in the Aqaba area.

M3148 For the purpose of encouraging the development of light and medium industries, the Government is executing the construction of industrial estates in such regions as Amman, Salt, Irbid and Aqaba, as mentioned in Paragraph M2203.

M3.1.5 Income

M3151 As mentioned in B of Paragraph M2.1, the Gross National Income (GNP at market prices) in 1985 amounted to JD 1,581 million and the per capita income was JD 689 in the same year. The average annual growth rate was 9.4% for the former and 5.2% for the latter during the period from 1980 to 1985.

M3152 Based on the per capita income on the National level, that on each Governorate level is estimated as follows:

Estimates of Average income per Capita by Governorate in 1985

Governorate	Per Capita Income	
	JD	%
Amman	738	107
Irbid	618	90
Balqa	651	94
Karak	758	110
Ma'an	451	65
National Level	689	100

Among governorates, Karak and Amman were in the relatively high level of the per capita income, while that on Ma'an was only 65% of the National level.

M3153 The above estimates are made using the following data:

(1) Results of the family income survey by governorate which was carried out by the Department of Statistics as an event to "Family Expenditure Survey 1980",

(2) Number per household in 1979 shown in Table A-23 of Appendix-(I)A, and

(3) Per capita Income at the National level in 1980 and 1985.

M3.1.6 Electric Power

M3161 The electrical business in Jordan is mainly operated by Jordan Electricity Authority (JEA) and Jordan Electric Power Company (JEPCO), except some municipalities and industrial companies which have their own power plants. In 1985, JEA had a share of more than 80% in the field of the electric power generation, and JEPCO had a share of nearly 50% in the

field of the power distribution system.

M3162 The capacity of power stations in Jordan totaled 712 MW in 1985 (see Table A-27, Appendix-(I)A) and the overhead transmission lines extended to a length of 1,318 km. The electric power generated in Jordan amounted to 2,495 GWh in 1985 against 1,237 GWh in 1981, at an average growth rate of 19.2% per annum (see Table A-28, Appendix-(I)A).

M3163 Among the entire electric energy production in 1985, the thermal power amounted to 2,236 GWh (or about 90% share) consisting of 1,916 GWh at HTPS (Hussein Thermal Power Station) and 320 GWh at the industrial companies. The remaining 259 GWh was composed of the diesel power of 255 GWh and the gas turbine power of 4 GWh (see Table A-29, Appendix-(I)A).

M3164 The electrical energy consumption in Jordan rose from 1,028 GWh in 1981 to 2,151 GWh in 1985 at the average increase rate of 20.3% per annum (see Table A-30, Appendix-(I)A). Especially, the consumption of industrial sector which showed the high growth rate of 26.8% per annum reached 903 GWh in 1985. The domestic sector consumption in 1985, 655 GWh, was supplied for 401 thousand consumers corresponding to about 2.5 million population or 93% of the total population. The Greater Amman area which has been supplied the electricity by JEPCO had about 250 thousand consumers (63% share) in 1985.

M3165 According to the demand forecast of electrical energy by JEA, it is expected that in the year 2,000 the demand will reach about 7,000 GWh per annum which corresponds to three times of that in 1985, of which the demand of industrial and commercial sectors is estimated to be about five times.

M3.1.7 Transportation

A. Road

M3171 Transportation in Jordan depends mainly on the road traffic. In 1985, Jordan had the primary roads of 2,500 km, the secondary roads of 1,000 km and the rural roads of 2,500 km. The total length of these roads, 6,000 km, consisted of paved roads of 5,400 km (or 90%) and the unpaved roads of 600 km (or 10%). The primary and secondary roads were increased at the annual rate of about 3% in length during the period from 1977 to 1985 (see Table A-31, Appendix-(I)A).

M3172 Of the primary roads, the routes No.15 and No.30 are the trunk roads running through the Study Area. The former runs from the Syrian Border on the north to the Saudi Arabia Border on the south including the Desert Highway as a part of this route, and has the total length of 432 km. The latter runs from east to west through Mafraq, Zarqa, Amman and Na'oor extending to the length of 385 km from the Iraq Border to the Jordan River. Besides the above two trunk roads, the Kings Highway , an important trunk road in the Study Area, runs through Madaba, Karak and Tafiela from Na'oor to near Ma'an in parallel with Route No.15. In addition, the primary roads such as Routes Nos. 11, 24, 25, 26, 27 and 29 and many secondary roads form an important transportation network in the Greater Amman area.

M3173 The number of vehicles registered in Jordan rose from 135 thousand vehicles in 1980 to 235 thousand vehicles in 1985 at an average annual rate of 11.8%. In 1985, the passenger cars numbered about 145 thousand or accounted for 60% of the total number of vehicles (see Table A-32, Appendix-(I)A). At present, more than 85% of vehicles in Jordan are registered in the Amman and Zarqa cities. The traffic volume on each roads was remarkably increased in proportion to the number of registered vehicles in recent years. For example, the average daily traffic volume on Route No.15 between Amman and Suweileh reached about 13,600 vehicles in 1985 increasing by 18% against 11,200 vehicles in 1982, and also on Route No.30 between Amman and Zarqa it amounted to 10,300 vehicles in

1985 increasing by 31% against 7,100 vehicles in 1982.

B. Railway

M3174 Railway of Jordan was constructed for the first time in 1908 extending from Damascus of Syria to Medina of Saudi Arabia by the Hejaz Jordan Railway (HJR). However, this railway operates at present only range from Amman to Damascus due to the damage of facilities and the business depression. The business has mainly been done for passengers, but during recent few years the number of passengers carried was not more than 60 thousand per annum (see Table A-33, Appendix-(I)A). On the other hand, in 1975 a railway was opened between Aqaba and Hasa by the Aqaba Railway Corporation (ARC) to transport the phosphate rock produced at the Hasa mines, and in 1981 the line was further extended to Abiad. Quantities of phosphates transported by the railway from Hasa and Abiad increased from 1.6 million tons in 1981 to 2.6 million tons in 1985.

M3175 These Railways are operated by the single track with a narrow gauge of 1,055 mm. HJR with the super-annuated facilities has transported a few passengers and cargoes, or less than 1% of the total quantities of transport in Jordan. Such unfavorable situation of HJR may continue for the time being, unless the equipment and facilities are improved and strengthened adequately. On the other hand, ARC's facilities are expected to be further strengthened in proportion to increase in the phosphate production.

C. Port

M3176 Jordan has only a port, Aqaba, located in 300 km south of Amman. Aqaba has prospered as an important station of transport in Arab countries. In 1952, the Aqaba Port Authority (APA) was established expecting that the Aqaba port would develop as a modernized port. In 1954, APA changed the name to the Aqaba Port Department (APD). According to the statistical data on the trade, the share of the Aqaba port to

external trade of Jordan accounted for about 40% in amount. For example in 1985, exports and imports in the Aqaba port amounted to JD 133 million (43% share) and JD 453 million (42% share), respectively. Quantity of goods loaded in the Aqaba port reached 8.2 million tons in 1985, corresponding to 2.3 times of 3.5 million tons in 1981,and on the other hand the quantity of goods unloaded was 6.4 million in 1985, or 1.1 times of 5.8 million tons in 1981 (see Table A-34, Appendix-(I)A).

M3177 In response to increase in the handling cargoes, authorities concerned implemented the following projects during the Second Plan period (1981-1985): extension of berth for handling containers (580 m long), construction of industrial berth to handle potash and fertilizers, rehabilitation and increase of ship-loader capacity at phosphate berth, construction of parking areas with 200 thousand sq. m, and purchase of tugboats and other various equipment and materials. Following the Second Plan, the Present Third Plan is designed to complete the port facilities to meet increase in cargoes handled in the future. To complete these projects about JD 13 million will be disbursed during the Plan period 1986-1990.

D. Airport

M3178 Jordan has at present two airports for general passenger and freight uses; the Queen Alia International Airport and the Aqaba Airport. The former located in 29 km south of Amman succeeded the transportation business from the Amman International Airport on May 1983. The latter is exclusively used for the inland transportation purpose. Both airports are controlled by the Civil Aviation Authority. The Queen Alia International Airport was designed to accommodate three million passengers a year, with possibilities for expansion to eight million passengers by the year 2,000. On the other hand, the air transport services of Jordan are done by the Royal Jordanian Airlines (Alia). For the period 1980-1985, the following passengers and freight were carried by Alia:

Category	1980	1981	1982	1983	1984	1985
Passengers (thousand)	1,112	1,443	1,666	1,582	1,347	1,290
Freight (thousand tons)	29	37	39	40	38	43

Source: Statistical Yearbook 1985, Department of Statistics

M3179 Number of flights which were used for the purpose of passengers and freight transport reached about 16,300 in 1985 increasing by 16% against 14,000 in 1980. Among them, Alia accounted for about 60%. Currently, Alia holds 32 aircrafts, consisting of 4 Boeing 747's, 16 Lockheed Tristars, 9 Boeing 727's and 3 Boeing 707's and connects with more than 30 cities in the world.

M3.1.8 Telecommunications

M3181 All telecommunications in Jordan are operated by Telecommunications Corporation of Jordan (TCC) which has major two installations; National Switching Center serving domestic needs and International Switching Center which provides links with foreign countries. The former currently provides direct dial services between Amman and a network of 48 localities in Jordan, and the latter provides 534 international circuits to 57 countries via the satellite earth station system.

M3182 Number of telephone subscribers in Jordan increased from 73 thousand in 1981 to 145 thousand in 1985 at the average rate of 18.6% per annum. In 1985, the Greater Amman area had 114 thousand subscribers corresponding to nearly 80% of the total subscribers in Jordan (see Table A-35, Appendix-(I)A).

M3183 An average number of telephones per 100 inhabitants reached 5.5 units in Jordan and 7.2 units in the Amman Governorate in 1985 rising at an average annual rate of about 15% and 17%, respectively, during the period 1981-1985 (see table A-36, Appendix-(I)A). According to the Third Plan, by the end of the year 1990 it is expected to rise to 16.3 units in Jordan and 19.2 units in the Amman Governorate. This figure means on the other hand that the percentage of telephone number per household will reach nearly 100% in Jordan and 115% in the Amman Governorate. To achieve these figures, the Third Plan envisages to provide an additional 220 thousand telephones.

M3.2 Present Condition

M3.2.1 Topography and geology

M3211 The Study Area is situated in the southern part of the Governorate of Amman and northern part of the Governorate of Karak. The fault escarpment on the eastern side of the Jordan Valley graven forms the natural western boundary of the Study Area. Maximum elevations along the crest of the escarpment are 800 m east of Madaba, 800 m east of Dhiban, 1,100 m east of Karak and 1,250 m near Mazar. The escarpment is breached by Mujib Valley which is the largest wadi in the territory of the Hashimete Kingdom of Jordan. Erosion in the valley has been rejuvenated by successive lowerings of base level in the Dead Sea. As a result a deep groge has been cut in the Mesozoic sediments which underlies along the Western Highland. The head-waters of this drainage extend far into the Central Plateau. In the southeastern part of the Mujib basin, there lies a flat muddy swamp of Qa El Hafira with an area of 30 km^2. The Study Area is 6,600 km^2 in area with an irregular shape. Its approximate measurements are 70 km wide in the east-west direction and 120 km in the north-south direction.

M3212 The geology of the Study Area consists of arenaceous deposit of lower cretaceous and carbonate rocks of middle to upper cretaceous as seen in Annex M3212-1 and M3212-3. The sandy facies of the Kurnub Group persists as the basal unit of the cretaceous succession throughout the Study Area. The sediments which underlie the Kurnub Groups are mainly carbonates and consisting of limestone, marl and chert. As this report is concerned with hydrogeology and engineering geology of the carbonate rocks, emphasis is paid to the geology of Ajuln and Balqa Group. These two groups of middle to upper cretaceous are divided into several formations of A1 to A7 and B1 to B3 which are superposed monoclinically from lower to upper horizons in order. Localized lacustrine sedimentation occurred during the upper tertiary and pleistocene. The fluviatile gravels and lacustrine clays cover a part of southern Mujib watershed.

M3213 Most of the soils in the Study Area are formed of materials directly derived from sedimentary rocks. Alluvial soils which widely nextend over the Highland desert are medium to fine in texture, moderately low in permeability and rather low in inherent fertility. The soils are composed of complex soil associations of Haplargids, Calciorthids, Torrioirthents, Torrifluvents and Chromoxererts.

M3214 Most of the vegetation in the Study Area are affected by man's activities. Wheat is a common crop in the western plateau where annual rainfall exceeds 250 mm and is harvested by early summer. Some vegetables are irrigated by groundwater wells. In the lower reaches of Wadi Wala and Wadi Mujib where baseflow flows over the wadi bed, a sweet oleander grows in local with scenic beauty. A reforestation program is being carried out in a part of northern mountainous area with elevation of 800 m or more. A green belt consisting of two to three rows of trees is afforested along both sides of major highway of Kings Highway and Desert Highway where annual rainfall exceeds 300 mm. In the desert highland, the terrain is stony and almost deoid of plant growth except in a few small localities with desert grasses.

M3215 In the Study Area, there is only one reserve area of Mujib Wild Reservoir, which is located in the lower reaches of Wadi Mujib with an area of 220 km^2 and elevation between 400 m to 800 m . The purpose is to protect and reserve representative escarpment together with indigenous flora and fauna

M3.2.2 Climate

M3221 The Study Area generally lies within the Mediterranean bioclimatic region and its climate is characterised as semi-arid to arid. Essential feature of this climate is to receive a concentrated rain during the cool winter season thru October to May and to have a very marked summer drought.

M3222 Rainfall observation in and around the Study Area has been carried out since 1930s. Presently, about 70 stations are operated under the management of WAJ. Of them, 25 stations are equipped with automatic rain recorders. The Study Team installed the additional 4 units of automatic gauging stations in the key areas to estimate the optimum siting of the potential damsite.

M3223 Rainfall data are well arranged and kept in the Directorate of Water Resources Department of WAJ. Most of them are found to be comparatively useful for the arrangement of daily and monthly rainfall data. These data were installed in micro-computer data base (IBM-5550) which was programmed and equipped by the Study Team. This hydrologic data base was also used for the runoff model simulation analysis.

M3224 Locations of the rain gauging stations and an isohyetal map of annual rainfall are shown in Annex 3224. The isohyetal lines are almost parallel with the elevation contour lines in the western plateau and decrease the amount eastwardly to the inland desert. Eastwards from the Desert highway, the annual rainfall is less than 100 mm per annum. Average annual rainfall in the Study Area is estimated to be 130 mm.

M3225 Evaporation pans of U.S. Weather Bureau Class-A of 10 in number have been installed and observed in and around the Study Area since 1960. Additional Class-A pans which include one unit of automatic recorder and one unit of accumulative type recorder were installed at the selected stations in the Study Area by the Study Team as also seen in Annex 3224.

M3226 Estimated potential evaporation increases eastwards from 1,500 to 2,500 mm per annum, which is almost parallel to the rainfall distribution with opposite relation in amount. Average annual potential evaporation in the Study Area is estimated to be 2,200 mm, which is more than ten times as high as annual average rainfall of 130 mm/y.

M3227 Monthly mean air temperature varies, ranging between 5^{o} and $25^{o}C$. Some snowfall were recorded between January and March in the highland of Madaba and Karak. Relative humidity is low, ranging between 30 to 55 %.

M3228 Average wind velocity ranges between 1.0 and 2.0 m/s throughout the year except the period of sandstorm in the dry season. The sunshine hours during the dry season is 7 to 8 hours, while those are ranging between 4 and 5 hours in the wet season. The monthly potential evaporation ranges between 67 and 297 mm. The maximum usually occurs in July to August, while the minimum occurs in December to January.

M3.2.3 Drainage

M3231 The Study Area is drained westwards to the Dead Sea by the Wadi Mujib and its major tributary of the Wadi Wala. The catchment area is 6,530 Km^2 in total at the confluence with these Wadis, which includes 4,500 Km^2 of Mujib catchment and 2,030 Km^2 of Wala catchment. The Wadi Wala drains the northern part of the Study Area with an annual flood runoff of 23 MCM/y at the bridge of The King's Highway. The Wadi Mujib drains much of the southern part of the Study Area with an annual flood runoff of 26 MCM/y at Mujib gauging station at King's highway. The upper reaches of the wadis lie in the desert area with annual rainfall of 100

mm or less, where rainstorms are localized and floods are comparatively few.

M3232 The floods are immediately drained to the Dead Sea within a few days after the rainstorm and dried up to be wadis , except the area of Qa el Hafira and Abyad muddy swamps in the southeast Mujib cacthment, where floods stagnate for a few weeks until the stored water dries up mainly by evaporation. The amount of this stagnant water is estimated to be about 3 MCM/y.

M3233 The base flow in the Mujib is derived from a number of small springs and seepages in the two wadis. These two westwards wadis have cut down to intersect zones of saturated aquifers underlying the Western Highlands and perennial flow is maintained by spring discharge. The lower reaches of Wadi Wala, which is called Wadi Heidan, drains base flow with an annual groundwater runoff of 20 MCM, which is almost two thirds of the total base flow of 35 MCM in the Mujib. The occurrences of the base flow in the Wadi Heidan is mainly dependent on B2/A7 limestone aquifer unit, showing low range in Total Dissolved Solid (T.D.S) of about 500 mg/l, which is due to occurrence of the aquifers.

M3.2.4 Groundwater

M3241 Aquifers are recognized in the pervious limestone unit of B2/A7, A4 and A2 in Belqa and Ajuln Group and sandstone unit in Kurnub Group, which underlies the Study Area as seen in Annex M3212-2. The Siwaqa fault bisects the groundwater basin into two parts. In the northern part, groundwater flows generally towards the estuary in accordance with the surface drainage trends in the Wala catchment. In the southern part, there is an indistinct ridge of the groundwater contour approximately along the Desert Highway. The groundwater flows towards the estuary in the western part of the ridge, but flows in the north-east direction towards the Azraq oasis in the eastern part. Piezometric head contour is also shown in Annex M3212-1. Quality of groundwater in the B2/A7 aquifer unit is good to fair with less salinity

of Total Dissolved Solid (T.D.S) in the range of 500 to 1,200 mg/1, whilst higher salinity of more than 2,000 mg/1 of T.D.S is measured in some deep sandstone aquifers.

M3242 The B2/A7 aquifer system, which is the most important in the Study Area, outcrops in a large area of the Western highlands, where a part of rainfall directly recharges the water table aquifers. The piezometric surfaces is about 150 m below ground surface on the plateau in the northern part of the groundwater basin, while the groundwater table is about 100 m deep in the southern part except in some deeply incised wadis. The maximum thickness of this system is about 300 m as seen in Annex M3212-2.

M3.2.5 Soils and land classification

M3251 The field reconnaissance soils survey on possible irrigation area of about 400 km^2 and physio-chemical analyses of the representative soils at 5 test pit sites and 50 anger pit sites are carried out to clarify soil properties and to provide basic data for agriculture development.

M3252 Soils Classification: Soils in the surveyed area are classified into the two (2) Soil Orders namely, the Entisols and the Aridisols. The Entisols are the immature soils which have been formed recently and have only an ochric epipedon. These soils cover about 5,700 ha of the surveyed area. The Aridisols are typical desert soils which have ochric epipedon and one or some sub-surface horizons such as argic, cambic, natric, gypsic, calcic, petrocalcic horizons and duripan. These soils cover about 34,700 ha of the area.

M3253 The two (2) Soil Orders in the surveyed area are, furthermore, classified into the four (4) Soil Great Groups and the two (2) Soil Sub-Groups as shown below.

Soil Order	Soil Great Group/Sub-Groups	Area (ha)
1. Entisols		(5,678)
	1.1. Torriorthents	5,143
	1.2. Torrifluvents	535
2. Aridisos		(34,726)
	2.1. Paleorthid	6,136
	2.2. Calciorthid	
	2.2.1. Typic Calciorthid	27,475
	2.2.2. Xerrolic Calciorthid	1,115
Total		40,404

Suitable soils for agriculture development are the Torrifluvents, some of the Typic calciorthid and the xerrolic calciorthid.

M3254 Land Classification: The surveyed area is classified into five (5) classes, namely the Class I to the Class III, the Class V and the Class VI. The land classification in the surveyed area is as follows:

Land Class	Area (ha)	Proportion (%)
Class I	14,364	35.6
Class II	9,562	23.7
Class III	1,929	4.8
Class V	7,569	18.7
Class VI	6,980	7.3
Total	40,404	100.0

The Hamman, Jiza and Shabik regions are covered by only suitable lands of the Class I and/or the Class II. In the Rumeil and Wala, Siwaqa and Sultani regions, about 30% to 60% of each area is covered by the Class VI. In the Zainab and Qatrana regions the Class VI area is found out to be less than 10% of total area but the Class V area ranges from about 30% to 45%.

M3.3 Agriculture

M3.3.1 Land use

M3311 According to the National Village Survey 1984, the Ministry of Agriculture, land use in the Study Area, excluding the Azraq Nahia area of the Amman Governorate and the Ma'an Governorate, is respectively estimated at about 8% of forest, about 21% of cultivated area and about 71% of other types of land such as uncultivated land, lands for rest, urban and village area, desert land, etc.

M3312 Planted Area and Crops:

(a) According to the Statistical Year Book 1985 and the Field Crops and Vegetables, Village Survey, the Ministry of Agriculture, planted areas of the East Bank, the Ghors, the Amman and Karak Governorates and the Study Area are as follows.

(Unit: ha)

Crops	East Bank	Ghors	Amman & Karak Gov.	Study Area
1.Field Crops	149,675(65.8%)	1,703(4.9%)	51,688	52,276(76.8%)
2.Vegetable	22,530(9.9%)	26,559(76.3%)	(No data)	5,460(8.0%)
3.Fruit Trees	55,429(24.3%)	6,529(18.8%)	10,289	10,347(15.2%)
Total	227,634(100.0%)	34,791(100.0%)	-	68,083(100.0%)

(b) Agriculture in highlands including the Study Area is susceptibly affected by the annual hydrologic conditions, and planted area, production and quality of crops in rainfed farms change strictly. In the Study Area, planted area of field crops such as wheat, barley and other winter field crops declined extremely from about 75,000 ha in 1983 to about 26,000 ha in 1984 because the year of 1984 was the most droughty hydrologic year for the 5 years from 1981 to 1985. However, planted areas of vegetables have increased moderately for the 5 years. Main reason of this increase is that majority of vegetable areas have been

irrigated by groundwater and or base flow of some wadi surface flow and modernized horticulture techniques such as plastic house plantation, mulching techniques and drip tube irrigation method have been carried out.

(c) According to the Agricultural Census in 1983, rainfed area and irrigated area of the Study Area are respectively 87.8% and 12.2%. Crop planted in irrigation farms are classified into two (2) vegetable groups by farm types such as field plantation and plastic house plantation. Plastic house plantation was carried out in irrigated area of about 11% in 1983, referring to data on irrigation area of the Amman and Karak Governorates. The majority of planted crops of the both farm types are tomato, cucumber and eggplant. The most widely planted crop is tomato (See Appendix-(I)G and Table G-2.9).

M3313 Cropping Pattern: The majority of winter season crops in rainfed farms are cereals such as wheat and barley. A little amount of vegetables are planted in irrigated field farms and plastic house farms. Ploughing for cereals in rainfed farms roughly starts on November, before and after the first rainfall, and harvest period of these crops typically ranges from June to July. Planting period of winter season vegetables in irrigated field farms and in plastic houses are about five (5) months from August to December. Main summer season crops are vegetables in irrigated field farms and plastic house farms. Planting period of summer season vegetables in the both farm cases are about seven (7) to eight (8) months from January to July or August.

M3314 Farming Practices: The majority of field crops is planted in rainfed farms. Ploughing is carried out by tractors and/or by animal powers and mechanical harvesting is usually carried out. In some farms, harvesters are sometime used. Threshing of grains is usually carried by threshers. Plantation of vegetables is mostly carried out by drip irrigation. Modernized agricultural facilities such as plastic houses, mulching sheets, soluble fertilizers and spray for agrochemicals have been introduced. As for sowing vegetables, direct sowing in open field and transplanting in plastic houses and in mulching farming areas are

usually carried out.

M3315 Crop Yield and Production:

(a) According to the report of Field Crops and Vegetables, Village Survey 1985 by the Ministry of Agriculture, Crop Yield and Production in the East Bank, the Ghors, the Amman and Karak Governorate areas and the Study Area are summarized as follows.

(1) Field Crops:

Unit crop yields of wheat and barley show the similar figures with the ranges from 0.6 to 0.8 ton/ha of wheat anf from 0.5 to 0.7 ton/ha of barley in the East Bank, the two (2) Governorate areas and the Study Areas. However, unit crop yields for field crops in the Ghors shows about 1.2 ton/ha of wheat and 1.8 ton/ha of barley.

Production of field crops in the Study Area reaches about 37% in wheat and about 47% in barley comparing to production of each crop in the East Bank.

(2) Vegetables:

Unit yields of majority of vegetables in the Study Area are lower than those in the East Bank, but unit yield of pepper in the Study Area shows higher figure comparing to that in the East Bank. Unit yields of vegetables excluding potatoes in the Ghors show higher figures comparing to those in the East Bank and the Study Area. Each vegetable production in the Study Area are generally less than 20% of that in the East Bank, but only production of pepper reaches about 65% of that in the East Bank. Out of vegetables in the Study Area, tomato has the largest production and production of watermelon follows.

(3) Fruits:

Generally, unit yield of fruits in the East Bank, the Amman and Karak Governorates and the Study Area are similar. However, unit yields of almond, peaches and cherry in the Study Area show higher figures than those in the East Bank and unit yields of apples, citrus and pears are lower than those in the East Bank.

In the Study Area, major productions of fruits are olives and grapes and these productions reach about 17% and about 33% of that in the East Bank respectively. Productions of other fruits reach about 30% of those in the East Bank.

(b) Production amount and unit yield of major crops in the Study Area are as follows.

Crops	Unit Yield (ton/ha)	Production (ton)
1. Field Crops		
Wheat	0.78	24,404
Barley	0.66	9,421
2. Vegetables		
Tomato	12.71	17,840
Watermelon	14.93	7,914
Cucumber	18.53	5,634
Cauliflower	16.79	5,206
3. Fruits		
Olives	0.93	4,118
Grapes	3.68	14,725

M3316 Marketing:

(a) Marketing System of Agricultural Products and Inputs: The Ministry of Agriculture (MOA) controls the amount of import and export of agricultural products through licensing, and the Ministry of Supply (MOS) provides leadership in the regulation of prices.

Marketing of some imported agricultural commodities such as wheat, sugar, rice and meat excluding frozen goods are monopolized as the essential or basic food under the MOS. As for local production such as wheat, barley, chickpeas, lentils, purchasing prices are announced prior to the crop season, and the Government committee purchases the products with the announced prices, while the prices of local meat and milk are determined under the market mechanism.

The prices of fresh products are determined what the price should be that day.set by the Government committee in reviewing the previous day's examining wholesale prices at the current day's auctions, and assessing the volume of products in the wholesale market.

(b) Production Control of Some Crops: The Government has launched a production control program with the major objectives to avoid problems in marketing of some overproduction vegetables such as tomatoes, cucumbers, eggplants and squash and to promote production of some deficit crops such as onions, potatoes, garlic and grains, etc.

The production of tomatoes was subjected to decrease from 412 thousand tons in 1985 to 242 thousand tons while that of eggplants was projected to increase to about 160%. Production of squash was projected to increase 130% in the East Bank and in the Valley in total while, in the Highlands was decreased.

(c) Demand and Supply of Agricultural Products: During five (5) years from 1981 to 1985, annual imports of food and live animals were counted at about JD180 thousand. Wheat and flour of wheat was counted at about JD31 thousand followed by meat, fruits vegetables and nuts.

Export of food and live animals earned about 19% of the total export value in the Jordan. Export of fruits and vegetables counted more than 70% of the total export value of food and animals. Major fruits exported from the Jordan were citrus fruits like oranges, mandarines and lemons followed by banana and melons. The export of vegetables counted about 47% of the total export value of food and animals. Main vegetables exported were tomato, cucumber, squash and eggplant.

Consumption per capita on major crops reaches more than 580 kg. Main import crops such as wheat, barley and apples are composed of about 36% of consumption per capita. Main export crops such as tomato, eggplant, cucumber, citrus, sweet melon and pepper are consisted of about 47% of consumption per capita.

M3317 Farm Inputs and Output : The estimated total production cost for each crop ranges from about JD30/ha to JD310/ha in rainfed farms, from about JD620/ha to JD1,200/ha in irrigated field farms and from about JD1,900/ha to JD2,600/ha in plastic house farms as shown in Appendix-(I)G and Table G-2.25. Production costs for plastic house farms become about 2.5 times of those for irrigated field farms. Main reasons of the increase of production cost are facilities cost of plastic houses and intensive labour requirements.

Net income on farm of each crop is estimated to range from about JD25/ha to JD180/ha in rainfed farms, from about JD500/ha to JD1,350/ha in irrigated field farms and from about JD650/ha to JD3,800/ha in plastic houses farms.

M3.3.2 Existing irrigation system

M3321 Surface Water Irrigation Areas: Small surface water irrigation areas are scattered around the Wala bridge of the Kings Highway and downstream from the Mujib bridge of the Kings Highway. Majority of irrigation areas are located at gentle side slopes of the wadis and flat

lands of small hills. Irrigation water is lifted up by portable pumps and conveyed by small pipelines. Total irrigated areas are respectively estimated at about 360 ha (registered irrigation area: approximately 600 ha) in the Wadi Wala area and at about 70 ha in the lower reaches of the Mujib. Main planted crop in the both areas is vegetables.

M3322 Pilot Irrigation Schemes: Out of the nine (9) pilot irrigation schemes constructed by the Government, the following two (2) schemes, namely the North Qatrana irrigation project and the South Qatrana irrigation project, are located in the Study Area. The both Qatrana irrigation projects were constructed at the beginning of 1970, as one of the bedouin settlement projects. At present, the total irrigation area of both projects is 165 ha and the water resource of irrigation is groundwater. The majority of planted crops are vegetables, such as tomato, eggplant, potato, cucumber and watermelon.

M3323 Other Groundwater Irrigation Area: Groundwater irrigation areas expand from southern area of Amman to northern area of Madaba along the Kings Highway, and from the eastern area of Jiza to southern area of Dab'ah along the Desert Highway. These areas are irrigated by using private production wells and total irrigation area is estimated at about 3,000 ha. The main planted crops are vegetables and fruit trees. In the Amman Governorate area, private production wells of about 250 numbers are estimated. However, in these areas, about 160 numbers of production wells are confirmed by the WAJ's data of well drilling.

M4. WATER RESOURCES

M4.1 Surface Water Resources

M4.1.1 Flood flow

M4111 Flood water in the wadis is dependent on the intense storms in the catchments, which occur during the rainy season from October to May. These flash floods are directly discharged out to the Dead Sea within a few days after a storm, without water to be used for any purpose except the water stored in the existing two small dams on the upper tributaries in the Wadi Mujib basin. These two existing retention dams of Qatrana and Sultani were constructed by the fund of U.S. AID in 1960s. According to recent survey conducted by WAJ ,Qatrana dam reservoir has the capacity of 2.0 MCM/y which is a half of the original value. The reservoir of the Sultani dam has been silted up to more than half of volume by the muddy effluents of waste disposals from the upper Abyad phosphate mining and by soil erosion. The reservoir dries up in the midst of summer season. Flood water stored in the two existing reservoirs is estimated at be about 2.8 MCM/y, or 4.3% of the total flood flows of 65 MCM/y in the whole Mujib basin. Some flash floods are retained in the muddy swamps which are located in the upper reaches on Qa El Hafila and Wadi Abyad. The retained water is estimated to be 2 MCM/y in total, which soon dries up within one month by heavy evaporation.

M4112 There are existing 5 water level gauging stations in the Study Area. These gauging stations with automatic recorder were being monitored by the directorate of Central Water Authority since 1960 ,and presently succeeded by Water Resources Department of WAJ. Additional four units of automatic water level recorders with pressure sensor type were installed in the selected major tributaries by the Study Team in Dec. 1986, taking into account the optimum siting for the proposed dams. These water level gauging stations and their locations are also shown in Annex M3224.

M4113 At the sections of Wadi Wala,Wadi Mujib and Wadi Siwaqa gauging stations , a series of direct measurements have been carried out for the conversion of water level data into discharge data, which is used for the calibration of synthesized runoff data by a simulation model. This simulation model consists of 24 tank models and each of them represents a divided subbasin of planned damsite in the Study Area. Annex M4113 shows the basin diagram used in this simulation . Conditions and assumptions of the simulation study are described in Appendix-(I) B.

M4114 Daily mean discharge is calculated from the synthesized data mentioned above. These values at planned damsites are presented in Appendix-(I) B, as an information of the potential of flood runoff in the Study Area.

M4115 The Wadi Wala has a catchment area of 1,800 km^2 at King's Highway Bridge and its annual flood runoff is 23 MCM/y. The Wadi Mujib, 4,350 km^2 in catchment area at King's Highway Bridge, has an annual runoff of 26 MCM/y. The flood volume from the residual basin is relatively high, and its volume reaches 13 MCM/y. Runoff coefficient from the tank model simulation ranges from 3% in the southern area to 15% in the northern and western mountainous areas. These values are shown in Annex M4115-1. Estimated annual flood runoff volumes for some return periods at planned damsites are tabulated in Annex M4115-2. Estimated most frequent flood volume (2 years return period) is 19.3 MCM at Wala proposed dam site and 20.8 MCM at Nukheila proposed damsite.

M4116 The envelope curves of peak discharge and flood volume are developed at water level gauging stations to obtain design flood at each damsite. This relation indicates that flood duration is proportional to the flood peak in Wala Basin, on the other hand flood duration does not change so much for each flood and its hydrograph gets steeper according to the flood volume in Mujib Basin. Daily Flood volume of return periods at planned damsites are converted into the peak discharge of the same probabilities by the envelope curve, with an allowance of 20% to the calculated discharge.

M4.1.2 Base flow

M4121 Base flow measurement has been carried out at the mouth of the Wadi Mujib since 1956. Intermittent measurements have been taken at the Mujib-Wala confluence since 1962 and at Heidan spring, the biggest one of Wala downstream, since 1960. Intensive measurements of base flow have been performed at downstream of the Wadi Wala by the directorate of Study and Research and Dams Department of WAJ and the Study Team at regular intervals by current metering since 1986. Of them, spring data are well arranged and kept in computer data bank system in the directorate of Water Resources of WAJ.

M4122 Perennial base flow is maintained by springs from the discharge of aquifers in the bottom of wadis. In the Wadi Wala, the base flow springs out at just upstream of Wala bridge where Kings Highway crosses the Wadi Heidan at the elevation of 450 m. This base flow suddenly increases up to mean annual discharge of 15 MCM at 5 km downstream from the bridge at the elevation of 350 m. Downwards to the confluence at Wadi Mujib, the base flow increases up to 23 MCM/y. Annex M4122 shows the profile of the base flow along the lower reaches of Wadi Wala . In the Wadi Mujib, the base flow springs out from just upstream of the Mujib bridge where Kings Highway crosses the Wadi Mujib at the elevation of 150 m. The base flow gradually increases downwards collecting the spring water from sandstone aquifers with rather high salinity. The flow discharge just upstream of the confluence is about 12 MCM/y, which is one third of the total base flow of 35 MCM in the whole Mujib basin.

M4124 Most of the base flow in the Wadi Heidan is dependent on the groundwater runoff from the B2/A7 aquifer which is the major exploiting aquifer in the Study Area. There is a direct hydraulic interrelation between the base flow and the B2/A7 aquifer along the reaches at an eleva tion of 250 m to 450 m, that gives us a caution of developing groundwater in the B2/A7 aquifer in and around the area. According to the result of groundwater model simulation, most of the base flow will be extinct by

extracting groundwater from the wells in Heidan area. From the view point of the water balance, groundwater exploitation without any artificial recharge consideration is not recommended in the Wadi Heidan.

M4125 The water quality test has been conducted from time to time on the water samples collected together with measurement of the base flow since 1965. Water quality of the Wala base flow is in a range between Total Dissolved Solid (T.D.S) of 400 and 900 ppm, or irrigation class C3S1. While the salinity is rather high as more than 1,000 to 1,300 ppm to the base flow in the Wala Mujib, or irrigation class C3S2. The results of water quality analysis show that the base flow in the Wadi Wala is fairly good for agriculture use and can be used as the raw water for drinking purpose with corresponding simple purification process such as settlement and chlorination. Some attention shall be paid to use water which is in rather high salinity level of T.D.S more than 1,000 ppm in the Mujib base flow.

M4126 Base flow in the lower reaches of Wadi Mujib consists of the seepage from deep sandstone aquifer in the Kurnub Formation which contains high salinity. On the other hand, base flow of Wadi Wala consists of two different components. One is from shallow aquifer in the B2/A7 Formation and its quality is excellent to good, which appears suddenly in the upper reach of Wadi Heidan. Another is from deep sandstone aquifer in the Kurnub Formation with rather high salinity. This component seeps along the lower reaches of Wadi Heidan. Based on the direct measurements, which have been carried out by WAJ, mass balance of salinity is examined, to estimate the influence of water extraction in the upper part of Wadi Heidan on the lower reaches. The TDS at the confluence under the present condition is 1,056 ppm, which will be increased up to 1,400 ppm by extracting base flow at the upper reaches of Wadi Heidan. Sensitivity analysis was made to predict the change in flow discharge and its water quality in T.D.S at the confluence by extracting different rates of base flow at the upper reaches of Wadi Heidan. Followings are the summary of the sensitivity analysis.