Extraction Volume at Heidan (MCM/y)	Base flow at the confluence(MCM/y)	TDS at the confluence (ppm)
0	35	1,056
5	30	1,137
10	25	1,269
15	20	1,466

M4.2 Groundwater Resources

M4.2.1 Hydrogeology

M4211 The groundwater in the Study Area is in both unconfined and confined conditions. Promissing aquifer is recognized in the B2/A7 limestone unit, which is the most important due to subjecting groundwater recharge through outcrops in a large area of the northwestern and western edge of the highland where annual rainfall exceeds 250 to 300 mm. The depth to the groundwater table from ground surface varies from 100 to 200 m.

M4212 Test wells have been drilled at many places in the Study Area by WAJ. Among them, two test wells with maximum depth of 750 m were drilled at the Mujib bridge with elevation of 150 m, in order to examine the hydrogeology of the lower Ajuln Formation and Kurnub and Disi Group. One test well was drilled in the Wadi Heidan with a depth of 430 m and penetrated into the deep limestone aquifer of the A4 Formation. The hydrostatic head in the A4 formation is measured to be poor, introducing less attractrive feature of exploiting the deep aquifer systems in the lower Ajuln Formation. The groundwater in the Kurnub and Disi sandstones are believed to be fossils with different salinities, which depend on the occurrences in sandstones in the Cambrian to Mesozoic sedimentary basins. Four additional test wells were drilled in the B2/A7 Formation by the Study Team. Location of these test wells were selected in the area where no hydrogeological data were available. These results of the drilling explorations with pumping tests are coordinated to the model simulation study by providing detailed hydrogeological informations with estimated aquifer parameters.

M4213 Most of the production wells have been drilled in the northern part of the Study Area and the area along the zone of Desert Highway in the southern part. The depths of the wells range from 200 to 350 m. The aquifer is recognized in the B2/A7 Formation which is composed of alternating silicified limestone, chert, marl and limestone. The yield of this aquifer varies from place to place depending on the variable permeabilities of the B2/A7 Formation which is largely due to joints and/or karstification of the limestones. However, zones of permeability are grouped to relate more to geological structures such as fault system.

M4.2.2 Quality of groundwater

M4221 Quality of groundwater in the B2/A7 aquifer is fair to good with salinity in the range between Total Dissolved Solid (T.D.S) of 500 and 1,500 ppm. Eastwards from the Dessert Highway, where the annual rainfall can not exceed 150 mm and no direct groundwater recharge is expected, the T.D.S increases from 1,000 to 1,500 ppm or more. In and around the recharge mounds along the north and southwest ridge of the Highland, where annual rainfall exceeds 300 mm, the T.D.S is low as less than 500 ppm. Most of the production wells which are being used for domestic and/ or agriculture are located in the area of less than T.D.S of 1,000 ppm as seen in Annex M4221-1 and M4221-2. Future change in water quality by long term of pumping is preliminarily estimated by taking account of the non-uniform hydrochemical structures of the B2/A7 Formation. The T.D.S will be increased by 50 to 80 % at the maximum, corresponding to the future increment of drawdown which will be caused by a long term pumping up to 20 to 100 years.

M4.2.3 Groundwater simulation and potential evaluation

M4231 Groundwater model simulation is carried out to estimate the sustained yield of the B2/A7 aquifer system. Annex M4231-1 shows the finite-element grid showing boundary conditions of the groundwater simulation model. The sustained yield of groundwater, which will not give a serious adverse effect on existing base flow in the wadis, is estimated on the simulation study. The sustained yield is estimated to be 26.9 MCM/y in total from the proposed four well fields on top of existing extraction of 28.4 MCM/y. Taking into account the future water demand, water pipeline plan and estimated aquifer potential, four major well fields are proposed in the Study Area. From the simulation study, potential yield from each proposed well field is estimated to be 9.6 MCM/y in the "Siwaqa-Qatrana", 6.3 MCM/y in the "Sultani", 7.0 MCM/y in the "Rumeil" and 5 MCM/y in the "Lajjun". Calibrated piezometric head which is estimated by simulation model as of year 1986 is shown in Annex M4231-2. Computed drawdown of as year 1995 to 2005, which include the extraction rates mentioned above, are presented in Annex M4231-3 and M4231-4. Computed average drawdown in the major well fields to the year of 2004 is in the range between 30 to 60 m, corresponding to the assumed pumping rate of 55.3 MCM/y in total which includes 26.9 MCM/y from the proposed four well fields. It will take more than 50 years to find the average drawdown of 100 m in the major well fields which is considered to be a critical water level from the view point of water economy. Annex M4231-5 presents a result of a long term prediction at major control points up to year 2145. Artificial groundwater recharge is also examined by the simulation model, to increase the groundwater potential in the B2/A7 aquifer and then to formulate a more intensive and/or stable long term pumping program. Methodology is dependent on the concept of utilizing flood water which is being wasted to the Dead Sea. Flood retention methods with coupling of artificial groundwater recharge are studied, taking account of the best hydrogeological setting of the promissing dam site and its potential runoff. Among them, Wala recharge dam is the most promissing, of which schematic is shown in Annex M4231-6. From the result of the simulation study, the Wala recharge dam will give a good influence on not only enhancing the groundwater potential in and around the area of Rumeil and Heidan but increasing the amount of base flow at downstream area as shown in Annex M4231-7.

M4.3 Present Use of Water Resources

M4.3.1 Municipal and industrial water

M4311 General: Of the total water consumption for Jordan, 85% is utilized for agriculture and the remaining 15% is municipal and industrial water.

In Jordan, the municipal water is supplied by pipelines. Municipal water is also provided for normal to small size factories. Large scale factories, however, have their own wells to provide water.

Surface water is mainly used for agriculture but some groundwater is also used for this purpose.

M4312 The Study Area consists of Wadi Mujib basin and the Greater Amman area, adjacent to the northern side of Mujib basin and forming a circle with a radius of 30 km centered around Amman city.

The estimated area and population as of 1985, are as follows:

Section	Area	Population
Wadi Mujib basin	6,600 km^2	77,000
Greater Amman area	2,827 km^2	1,620,000

The Greater Amman area occupies only 3% of the entire area of the East Bank's 89,000 km^2, however, its population is more than 60% of the total population of Jordan.

Moreover, the population is increasing by 5% each year. This population growth, greater than in the other areas, is expected to continue in the foreseeable future.

The amount of water consumption is approximately proportionale to the population so that the description of water demand/supply focuses on the Greater Amman area.

M4313 The metropolis area consists of four governorates; Amman, Zarqa, Irbid and Balqa. The estimated population of Greater Amman in 1985 is as follows:

Governorat	Population	%
Amman and Zarqa	1,471,000	91.0
Irbid	5,000	0.3
Balqa	140,000	8.7
(Total)	(1,616,000)	(100.0)

This shows that population of Amman and Zarqa is overwhelmingly larger than the other governorates. The total population of Amman and Zarqa, 1,517,000, is almost the total population of the Greater Amman area.

From this point of view, the total water supply volume to the Greater Amman area is almost equal to the water supply volume to Amman and Zarqa governorates.

M4314 Minicipal Water Supply : At present in Jordan the management of municipal water, from development of resources to distribution, is done by WAJ. The supply volume to each governorate managed by WAJ (in 1985) is as follows:

Governorate	Supply Volume (MCM/y)	%
Amman	52.3	56.5
Zarqa	9.2	9.9
Irbid	16.0	17.3
Balqa	2.6	2.8
Karaq	4.4	4.8
Ma'an	8.0	8.3
(Total)	(92.5)	(100.0)

Note: A detail of this is shown in Annex M4314.

The water supply volume to the Greater Amman area can be considered to be the total supply volume to Amman and Zarqa and is estimated to be 61.5 MCM/y, accounting for 66.4% of Jordan's total water supply volume.

M4315 Industrial Water: Industrial water used in small to normal sized factories is municipal water included in the table of Para M4314 however, water used by large factories is not. Large factories in the Study Area have their own wells as shown in the following:

Greater Amman area: phosphate mine, oil refinery, cement factory, glass factory, Pepsi factory

Mujib basin: Abyad phosphate mine

These large factories require too much water for municipal water sources to meet their demands. If a factory requires more water in the future, it will have to develop its own additional wells.

M4316 Municipal water to the Greater Amman area is supplied from the following 5 sources. Water supply volume at the time each source was planned and actual volume in 1985 is given. Details are shown in Annex M4316.

Water Source	Assumed Supply Vol.	Actual Vol.
	(MCM/y)	(MCM/y)
East Ghor Main Canal (Deil Alla)	(45)	1.5
Azraq well field	12	15.6
Qatrana, Siwaqa, Qastal well field	7	15.1
Amman bore holes	13	20.1
Zarqa bore holes	7	9.2
(Total)	(39*)	(61.5)

* note: not including Deil Alla

Initially, the supply volume was assumed to be 39 MCM/y but the actual volume was 61.5 MCM/y. Thus, the actual supply volume exceeded the initial estimate, which led to the over extraction of water sources to meet the demand in the Greater Amman area.

From the water sources listed, the well fields of Qatrana, Siwaqa and Qastal are in Mujib basin. Water supply volume to the Greater Amman area is 15.1 MCM/y or about 25% of the total supply volume. This shows the importance of these sources to the water supply for the Greater Amman area.

M4317 Deil Alla: The system for supplying water from Deil Alla, which is on the bank of East Ghor Main Canal (EGMC) to the Greater Amman area was completed in the latter half of 1985. Because EGMC is an irrigation canal, its water is used mainly for irrigation in the summer and cannot be used for municipal water supply in dry years. Therefore, water supply from the above mentioned system will be interrupted many times during summer. Accordingly, water from this source cannot be relied upon as a perennial water source, so EGMC is considered as only an emergency source of municipal water. The system has been mostly out of operation since its completion which is due to dry weather during these years. This is in fact, a part of the cause of the water shortage in the Greater Amman area.

M4318 Seasonal Fluctuation of Water Supply: Generally, the consumption of water in Jordan decreases in winter and increases in summer. The monthly water supply volume in 1985 for each governorate is shown in Annex M4314. In Amman governorate, the annual mean daily water supply volume is 143,400 m^3/day and the monthly mean daily water volume (in July when the volume is the largest) is 153,700 m^3/day. The ratio of peak/average is estimated to be 1.07. A record of actual water supply volume to Amman municipality is shown in Annex M4318. These data show that the peak/average ratio varied from 1.08 in 1983 to 1.16 in 1984. Accordingly, the peak/average ratio is approximately 1.1 to 1.2.

M4319 The above peak/average ratio based on the wide regional area. On the other hand the following is the peak/average ratio classified by each water supply system:

Supply System	Year	Peak/Mean
Azraq	1983	1.21
	1984*	1.20
	1985	1.22
Qatrana-Siwaqa-Qastal	1985	1.34

* note: The volume in October is abnormally high, so the value in August (the second highest in 1984) is substituted for it.

The actual water supply volume of the Azraq conveyance system and the Qatrana-Siwaqa-Qastal conveyance system are shown in Annex M4319. These rates fluctuate from year to year with some years exceeding 1.3. A safe estimate is considered to be 1.2 to 1.3.

M4.3.2 Sustained yield

M4321 All existing water sources in the Greater Amman are groundwater sources utilizing wells. The actual extraction volume of these wells in 1985 is shown in the table in section M4316.

This volume is too large. The sustained yield-amount of water that can be pumped without drying up the source is estimated as below:

Water Source	Yield (MCM/y)
Azraq well field	15
Siwaqa, Qatrana well fields	9 (6+3)
Qastal well field	2
Amman bore holes	15
Zarqa bore holes	9
(Total)	(50)

These water sources are explained in Annex M4320.

M4.3.3 On-going project

M4331 Water is presently being supplied to Amman by over extraction as mentioned in M4316. But the supply is still short. According to WAJ, in the summer of 1986 daily water consumption was estimated to be 190,000 m^3/day but only 170,000 m^3/day could actually be supplied, a shortage of approximately 10%.

In the fall of 1986, the following five water supply projects were decided on to alleviate the shortage problem:

Wala water conveyance project
Muheiba water conveyance project
New Siwaqa water conveyance project
Ring pipeline, Yaduda-Suweilih pipeline project
Ring pipeline, Yaduda-Abu Alanda-pipeline from Azraq.

An outline of these projects are described in Para F1104 in Appendix (II) and their routes are given in Annex M4316 and M4321.

M4332 The Mujib basin water sources are quite profitable because they are a domestic resource for Jordan and they are near Amman where demand is the greatest. All on-going projects (except the Mukheibah project) involve the development of water sources in Mujib basin. In the future, when new water resources in the basin are developed it can supply water to Amman by connecting a pipeline to one of these systems. From this point of view, the on-going projects are considered to be very effective.

M4.4 Irrigation Water

M4401 Surface Water Irrigation Area: Existing irrigated areas of about 340 ha in the Wadi Wala and of about 70 ha in the lower reaches of the Wadi Mujib use perennial surface flow (basic flow) of the each Wadi for irrigation. The surface flow is taken by portable pumps and conveyed by small pipelines. However, detail water uses for these areas are not clarified because of private sector's use and no available data on operation.

M4402 Groundwater Irrigation Area: Existing groundwater irrigation areas is about 3,200 ha ,including the two (2) Pilot Irrigation Schemes and detailed water use is also not clarified at present because of no available data. However, based on the data on pumping test of these production wells, well yield of each production well ranges from 5 l/sec to 25 l/sec. Therefore, present daily groundwater use is estimated a range from about 0.07 MCM to 0.35 MCM, taking into account about 160 numbers of production wells in the Study Area.

M5. WATER DEMAND

M5.1 Basic Concept for Water Demand Projection

M5101 Water demand is divided in general three categories: municipal, industrial and irrigation water demand. In the present study, taking into account the objective of study, the water demand is further classified as follows: the municipal water demand is divided into domestic and non-domestic water demand, and the non-domestic water is composed of commercial, medium and small-scale industrial water and water for institutions such as hospital, hotel, school and office. In the present study, the water demand projection will be chiefly made in terms of the municipal water. The irrigation water demand is discussed in Para M5.4 and the water demand for large-scale industries, which have their own well water supplies, is explained in Para M5.5.

M5102 The water demand for municipal purpose is estimated for all cities, towns and villages in the Study Area; the Greater Amman area and the Mujib basin. This estimate is based on a review of the following references related to the water supply and demand in Jordan:

[1] NATIONAL WATER MASTER PLAN OF JORDAN, Vol. I, V, VI and VII, 1977, Natural Resources Authority.

[2] NORTH JORDAN WATER USE STRATEGY, 1978, Vol. 3, Howard Humphreys and Sons.

[3] WATER SUPPLY PROJECT FROM THE RIVER EUPHRATES, Vol. 1, 1983, National Planning Council.

[4] STUDY OF THE PRIMARY AND SECONDARY CONVEYANCE SYSTEMS FOR DOMESTIC WATER SUPPLY IN THE AMMAN, BALQA AND IRBID GOVERNORATES, Vol. 1, 1984, National Planning Council.

[5] WATER SECTOR STUDY, 1984, World Bank.

[6] FEASIBILITY STUDY FOR AMMAN WATER SUPPLY AND SEWERAGE FACILITIES, 1977, VBB.

The most suitable estimate would be obtained from a comparative study among the respective estimates in the above references.

M5103 To estimate the municipal water demand by the target year of 2005, the following factors would be studied: (1) Future population, (2) Per capita water demand for domestic use, (3) Water demand for commercial, industrial and other non-domestic uses, and (4) Water losses in distribution system.

M5.2 Population Projection

M5.2.1 General

M5211 In recent years, a detailed population projection in Jordan was made in the study of National Water Master Plan (NWMP) 1977 [1]. In 1983, National Planning Council (NPC) forecasted the future population by 2005 through the study of " Water Supply Project from the River Euphrates [3]" quoting the result of "Jordan Urban Sector Review, IBRD 1982". World Bank also projected the future population of Jordan by small locality through the Water Sector Study (WSS) 1984 [5]. In addition to the said projections, Ministry of Planning (MOP) at present has figures of population projected based on the results of National Village Survey 1984. The projected population together with the 1985 population estimated by the Department of Statistics (DOS) is summarized as follows:

Population Projections of Jordan

Sources	Census	Projection (10^3 persons)			
	1979	1985	1990	2000	2005
NWMP[1]	-	2,743	-	4,445	-
NPC [3]	2,147,594	-	3,175	-	4,949
WSS[5]	2,147,594	2,674	3,197	4,351	-
MOP	2,168,400	2,671	3,157	-	-
DOS	2,132,997	2,694	-	-	-

M5212 Although there is a little difference among the above population number in the 1979 base year, it will not produce a serious effect on the projection. For example, as seen in the above table, the 1985 population projected by the respective authorities ranges from 2,670 thousand to 2,740 thousand, namely, the difference between the upper and lower is less than 3% of the projected population.

M5213 Taking into consideration such a situation on the population projection, the following conditions are assumed for a convenience of our study:

(1) To apply the final result of the 1979 Census as a population in the base year, and

(2) To apply the population growth rate by locality group classified by the size of population in the 1979 Census.

The final result of the 1979 Population Census by locality group is given in Table A-22, Appendix A, and the growth rate to be applied to population projection is quoted from the result of Water Sector Study (WSS) by World Bank, which is said to be among "the best estimates". The detailed discussion is given in Paragraph 7.2.1 of Appendix A.

M5.2.2 Population growth rate

M5221 Annex M5221 shows an average annual rate of population growth to be applied to the population projection. For example, the growth rate of the whole country is assumed to be 3.7% for the period from 1979 to 1985, 3.6% between 1985 to 1990, and falling to 3.1% thereafter. A fairly high growth rate is applied to the population in cities such as Amman, Zarqa, Irbid and Ruseifa.

M5.2.3 Population projection

M5231 The future population in the Study Area is estimated for each town and village by stage till the year 2005, using the final result of the 1979 Census (Table A-22, Appendix A) and the population growth rate shown in Annex M5221. As a result, the population in the Study Area is estimated to be nearly 1,700 thousand in 1985 and 3,500 thousand in 2005. On the other hand, it is expected that Jordan will have population of about 2,700 thousand in 1985 and 5,000 thousand in 2005. According to this projection, the share of population in the Study Area to the national population will rise from 62% in 1979 to 63% in 1985, and further to 70% in 2005 (see Annex M5231).

M5.3 Municipal Water Demand

M5.3.1 Per capita domestic water demand

M5311 In general, the per capita domestic water demand (PCDWD) has a tendency to increase due to growth in consumers' incomes and improvement of living standards of inhabitants. Taking into account such increase in water demand, the PCDWD was estimated in the respective studies listed in Paragraph M5102. The results are summarized in Table A-39 of Appendix A. An average value is estimated from four figures shown in the table and the result is summarized in Annex M5311.

M5312 Annex 5311 shows that the PCDWD in the Amman city having the highest value is estimated at 95 litre/capita/day (l/c/d) in 1985 and 115 l/c/d in 2005, and for the smallest community group it is estimated at 45 l/c/d in 1985 and 65 l/c/d in 2005. The domestic water demand (except non-domestic water demand and water losses in the distribution system) can be estimated from the PCDWD and population by locality group, and in the Study Area it will amount to about 50 MCM in 1985 and 130 MCM in 2005. The detailed discussion is given in Paragraph 7.3.1 of Appendix A.

M5.3.2 Non-domestic water demand

M5321 The non-domestic water demand (NDWD) was forecasted in four studies ([1], [2], [3] and [4]) (see Table A-41, Appendix A). In these studies, the NDWD was shown in litre/capita/day (l/c/d) and/or in percent/capita/day (p/c/d). In this study, p/c/d is applied to the expression of NDWD as a matter of convenience. Where the percent means a ratio of the non-domestic water demand to the domestic water demand.

M5322 An average value is estimated from these forecasted NDWD, and the result is given in Annex M5322. The result indicates that for example in the Amman city in 2005 the NDWD will be 25% of the domestic water demand, 20% in the Zarqa and Irbid cities, 15% in each city and town with population of 3,000 and more, and 10% in each community with below 3,000 population. The detailed discussion is given in Paragraph 7.3.2 of Appendix A.

M5.3.3 Water losses in distribution systems

M5331 *Water losses in the distribution systems were studied in* [1], [2] and [3] listed in Paragraph M5102, and these studies were based on the Feasibility Study for Amman Water Supply and Sewerage Facilities, 1977, VBB, Fawzi & Associates (VBB Report). The VBB Report had the following conclusion on the lost and unaccounted water in the distribution system based on actual field survey and detailed study in 1975:

Items	Rate (%)
(1) Unknown or illegal connections	0-1
(2) Leakages	12-15
(3) Overflowing at reservoirs	0-1
(4) Overestimated production	5-10
(5) Underregistration in consumer meters	20-30
(6) Unmeasured deliveries outside Amman	0-1
Total	(37-58)

The above table indicates that the total quantity of unaccounted water ranged between 37 and 58% of the produced water in 1975. Such a quantity, for example, would have to be considered as the decrease in income which accrues from the sale of water. Based on the result of study in 1975, the VBB forecasted that the unaccounted quantity would decline from 37% in 1985 to 30% in and after 2000 due to improvement of materials and effort to detect leakage and illegal connections in the water distribution systems. In the present study, this percentage forecasted in the VBB report will be considered as a decrease in benefit which accrues from implementation of the pipeline projects described in Chapters F4 and F5 in Appendix (II).

M5332 Nevertheless there was such a great quantity unaccounted in the water distribution systems, the real losses were little quantity which ranged from 12% to 16% consisting of the leakages (12 to 15%) and the overflowing at reservoirs (0 to 1%). On the other hand, the real water losses estimated in the said references [1], [2] and [3] were 20% on average during the period from 1985 to 2005 as shown in Annex M5332. Where this average percentage indicates a ratio to the sum of domestic and non-domestic water demand, namely, it corresponds to 17% of the total water demand (including the losses). This percentage is close to the real losses indicated in the VBB Report. Besides, according to a result of questionnaire in terms of water losses to 67 cities (25 countries) in the world by the Japan Water Works Association, the rate of water leakage which accounts for the majority of the real water losses was 15% on average of quantity of water produced in 1982. The detailed discussion on water losses is given in Para. 7.3.3 of Appendix A.

M5333 As indicated in previous paragraph, the real loss rate ranges between 12% and 17% of produced water. Taking into account the unfavorable condition of long distance transport from the Mujib basin, the real water losses in the estimated water demand are assumed, in the present study, to be 17% of the total quantity of water to be supplied, or 20% of the sum of domestic and non-domestic water demand. This loss rate will be applied to estimate of the future municipal water demand in the Study Area.

M5.3.4 Per capita municipal water demand

M5341 The water demand per capita for municipal use, consisting of domestic and non-domestic uses and water losses in the distribution systems, is given in Annex M5341. The result indicates that the municipal water demand per capita in the Amman city will be 137 l/c/d in 1985 and 172 l/c/d in 2005, and in the small localities with population less than 3,000 it will be 59 l/c/d in 1985 and 86 l/c/d in 2005.

M5.3.5 Projections of municipal water demand

M5351 Municipal water demand in the future is estimated by town and village in the Study Area, using both estimates of the future population and the municipal water demand per capita. The results are summarized in Annexes M5351-1 and M5351-2. In this case the served ratio is assumed to be 100%. It is expected that the water demand in the Study Area in 1985 amounts to 70 MCM per year, which is composed of 68 MCM per year for the Greater Amman area and 2 MCM per year for the Wadi Mujib basin. In a target year of 2005, the Study Area will demand water of 192 MCM per year for the municipal purposes including 188 MCM per year for the Greater Amman area and 4 MCM per year for the Wadi Mujib basin. The share of municipal water demand in the Study Area to that in the entire country will increase from 71% in 1985 to 75% in 2005.

M5352 According to the statistical data of WAJ in terms of the water supply, in 1985 water of 61.5 MCM was supplied as a municipal water to the Amman and Zarqa Governorates. On the other hand, the water demand for municipal purpose is estimated at 64 MCM in the same year in the said both Governorates as shown in Annex M5351-1, namely, this estimate is close to the said actual supply. it suggests that estimates of water demand in the present study will give the reliable figures relatively.

M5.3.6 Water balance in the Greater Amman area

M5361 Annexes M5351-1 and M5351-2 show that the municipal water demand in the Greater Amman area is estimated at about 68 MCM per annum in 1985. It consists of 64 MCM per annum for Amman Governorate (including Zarqa Governorate under the new administrative units) and 4 MCM per annum for a part of Balqa Governorate.

M5362 On the other hand, the municipal water in Amman and Zarqa Governorates since 1983 has been supplied from four water sources; Amman bore holes, Zarqa bore holes, Azraq well fields and Qastal well fields. These sustained yields are estimated at about 50 MCM per annum in total. (Detailed breakdown is given in Appendix G.)

M5363 In 1985, the water balance in Amman and Zarqa Governorates was apparently a deficit of supply by about 14 MCM per annum. However, actual water supply volume in the same year recorded about 61.5 MCM in total, including the emergency water supply of about 1.5 MCM from the East Ghor Main Canal. It appears that a difference between actual and sustained yields is due to over extraction at the said four sources, and the actual water supply volume (61.5 MCM) which includes the over extraction volume met nearly the estimated water demand as mentioned in Paragraph M5352.

M5364 To relieve such water shortage in the Greater Amman area, the Wala and Mukheiba conveyance projects are at present planned to be completed in 1987 for the former with the water supply volume of 15 MCM per annum, and in 1990 for the latter with 26 MCM per annum. By completing these two projects, an available water for the municipal purpose in the Greater Amman area will amount to more than 90 MCM per annum in 1990, which will meet the municipal water demand of 90 MCM forecasted in the same year.

M5365 Further, to meet the municipal water demand expected in the same area after 1990, the supply from Siwaqa-Qatrana-Sultani and Rumeil well fields will be expected based on a potential studies of ground and surface water in the Mujib basin. The sustained yields in these well fields are estimated at about 23 MCM per annum in total, consisting of 16 MCM from the Siwaqa-Qatrana-Sultani well fields and 7 MCM from the Rumeil well fields.

M5366 Assuming that all of the said projects will be realized, in 1995 the available water to be supplied to the Greater Amman area will reach about 114 MCM per annum which is close to the municipal water demand of about 120 MCM expected in the same year. As a result water supplied from well fields in the Mujib basin to the Greater Amman area will increase from 11 MCM (22% share) in 1985 to 49 MCM (43% share) in 1995, nevertheless the unfavorable balance of water in the Greater Amman area appears to continue still after 1995, so far as the new water sources are not developed. The counterplan should be considered as promptly as possible.

M5.4 Water Demand for Irrigation

M5401 In the Study Area, suitable areas for the agriculture and irrigation development are widely expanded taking into account the soils and land classification. Hence, the subject of the agriculture and irrigation development in the Study Area is to find possibility and availability of irrigation water resources.

As for the two (2) scheme areas screened in this study, the Irrigation Water Demand is estimated as follows.

M5.4.1 Irrigation water requirements

M5411 Irrigation water requirement for proposed scheme areas consists of crop irrigation water requirement and leaching water requirement. Procedures and key factors of calculations are summarized as follows:

(i) $Cu = ETo \times Kc$

(ii) $CI = Cu + LP - Re$

(iii) $NI = CI/(1 - LR)$

(iv) $GI = NI/Ie$

where Cu = Consumptive use of crops
ETo = Potential evapotranspiration
Kc = Crop coefficient

CI = Crop irrigation water requirement
Re = Effective rainfall
LP = Land preparation requirement

NI = Net irrigation water requirement
LR = Leaching requirement

GI = Gross irrigation water requirement
Ie = Irrigation efficiency.

(a) Potential Evapotranspiration (ETo): To estimate potential evapotranspiration in the scheme areas, the modified Penman method authorized by FAO is adopted. The values for plan and design are determined as follows:

(Unit: mm/day)

Scheme Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
(I) Dab'ah-Hammam Scheme Area												
	5.0	4.0	2.0	2.0	2.5	3.5	5.5	7.5	9.0	9.5	9.0	7.5
(II) Qatrana Scheme Area												
	5.0	3.5	2.0	2.0	3.0	4.0	7.0	8.0	8.5	9.5	8.0	7.0

As for the potential evapotranspiration for plastic houses plantation, climatic conditions of each weather station and the Albedo factor of the modified Penman formula are roughly modified and the following design potential evapotranspiration is adopted.

(Unit: mm/day)

Scheme Area	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep
Dab'ah-Hamman	3.5	2.0	1.0	1.0	1.5	2.5	3.5	5.0	6.5	6.5	6.0	5.0

(b) Effective Rainfall (Re): Referring to the estimated effective rainfall of similar irrigation development projects in the semi-arid and arid regions, effective rainfall in the project areas where average annual rainfall is less than 300 mm has been evaluated being the lowest reliability in calculating the irrigation water requirement for crops and has been neglected in the calculation. The both selected scheme areas are located in the arid area and the annual rainfall is about 200 mm in the Dab'ah-Hammam scheme area and about 100 mm in the Qatrana scheme area.

Therefore, effective rainfall for the both scheme areas is not counted in calculation of the irrigation water requirement.

(c) Leaching Water Requirement: As for leaching water requirement for crops, tolerable degree of soil salinity for each crop is assumed to decrease minimum tolerance for crop production with non-yield decrement by land reclamation leaching .

According to the chemical analysis of water quality of the Wadi Qatrana, electrical conductivity of water sample is about 0.6 mmhos/cm. At present, since data on water quality of surface water in the Wadi Qatrana and Hamman are scarce, electrical conductivity of irrigation water which will be taken off the Wadi Qatrana and Hamman is assumed 1.0 mmhos/cm for the plan and design. Leaching requirements for crops in the both scheme areas range from 0.05 to 0.18 in the Dab'ah-Hammam scheme area and from 0.07 to 0.10 in the Qatrana scheme area. Therefore, leaching water requirement for the design of the both scheme areas is assumed at 0.1, considering into the average leaching water requirement for crops.

(d) Irrigation Efficiency (Ie): Conveyance irrigation efficiency for the both schemes is adopted 90% referring to those of pipe line system of similar irrigation development projects in and around the Study Area. Field application efficiency is adopted 85% because proposed crops for the schemes are vegetables and most suitable irrigation method for vegetables in the arid region is drip irrigation method. Therefore, overall irrigation effficiency for the schemes becomes 77%.

(e) The Gross Irrigation Water Requirement (GI) of each scheme area: The Qatrana Scheme area has no conjunctive use area and only winter season irrigation is carried out because of limmited availability and dependability of surface water stored in dam. Therefore, the GI for the Qatrana Scheme area is estimated at 757 mm per year equivalent to 567.8 x 10^3 m^3 per year. Peak water requirement in the area is 0.76 l/sec/ha.

The Dab'ah-Hammam Scheme area is composed of an existing area of 100 ha and proposed new area of 75 ha. The area is irrigated by groundwater. For determination of water amount to be taken from reservoir, the water to be distributed compensates nearly equivalent water amount which is exceeded by the proposed cropping pattern comparing with present annual groundwater use in existing farms. The distribution period of surface water supply is one half of year, from December to May because of the higher dependable storing period of surface water.

Based on these assumptions, seasonal irrigation water use in the conjunctive use area is obtained. The annual surface water amount to be distributed to the area from the dam reservoir is estimated at 236 mm equivalent to 236 x 10^3 m^3, and groundwater use in the future increases about 6 mm per year on the basis of the proposed cropping pattern.

Moreover,as for winter season irrigation for the newly developed area of 75 ha, the GI of 505 mm equivalent to 505.3 x 10^{2}T3^{2}T m^{2}T3^{2}T will be estimated.

Therefore, gross irrigation water requirement for the Dab'ah-Hammam Scheme is 741.3 x 10^3 m^3 per year. Peak water requirement is estimated at 0.36 l/sec/ha.

M5.5 Other Water Demand

M5501 The present chapter describes outline of the large-scale industrial water demand which is excluded from discussion of the municipal water demand for reason that almost all the large-scale industries have their own well water supplies.

M5502 In the Study Area, major industries such as oil refinery, 7-Up Company and cement factory together with military camps are mainly located in the Zarqa-Ruseifa area, except a mining industry, the Abyad Phosphate Mine, where lies southern end of Mujib basin.

M5503 The water demand for large-scale industrial uses was estimated in previous reports [1], [2], [3] and [4] shown in Para M5102, and a result of review of these reports the following matters have been identified:

(1) The quantity of water demand for major industrial uses by the year 2000 was first estimated in reference [1](1977) and after that its result was revised in reference [2](1978).

(2) In reference [3](1983), an estimate of major industrial water demand by the year 2005 was made taking into consideration the results of the above two reports and using the latest information in 1983, and its result was agreed by reference [4](1984). Accordingly, the estimate of water demand for major industrial uses shown in reference [4] is consistent with that in reference [3].

M5504 These results are summarized below:

Estimates of Large-Scale Industrial Water Demand in the Greater Amman Area

Unit:MCM

Reference	1985	1990	1995	2000	2005
[1]&[2]	13.6	17.0	20.5	23.9	27.4/1
[3]&[4]	12.4	16.4	21.0	24.9	27.8
Average	13.0	16.7	20.7	24.4	27.6

/1: estimated in the present study by the extrapolation using data by the year 2000.

M5505 The above table indicates that the water demand for large-scale industrial uses would rise from 13 MCM in 1985 to 27 MCM (twice as much) in 2005. Of these water demand, the large water demand for oil refinery, 7-Up Company, cement factory and military camp uses is estimated at 2.4 MCM, 4.0 MCM, 0.6 MCM and 1.3 MCM in 2005, respectively. On the other hand, the water demand for Abiad phosphate mining operation is estimated at about 3.5 MCM per annum during the period from 1985 to 1992 (closing year) according to information from the Jordan Phosphate Mines Company.

M5506 Besides the said industries, there are some large-scale industries such as phosphate mine and potash and cement factories around the Study Area. In 1985, the water consumption of these industries was about 7 MCM for the Hasa Phosphate Mine which lies outside the Mujib basin boundary at 30 km south of the Abyad Mine, 7 MCM for the potash factory located in the southern part of the Dead Sea coast and 0.6 MCM for the cement factory in the Tafielah Governorate. Among them, water required for potash refinery is expected to rise fairly in the future because the company envisages increasing the production of potash.

M6. WATER USE PLANS

M6.1 Development Strategy

M6101 General: Limited availability of water has at all times been the obstacle for the economic development of the Kingdom. The investment of about one sixth of the national budget for the water resources development. WAJ was established in 1983 mainly for coping with rationalization of water allocation in entire Kingdom.

M6102 Because of the difference of hydrogeological conditions, water resources in the kingdom are not distributed uniformly over the territory, but distributed unevenly in the north-western part. Then, the investments for the water resources development in the past years are also concentrated in the north-western part of the territory. And the development of major water resources in this part is mostly completed. Water resources development in future has to be made in the rest parts of the territory. The Mujib watershed has been highlighted because of the location being adjacent to the north-western part and also to the Greater Ammam area which is the largest consuming area of M&I water.

M6103 It has already been known that the groundwater resources in the Mujib watershed are relatively rich. The groundwater in the watershed has already been used to a considerable extent for irrigated agriculture and for water supply to Amman, Karak and almost all the villages spread over the basin. However, the potential of water resources including the surface water has not been assessed yet. In this context it became necessary to clarify the potential and distribution of the water resources so as to make systematic and optimum use of the water resources. The objective of the present study is to fulfill this basic need.

M6104 Present states of the water use of the Mujib watershed are that the water use has been already made partially and that there is no preceeding study on the overall potential and distribution of the potential. Under these states, the strategy of the water use is formed as follows; namely,

- Firstly, potential and distribution of the groundwater and the surface water are to be estimated,
- Necessary means to put use of potential water source are to be elaborated,
- While, posible future demand for water is to be estimated,
- Then, schemes are to be formulated combining the demand and available water source,
- Finally, the most promising schemes are to be studied further.

M6.2 Groundwater Use Plan

M6.2.1 Strategy

M6211 Groundwater sources close to population centers in Jordan have been extensively exploited for the purpose of M & I and irrigation. The groundwater is conceived to be the most important water source for drinking purpose. Most of these sources are currently being extracted to or beyond the capacity of the reliable aquifer yield. This hydrogeological study estimates unexploited sustained yields which exist in the area within a distance between 30 and 100 km southwards from the Amman. In view of transporting water up to 100 km, these sources are more economic to develop than alternative surface water sources which are located at much lower altitudes and require impounding, pumping and treatment to ensure reliability and quality for use.

M6212 Because of limitations in water resources in the country and given water allocation policy adopted by the Government which assigns priority for M & I uses, further groundwater development for the the purpose of agriculture in the Study Area would be regulated by the Government taking account of the possible surface water development.

M6213 Although the vast groundwater storage in the fossiliferous deep aquifers exist in the Study Area, groundwater in the B2/A7 aquifer which is recharged by precipitation could be fully developed before starting to mine the fossil groundwater. To enhance the scarce groundwater resources in the B2/A7 aquifer, artificial recharge by injecting flood water will play an important role in the future.

M6.2.2 Shallow groundwater

M6221 Shallow groundwater exists in the B2/A7 Formation which extends throughout the entire Study Area and forms the top layer of the desert highlands or plateau underlying a thin soil mantle in most places. Good groundwater recharge occurs from the relatively abundant rainfall through the outcrops of B2/A7 Formation. The B2/A7 aquifer is the most important aquifer system in the Study Area, taking account of the water economy, reliability and sustained yield estimated by the model simulation.

M6222 Groundwater of the proposed well fields of Siwaqa-Qatrana and Sultani, which has a sustained yield of 15.9 MCM/y, will be coordinated with WAJ's main water pipeline system along the Desert Highway. The proposed Rumeil well field, which has a sustained yield of 7 MCM/y will also be coordinated to the Madaba-Yaduda water pipeline system for the water supply to Amman. The groundwater in the proposed Lajjun well field with potential yield of 5 MCM per annum will be preserved for the purpose of future oil shale mining or local water supply in Karak region.

M6.2.3 Deep groundwater

M6231 Deep groundwater exists in the confined aquifers in the A4 and A2, which extend throughout the entire Study Area. Because its potential is not known yet, the groundwater in these deep aquifers would be preserved, until the details of the hydrogeology of the deep aquifers and the economic liability are known.

M6.2.4 Fossil groundwater

M6241 Fossil groundwater exists in the confined aquifers in sandstone formations both in the Kurnub and in Disi Groups, which extend throughout the entire Study Area with variable high salinity. These deepest aquifers may have a vast groundwater storage, however, taking account of the sense of mining groundwater resources and its water economy to pump up more than 700 m, this fossil water would be preserved until the above two shallow and deep aquifers are fully developed.

M6.3 Surface Water Use Plan

M.6.3.1 Strategy

M6311 General: The surface water in the Mujib watershed consists of the base flow and the flood flow. The base flow is perennial and almost constant, but available only on the extreme lower reaches downstream from the King's highway bridges. Though flood flow is available all over the watershed, it occurs occasionally only after the rainfall in the rainy season and also the timing of occurrence and outflow quantity vary very much from year to year. To use such flood flow, dam with suitable size of pocket is indispensably needed. After selecting planned damsites from the topographic point of view (1st screening), the most frequent flood, or 2- year flood is considered as an approximate potential of flood at each planned damsites.

M6312 As the first screening process of selecting out the promising damsites, the map study and map location works are made for all the Study Area on the general topographic map (1/50,000 scale with 25 m contour intevals) to find out the sites suited for the dam and reservoir. As a result, twenty sites are selected. Of them, 15 sites are those newly found, three are those once indicated by Jordanian side and two falls on the existing dam site. The location of the above dam sites are shown in Annex M6312.

M6313 Air-photo mapping with 1/7,500 or 1/15,000 scale is made for each selected damsite, according to the scale of available air-photos. Contour interval is 5 m for both scales. Works are undertaken by The National Geographic Centre of Jordan (JNGC) through WAJ. After preparing elevation - water surface area curves and the elevation - gross storage curves on each site, dam reservoir operation work is made by simulated runoff data on each site considering percolation loss and seasonal fluctuation of water requirement and evaporation. Finally, available discharge after the regulation by the reservoir is estimated on each site.

M6314 Engineering boring and test pitting are made on five selected sites. These sites are considerd to represent the geological feature and reservoir area as well as the property and availability of construction materials for other dams. Boring works are undertaken by WAJ. Additionally, the geological reconnaissance on every site is carried out and its result is summarized as the geological profiles .

M6315 Then, screening of the proposed dam sites is made in consideration of such conditions as;

- Hydrologic condition
- Geological condition
- Socio-economic problems, etc.

M6316 As for the screening process in view of the hydrology, the governing factor is the amount of inflow which is the most frequent value of annual flood flow. At this stage, dam sites to which inflow is very poor (less than 1.5 MCM/y or in other words, of which available regulated flow is very small) are put aside. By this screening, six sites (Sadir, Shabik, Siwaqa N, Siwaqa S, Sueida 2, and Sueida 1) are put aside and 14 sites remain.

M6317 As for the screening process in view of geology, followings are considered. First point is the leakage (percolation) of water through dam foundation and reservoir rim. Second point is the possibility of land slide on and near the dam site. Third point is the influence of the possible seepage water to the groundwater flow or base flow. The conceivable twenty dam sites in the Study Area are located in the limestone terrain where the representative geological units are B2, B1 and A3 Formations. Among them, large Lugeon values, 40 to 100 or more of the B2a Formation (silicified limestone) are due to rich and irregular distribution of joints and karstifications in the limestone. These hydrogeological features are common in the Study Area, and are not favourable conditions for the year-round storage by the conventional treatment of dam foundation and reservoir. As a result of screening, seven sites (Zeinab, Halq, Shabik, Sueida 1, Qatrana, Dabb'a and Mujib) out of 20 sites are put aside and 13 sites are remained.

M6318 As for screening process in view of the socio-economic problems, such problems as the inundation of farms and wells, highway, bridge, railway, factory and houses are considered duly. As the results, the following problems are found out.

Rumeil reservoir:	Private farm land (1.7km^2) and private wells (3 Nos.)
Halq reservoir:	Desert Highway and bridge (retention level: El. 670.5m)
Siwaqa C reservoir:	Wells of WAJ (2 Nos.)
Dabb'a reservoir:	Highway (Qatrana-Karak) and bridge (retention level: El. 657.1m)
Sueida 1 reservoir:	Wells of WAJ (2 Nos.)
Siwaqa S reservoir:	Railway (retention level: El. 761.5m)
Qatrana reservoir:	Desert Highway and bridge (retention level: El. 768.6m)
Sultani reservoir:	Factory and houses

M6319 By the above mentioned screenings seven dam sitesare remained. They are Wala, Hammam, Siwaqa C, Khabra, Nukheila, Qatrana (existing) and Sultani (existing) sites. Principal features of these dams are listed in Annex M6319.

M7. OUTLINE OF DEVELOPMENT PLAN

M7.1 Principle

M7101 Based upon the results of the studies on different categories, the development schemes are formulated. Strategy is that the groundwater potential (sustained yield to be added on top of existing extraction) is to be developed fully in as near future as possible, and that the promissing schemes to use the surface flow are identified for further study when such schemes are needed.

M7.2 Groundwater Development

M7201 Water supply to the Greter Amman area: In 1985, the supply of water to the Greater Amman area and the Mujib watershed was 61.5 MCM against the demand of 70 MCM. In the target year 2005, this demand will grow to 198 MCM with average annual growth rate of about 5.2%. (Note: this demand is a sum of those for the Greater Amman area, Mujib basin and the Karak Governorate which are connected by existing pipe network.) WAJ is undertaking many projects to increase the supply capacity. However, with all of the capacities of such projects added, the total capacity wil become 114 MCM leaving a deficiency of 84 MCM. Thus, further reinforcement of supply capacity is definitely needed.

M7202 Advantage of the Mujib groundwater: The groundwater potential clarified under the present study, about 23 MCM, is the only water source of which quantitative character is known at present. Mujib groundwater is located nearest to the Greater Amman area among all the conceivable water sources. And, the entire Mujib watershed is located in the Kingdom. These conditions indicate that the Mujib groundwater is higly suitable for the source of water supply of the Greater Amman area.

M7203 Allocation of groundwater: Under the Study, it is clarified Cthat the sustained yields of the well fields are 6.3 MCM/y of Sultani, 9.6 MCM/y of Siwaqa-Qatrana, 7.0 MCM/y of Rumeil and 5.0 MCM/y of Lajjun. Of them, the Lajjun well field is to be preserved for the future development of the oil shale by the Government policy. Total of the remainder makes some 23 MCM/y. This amount corresponds to about 27% of the aforementioned deficiency of 84 MCM/y and to reduce the deficiency down to 61 MCM/y. Moreover the extraction of the full amount does not give essential influence on the amount of the base flow on the lower reaches. Hence, it is planned to take this amount for the water supply of the Greater Amman area.

M7204 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 are to formulate a P/L project referred tentatively to as the Sultani-Siwaqa P/L Project. 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 and the Rumeil well field are to formulate a P/L project referred tentatively to as the Rumeil-Madaba P/L Project.

M7205 Sultani-Siwaqa Pipeline Project: To develop the sustained yield of the Sultani well field and the Siwaqa-Qatrana well field for the water supply of the Greater Amman area, the project consists of the following components; namely,

- 18 productin wells on the Sultani well field,
- 21 productin wells on the Siwaqa-Qatrana well field,
- 2 reservoirs at Sultani and Qatrana,
- 1 line of pipeline, 500-800 mm in diameter, 40.7 km long from Sultani to Siwaqa.

The sustained yield is 6.3 MCM/y of the Sultani well field and 9.6 MCM/y of Siwaqa-Qatrana well field, totalling 15.9 MCM/y.

M7206 Rumeil-Madaba Pipeline Project: To develop the sustained yield of the Rumeil well field for the water supply to the Greater Amman area, the project consists of the following components; namely,

- 20 production wells,
- 2 reservoirs,
- 1 booster pump station, 160 m in head and 1.04 m^3/s in maximum discharge,
- 1 line of branch pipeline, 300-500 mm in diameter , 13.9 km long,
- 1 line of main pipeline for 9 wells 300-700 mm in diameter, 27.4 km long.

The sustained yield is 7.0 MCM/y.

M7207 Further study on two P/L projects: In view of urgent necessity for implementing these two P/L projects, further study on a feasibility study level is made under the present study. Details of such study is set forth in Appendix II .

M7.3 Surface Water Development

M7301 General: Main area of groundwater production in the Mujib watershed is a belt-like zone along the Desert highway from Qastal to the south onward. There are tributaries in this area which cross this belt. Flood flow of these tributaries is to be used for recharging, mainly the existing well fields and partly the proposed well fields.

M7302 Group of dams in southern part: These dams in the southern part such as Qartana (existing), Sultani (existing) and Siwaqa C (proposed) have common purposes to recharge the existing well field. These dams are located along the Desert highway. Rivers on which these dams are located drain the desert area where the precipitation is scarce being 100 mm a year or less, and the outflow is not rich as compared with the size of catchment areas. However, these sites are located close to the existing well fields which are supplying water for Amman and Karak and extractions of water are made sometimes over the sustained yield. Hence, these dams are proposed to recharge the existing well fields and part of the proposed well fields.

M7303 Qatrana existing dam is located on the Wadi Hafira near the Desert highway draining 1,490 km^2 of catchment area where the precipitation is less than 100 mm a year. The dam is located closely to the existing Qatrana well field from which 3.5 MCM/y are extracted for the water supply of Amman. The gross capacity of the existing reservoir is 4.2 MCM and current silting is not very notable. Average inflow is 2.3 MCM/y and the most frequent flood inflow is 1.8 MCM/y.

M7304 It is proposed to use this existing dam positively for recharging the existing Qatrana well field. Stored water is taken through existing outlet to three proposed wells. When the most frequent flood runoff of 1.8 MCM/y will be injected through these wells in the rainy season, 1.4 MCM/y can be pumped again in the dry season. Such injection is also good for curing the existing wells from which over extraction is sometimes made.

M7305 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 dam, more evaporation loss and more seepage which join the groundwater flow towards Azraq. It is possible to improve this phenomenon by means of the drainage improvement works by digging drainage channels which can be carried out as dry works in the dry season as seen in Annex M7305. It is estimated that the outflow of the Wadi (or the inflow to the reservoir) will increase by 2.2 MCM/y by the full drainage improvement.(See Appendix (I)-F) By adding four wells, 1.8 MCM/y will be pumped up again in the dry season.

M7306 By combining the natural inflow and the increased outflow by the drainage improvement, 3.2 MCM/y by seven additional wells will become available in the dry season. The reservoir capacity of the existing dam is to be increased by means of heightening the crest and widening of the spillway.

M7307 Sultani existing dam: 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 counter measures to prevent the residue to flow into the upstream part of the Wadi. After the original reservoir capacity is restored, it is estimated that 0.6 MCM/y by two additional wells will become available in the dry season. This scheme as whole will be rather costly due to the restoration works by excavation.

M7308 Siwaqa C dam: Near the existing Siwaqa well field, the Wadi Siwaqa flows. By constructing a dam on the Siwaqa C site, 0.6 MCM/y 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, require 28,000 m^3 of fill volume and bring about 1.1 MCM of effective capacity. This scheme will be rather costly. As an alternative, a concrete gravity dam will be considered from view of geological and hydrological conditions.

M7309 Wala dam: 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. Whilst, WAJ has a plan (Wala P/L project) to take 15 MCM/y 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/y is needed.

M7310 For the compensation purpose, the Wala dam scheme is proposed. 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 through B2a layer by 17 MCM but flow on impervious B1 layer, and reappear on the riverbed around the bridge of King's Highway. Amount of the reapearing water on the river bed is provisionally estimated at some 6 MCM/y, which value is good for irrigating 600 ha. As many small pumps and pipes are already installed for the existing farms, no additional irrigation facilities are needed.

M7311 Further, artificial recharge of 5 MCM/y by using injection wells into the lower A7 Formation, will reinforce the groundwater potential of the Heidan well field in the lower reaches and the Rumeil well field in the upper reaches. The Wala dam scheme should be deemed as an integral part of the Wala P/L project.

M7312 Developement of irrigated agriculture :

(A) The Dab'ah-Hammam scheme alias Hammam scheme: The Dab'ah-Hammam area has somewhat much rainfall in winter season comparing with that of the Qatrana area and average annual rainfall ranges from 150 mm to 250 mm. The scheme area is located in shallow and wide valleys with somewhat gentle undulations. Salinity of soils is low to moderate and the electrical conductivity of soils ranges from 0.3 mmhos/cm to 4.3 mmhos/cm. The scheme area has a little agricultural background. Three (3) existing production tubewells for agriculture have been developed in the scheme area, and vegetable plantations such as cucumber, tomato and eggplants are managed in plastic houses and open fiels by using groundwater. The Dab'ah-Hammam Scheme area is delineated 175 ha as net irrigation area consisting of existing groundwater irrigation farms of 100 ha and newly development areas of 75 ha. Total net benefit of the scheme is assumed to be 405,000 JD (2,316 JD/ha).

(b) <u>The Qatrana Scheme:</u> The Qatrana area is located in downstream from existing Qatrana dam and the area extends in gentle side slopes of the Wadi. Average annual rainfall ranges from 50 mm to 100 mm. On the upper part of the existing dam, two pilot farms of about 160 ha have been developed. Main aims of the two existing pilot projects are make a settlement of Bedouin people and at present, plantation of vegetables and fodder crops and livestock production are carried out by using groundwater. In the scheme area, natural range development for livestocks is only carried out by using the rain water. Salinity of soils in the scheme area is low and its electrical conductivity ranges from 0.5 mmhos/cm to 7.5 mmhos/cm. The proposed Qatrana Scheme area is delineated 75 ha as net irrigation area. Total net benefit of the scheme is assumed to be 142,000 JD (1890 JD/ha).

(c) Construction costs for these schemes are estimated at JD9,002 x 10^3 for the Dab'ah-Hammam scheme and at JD527.5 x 10^3 for the Qatrana scheme as shown below. Total construction costs are composed of direct construction costs, physical and price contingencies, administration cost and engineering service cost. Direct construction costs for the both schemes are JD6,385 x 10^3 for the Dab'ah-Hammam scheme and JD389.2 x 10^3 for the Qatrana scheme. Physical contingency, administration cost and engineering service cost are assumed 10%, 5% and 10% of direct construction cost respectively. Price contingencies for local currency portion and for foreign currency portion are estimated by using overall wholesale price index for Amman from 1981 to 1985 and forecast of world manufacturing unit value index, IBRD, 1983.

Construction Cost

(Unit : 10^3 JD)

Items	Dab'ah-Hammam Scheme F.C	JD.C	Total	Qatrana Scheme F.C	JD.C	Total
1. Direct Construction Cost	3,740	2,645	6,385	304	85.2	389.2
2. Physical Contingency	374	264.5	638.5	30.4	8.52	38.92
3. ES/ and Administration Cost	638.5	319.25	957.75	38.92	19.46	58.38
Subtotal	4,752.5	3228.75	7981.25	373.32	113.18	486.5
4. Price Contingency	508.5	512.25	1020.75	26.9	14.1	41.0
Total	5,261	3741	9002	400.22	127.28	527.5

(d) Operation and maintenance cost for the both schemes are assumed to be composed of running costs for the scheme office, electric cost of pumps, maintenance costs of pump stations, dams and irrigation facilities. Running cost for the scheme office is mainly composed of labour costs for office workers and field staff, consummable and expenditure costs of office and vehicles, and maintenance cost for building. O & M costs for the both schemes are estimated at about JD229,000/year for the Dab'ah-Hammam scheme and at about JD6,500/year for the Qatrana scheme.

M7313 Nukheila dam plan: There is a possibility of flood flow storage on the Nukheila site. This site is located on the A3 formation which is fairly impervious. For the geological reason such as faults and accumulation of loose debris on the upper part of the left bank, the dam height may have a limit. If those uncertain geological limitations are ignored, the capacity of the reservoir will be 20.8 MCM. From this reservoir, a stored water of 8.8 MCM/y becomes available, directly from the reservoir as 80 % dependability , and 4.4 MCM/y will be added through aquifer to the base flow of lower reaches.

M7314 The dam is of zoned rockfill type, 61 m high, 350 m long, and 0.94 MCM of total fill volume. As an alternative a concrete gravity type is also possible. Use of the available water can not be defined at the present stage, but the following uses are conceivable;

- Use for M&I water supply on the highlands,
- Use on the highlands including the Karak area for any purpose if about 700 m of pump up is made (the damsite is about at El. 180 m),
- Uses on the further lowlands for any purpose.

M7315 Khabra dam plan: There is also a possibility of flood flow on the Khabra site. This site does not have large catchment area (being 290 km^2), but the catchment area receives relatively rich precipitation (being more than 200 mm). There is no limit in the dam height from the topographic point of view, and the foundation and reservior is relatively impervious. Effective capacity of 6.1 MCM is obtained by the dam. Then, amount of 2.7 MCM/y as a most frequent value becomes available from the reservoir.

M7316 The dam is of zoned rockfill type, 29.5 m high, 455 m long and 0.29 MCM of fill volume. Use of stored water can not be defined at the present stage, but the following uses are conceivable.

- Uses for any purpose on the highlands especially in the Karak area if more than 200 m of pumping is made (the dam site is at about El. 690 m),
- Partial substitution of groundwater for the development of the oil shale in the Lajjun area so that the equivalent amount of groundwaterwater could be used for the city water supply,
- Uses on the further lowlands for any purpose.

M7317 Sediment problems: All of the aforementioned dam plans are planned for the flood flow which carries considerable quantity of sediment load because of the hydrologic condition and states of the ground surface. Volume of the sediment will reach 1.0% of the trapped water. Hence the dead capacity becomes nearly one half of the total capacity. This problem decreases the storage efficiency of each dam. In future, it will become necessary to examin the design of sand-flash facilities and spillways.

M7318 *Combination of dam schemes:* It is possible that the dam plans are implemented in series on one system of river. Conceivable cases are the combination of Hamman and Wala schemes, and of the Khabra and Nukheila schemes. In the former case, the Hamman scheme will not affect very much to the downstream Wala scheme because the catchment area and the flood flow of the Hamman plan are very small. Whilst in the latter case, the available flow when the both schemes are implemented will differ from the simple sum of the available flows of each plan. Namely, the available flow of the independent cases of Khabra and Nukheila are 2.7 and 8.8 MCM/y respectively, whereas the available flow will become 10.0 MCM/y when both schemes are implemented.

M7.4 Green Belt

M7401 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/y. Irrigation can be made with tank lorry, and water can be taken from the nearest reservoirs or wells.

M8. OUTLINE OF ECONOMIC EFFECTS ON MAJOR DEVELOPMENT PLANS

M8.1 General

M8101 Of the afore-mentioned projects and schemes, the implementation of the groundwater development projects such as;

- Sultani-Siwaqa Pipeline Project to transmit water from the Sultani well field, and the Qatrana-Siwaqa well field, and
- Rumeil-Madaba Pipeline Project to transmit water from the Rumeil well field,

will bring about fair economic effects to the Greater Ammam area through the reinforcement of water supply. On the other hand, the irrigation schemes formulated under the present study, such as the Hammam and Qatrana schemes, will show the instances of the agricultural development on the highlands.

M8102 Implementation of these plans and schemes would required an amount of about JD 43 million which consists of JD 34 million for the construction of pipelines and JD 9 million for the investment to irrigation facilities. The investment would produce the economic effect so that the Economic Internal Rate of Return (EIRR) is estimated at 10% and 3%, respectively.

M8.2 Sultani-Siwaqa and Rumeil-Madaba Pipeline Projects

M8201 According to the feasibility level study for the pipeline projects which is discussed in depth in Appendix II, the Sultani-Siwaqa and the Rumeil-Madaba pipeline projects are assumed to be completed in 1992 after the construction period of four years. The construction cost to be disbursed during the said period is estimated at about JD 19 million and JD 15 million respectively, and water of 16 MCM and 7 MCM per annum in and after 1993 will be supplied through these pipes from well fields in the Sultani and Rumeil areas to the Greater Amman area mainly for the municipal purpose. The economic annual value of water conveyed through the said pipelines is estimated at JD three million or more and JD one million or more, respectively. Regarding the economic evaluation for the pipeline projects, the details are given in the paragraphs in F3 and F4 of Appendix II.

M8.3 <u>Hammam and Qatrana Irrigation Schemes</u>

M8301 Two irrigation schemes are formulated in two areas; the Hammam area with 175 ha and the Qatrana area with 75 ha (see M7312). An incremental benefit which accrues from the implementation of these schemes would be given as a difference between both net incomes with and without their scheme conditions, and the results are estimated at JD 405 x 10^3 per annum for the Hammam scheme and JD 142 x 10^3 per annum for the Qatrana scheme at the 1986 price level. These benefits are estimated using the farmgate prices of crops which are given from the border prices of them. They would therefore be regarded as economic benefits.

M8302 The construction cost for both schemes totals up to JD 8,468 x 10^3 at the 1986 price level of which consists of JD 7,981 x 10^3 for the Hammam scheme and JD 487 x 10^3 for the Qatrana scheme. The total cost includes the foreign currency portion of JD 5,126 x 10^3 (60% share) consisting of JD 4,753 x 10^3 for the Hammam scheme and JD 373 x 10^3 for the Qatrana scheme. The construction period is designed to be three years for the Hammam scheme and one year for the Qatrana scheme, after engineering services and contract procedure for three years. (The detailed breakdown on the investment is given in Tables G-5.6, G-5.7 and G-5.8, Appendix-(I) G. In addition to the above cost, the cost of operation and maintenance (OM-cost) of JD 225,000 per annum and JD 6,500 per annum is earmarked for the Hammam scheme and for the Qatrana scheme, respectively.

M8303 An economic analysis for these schemes is made approximately under the assumptions in terms of transfer payment and opportunity costs of wage and goods shown in Annex F4201 of Appendix II. As a result, the economic construction cost for both schemes is estimated at JD 7,915 x

10^3 comprising JD 7,447 x 10^3 for the Hammam scheme and JD 468 x 10^3 for the Qatrana scheme. The annual disbursements are summarized as follows:

ECONOMIC CONSTRUCTION COST FOR IRRIGATION SCHEME

Unit : JD 1,000

Scheme	Total	Year in Order					
		1	2	3	4	5	6
I. Hammam	7,447	220	29	185	2,240	3,182	1,591
II. Qatrana	468	13	2	11	425	11	6
III. Combined Scheme	7,915	233	31	196	2,665	3,193	1,597

The economic annual OM-cost is estimated at JD 186 x 10^3 for the Hammam scheme, JD 5 x 10^3 for the Qatrana scheme and JD 191 x 10^3 in total.

M8304 The economic life of irrigation facilities is taken as 50 years from the beginning of feasibility study stage, and the economic cost flow together with the economic benefit flow are given in Annex M8304. Where the benefit is assumed to accrue through some leaching period of reclamation after the completion of irrigation facilities. The leaching period is regarded as three years for the Hammam area and one year for the Qatrana area. The irrigation benefit is expected to increase year by year and to reach at the full benefit through three years after the leaching stage either of both schemes.

M8305 As a result of economic analysis, the Economic Internal Rate of Return (EIRR) is estimated at 0.9% for the Hammam scheme, 21% for the Qatrana scheme, and 3% for the combined schemes in two areas. Although EIRR for the Qatrana scheme is fairly high, it would be due mainly to the relative low cost which includes only the construction and OM-costs for irrigation facilities, excluding the costs of some facilities at the source of water supply. In the present study, such costs at the water source of the Qatrana irrigation area are designed to be included in the cost of water supply for municipal purpose. On the other hand, EIRR for the Hammam scheme is considerabley low. Nevertheless, implementation of this scheme as well as the Qatrana scheme seems to give a social and economic impacts to the region and encourage the development of highland agriculture as a pioneer scheme.

M9. CONCLUSION AND RECOMMENDATION

M9.1 Conclusion

M9101 As the results of the Master plan level study, the distribution, location and potential of the water resources which consist of the groundwater and surface water in the Mujib watershed have been clarified. (refer to the figure on the fly-leaf)

M9102 Of the potential clarified, the sustained yield of the groundwater is worthy of urgent development. In this context, two pipeline projects, the Sultani-Siwaqa Pipeline Project and the Rumeil-Madaba Pipeline Project are formulated and further studies on the feasibility study level have been carried out.

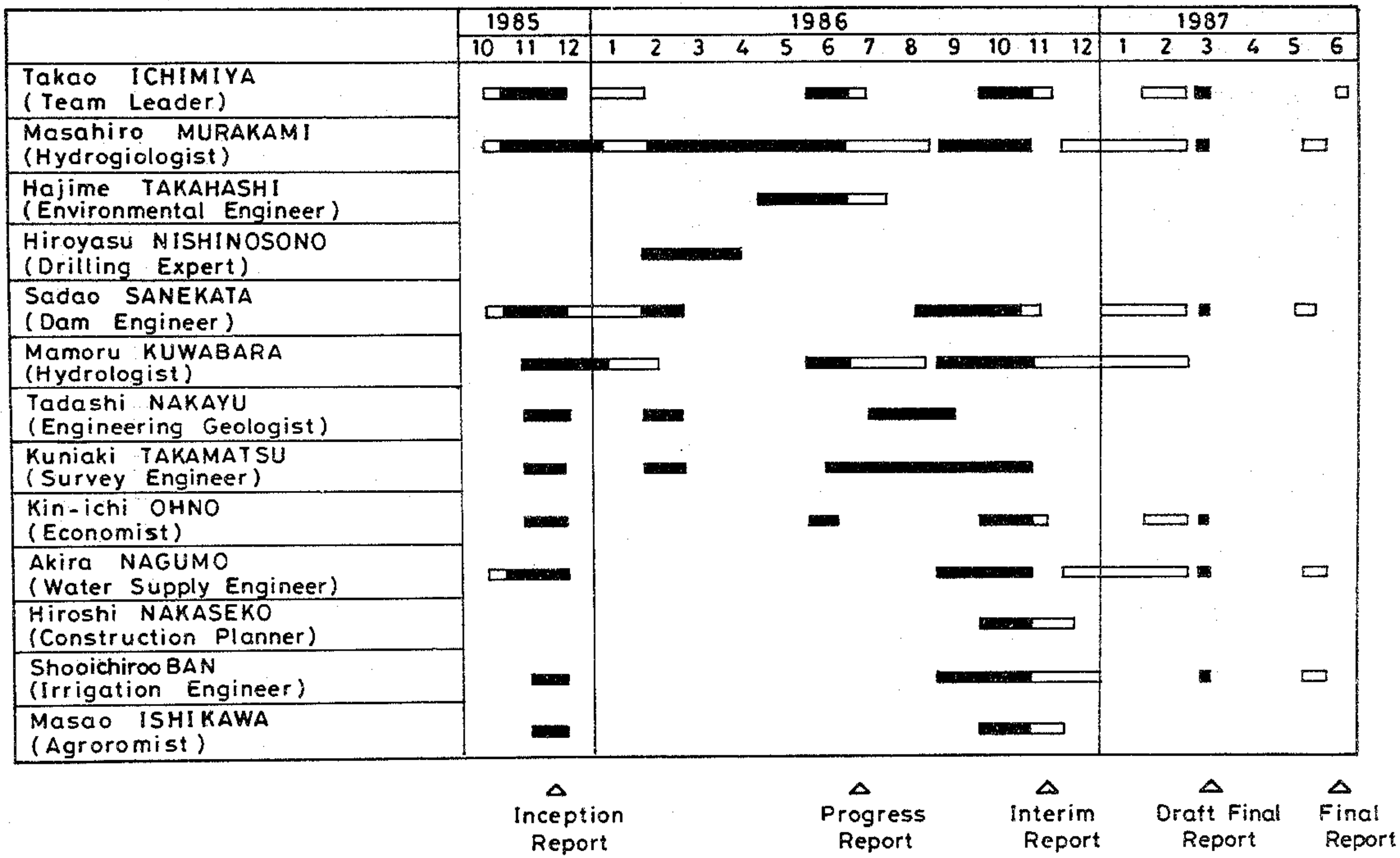
M9103 Of the potential clarified, availability of the surface water is studied, and possible schemes have been formulated.

M9.2 Recommendation

M9201 As the formulated two pipeline projects are technically feasible and economically viable, it is recommended to commence to take necessary steps for the early implementations of these two projects.

M9202 The schemes formulated under the present study are those promissing for the development of surface water for different uses. It is recommended to make further studies on particular schemes whenever such schemes become needed.

M9203 Of the schemes formulated for surface water development, two schemes are deemed to have the top priority. It is, therefore, recommended to make feasibility studies of these two schemes preferably soonest. One is the Wala scheme for the reason that this scheme is considered to form an integral part of the project undertaken by WAJ as well as to support the Rumeil-Madaba Pipeline Project proposed. The other is the Qatrana (existing) dam scheme including the drainage improvement on the upper river channel for the reason that the cost will be reasonable and the effects will appear quickly.



Annex M1401 Assignment Schedule

Annex M1402 LIST OF COUNTERPARTS PERSONNEL (1/2)

Department of Study, Water Research and Dams - WAJ

Dr. Omar M. Joudeh
Eng. Mahir Iskandar
Eng. Fayez Arikat
Eng. Abdel Rehman M. Hemud
Eng. Fayyad Y. Barakat
Eng. Ismail Hashem
Eng. Ibrahim Farah
Hydro. Deoud Hijazi
Geo. Adnan Al-Masri
Eng. Emad M. Araim
Geo. Mohammed Abu Maizer
Eng. Najib Ayub
Eng. Yousef Atiyeh
Geo. Walid Hussein

Department of Water Resources Development & Service - WAJ

Eng. Bader Hirzallah
Dr. Jamil Rashdan
Eng. Amin J. Wardem
Dr. Dosef Saman
Dr. Samir Hijazine
Geo. Eng. Mohammed Saud

Department of Irrigation Development - WAJ

Eng. Musa Nasir

Department WAJ

Eng. Nawaf Dawood
Department of Study & Planning, WAJ
Department of Irrigatioin, WAJ
Ministry of Energy
Ministry of Planning
Ministry of Public Works

Annex M1402 LIST OF COUNTERPARTS PERSONNEL (2/2)

Ministry of Transport

Department of Statistics

Department of Customs, Ministry of Finance

Central Bank of Jordan

Jordan Electric Authority (JEA)

Jordan Valley Authority (JVA)

Jordan Electric Power Company (JEPCO)

Annex M2107 Major Economic Indicators*

Unit: Million JD

Item	1980	1981	1982	1983	1984	1985	Average Growth Rate 1980–1985
1. Income from productive sectors (at factor cost)	346.3	416.5	461.3	464.2	478.4	494.5	7.4
2. Income from service sectors (at factor cost)	542.1	626.1	710.3	761.0	805.3	864.1	9.8
3. GDP (at market prices)	979.5	1,165.7	1,323.2	1,422.7	1,490.0	1,581.0	10.0
4. GNP (at market prices)	1,185.3	1,484.2	1,675.5	1,769.4	1,844.2	1,856.0	9.4
5. Consumer price index (1980=100)	100.0	107.7	115.7	121.5	126.2	130.0	5.4
6. Real growth rate of GNP (1980=100)	–	16.3	5.1	0.6	0.3	-2.3	4.0
7. Per capita GNP (JD)	534.3	643.4	698.3	709.1	710.6	689.0	5.2
8. Average JD exchange rate against US$	3.36	3.03	2.84	2.75	2.60	2.53	–
9. Public revenues	507.0	598.5	627.2	676.7	666.8	842.5	10.7
10. Public expenditures	563.1	647.1	693.5	705.3	729.4	818.8	7.8
11. Commodity exports	120.1	169.0	185.6	160.1	261.1	255.3	16.3
12. Commodity imports	716.0	1,047.5	1,142.5	1,103.3	1,071.3	1,074.4	8.5
13. Remittances from Jordanians working abroad	236.7	340.9	381.9	402.9	475.0	402.9	11.2
14. Foreign aid receipts	401.0	432.5	375.4	296.8	282.6	317.5	4.6
15. External loan repayments	145.0	213.6	187.3	126.2	239.0	193.6	6.0
16. Balance of payments (monetary sector)	-110.1	-15.3	62.4	-50.3	69.3	-18.5	–
17. The Kingdom foreign reserves	622.6	666.9	628.3	712.9	718.0	763.9	4.2

* The detailed breakdown is given in Paragraph 1.1.2, Appendix A.
Source : Annual Report 1984, 1985, Central Bank of Jordan.

Annex M3121 POPULATION AND AVERAGE ANNUAL RATE OF POPULATION GROWTH BY GOVERNORATE IN JORDAN

Governorate	Population		Average Annual Rate of Population Growth
	1961*	1979**	1961-1979 (%)
Amman	433,618	1,173,170	5.69
Irbid	273,976	611,280	4.56
Balqa	79,057	147,827	3.54
Karak	67,211	125,959	3.55
Ma'an	46,914	74,761	2.62
Total in Jordan (East Bank)	900,776	2,132,997	4.91

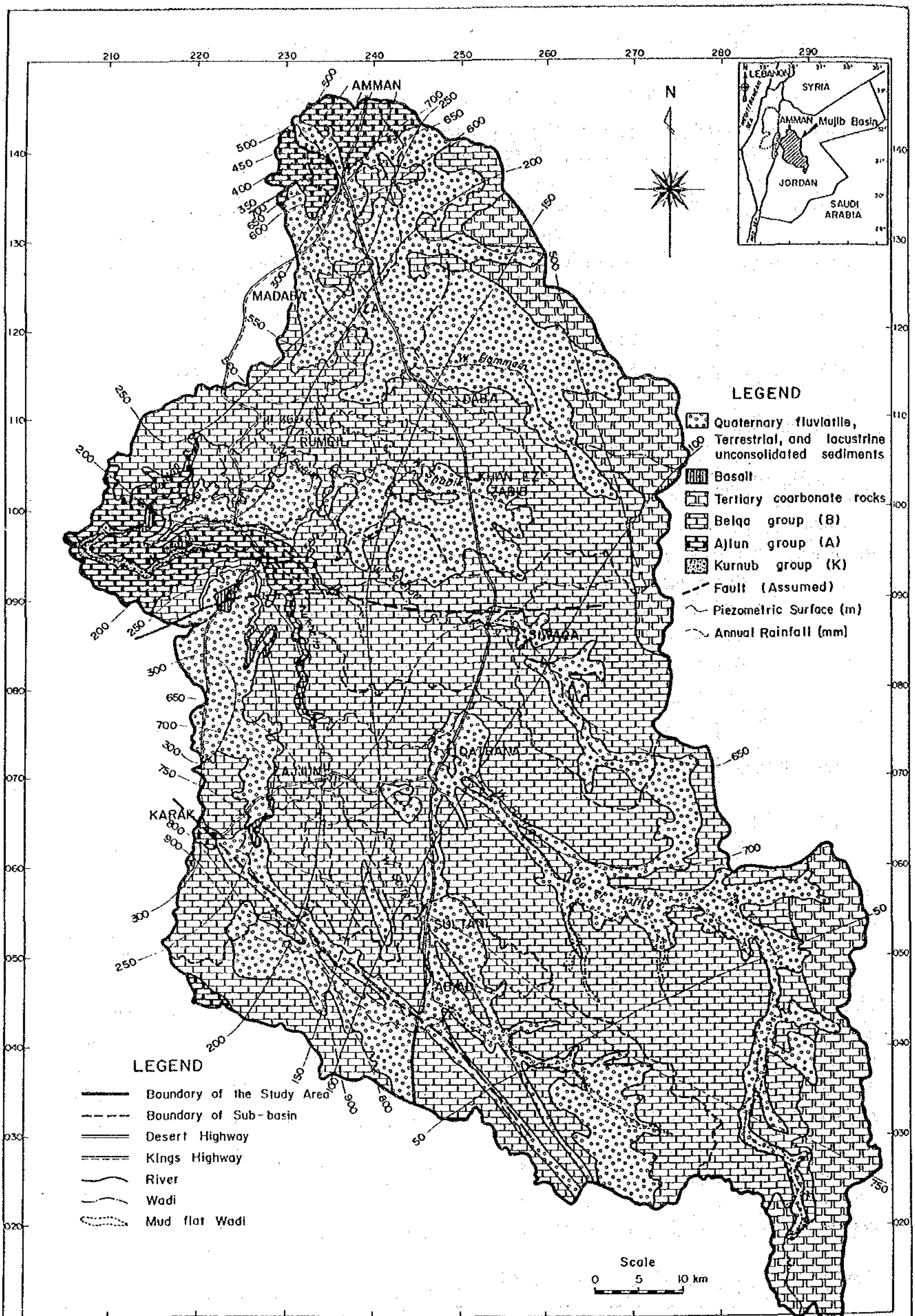
Sources; * Results of the First Census of Population and Housing on Nov. 18, 1961.
** Results of the Housing and Population Census on Nov. 10, 1979.

Annex M3122 POPULATION IN THE STUDY AREA BY GOVERNORATE (BASED ON THE 1979 CENSUS)

Unit : Thousand

Governorate*	Study Area			Outside Study Area	Grand Total
	Greater Amman Area	Mujib Basin	Total		
Amman	842	22	864	3	867
Zarqa	290	-	290	16	306
Irbid	3	-	3	535	538
Mafraq	1	-	1	72	73
Balqa	117	-	117	31	148
Karak	-	47	47	42	89
Tafielah	-	-	-	37	37
Ma'an	-	-	-	75	75
Total	1,253	69	1,322	811	2,133

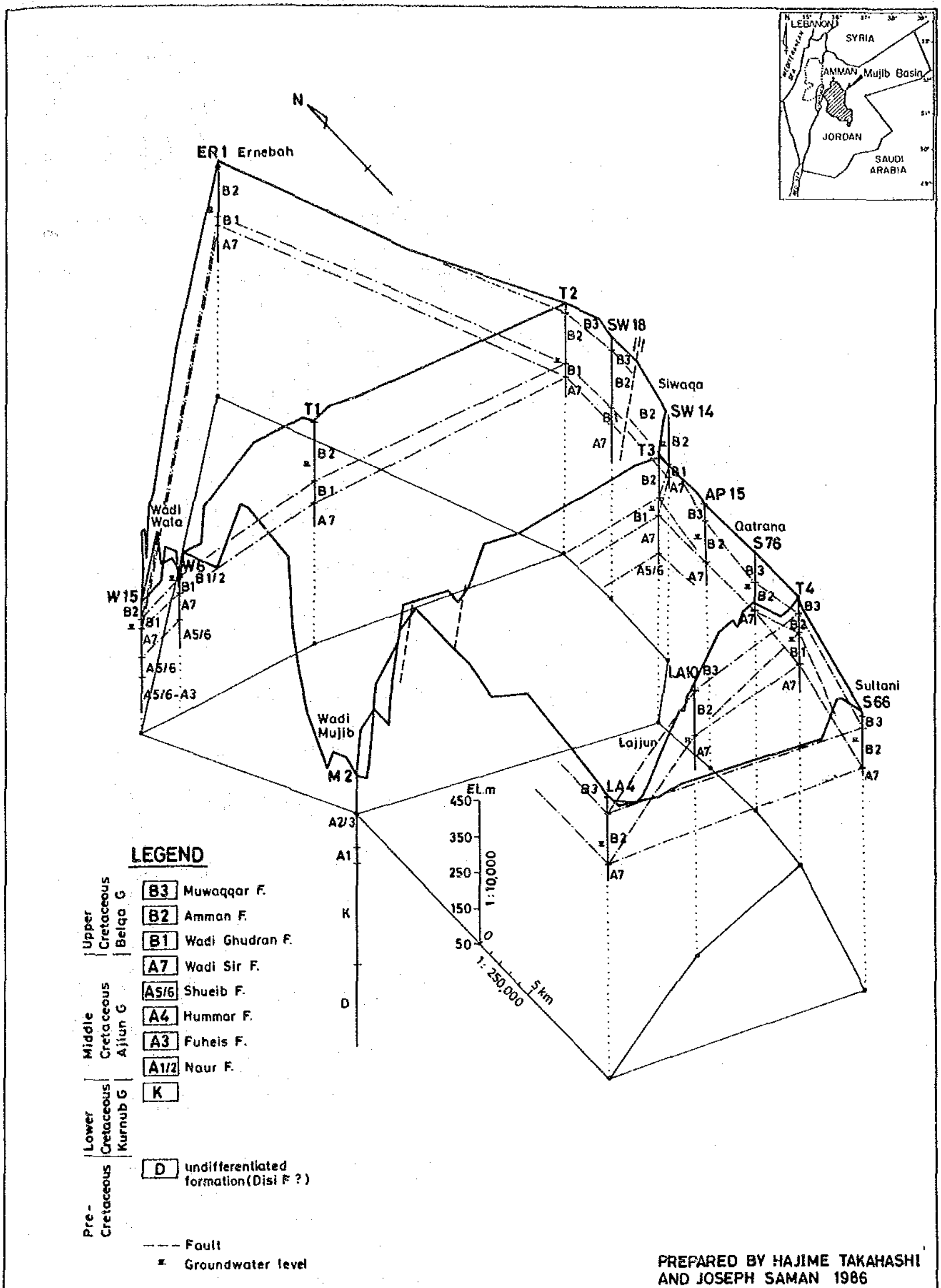
* New organization of governorate



Annex M3212-1

Hydrogeological Map

THE HASHEMITE KINGDOM OF JORDAN
HYDROGEOLOGICAL AND WATER USE STUDY OF THE MUJIB WATERSHED
JAPAN INTERNATIONAL COOPERATION AGENCY



Annex M3212-2

Fence Diagram of Geology in the Mujib Basin

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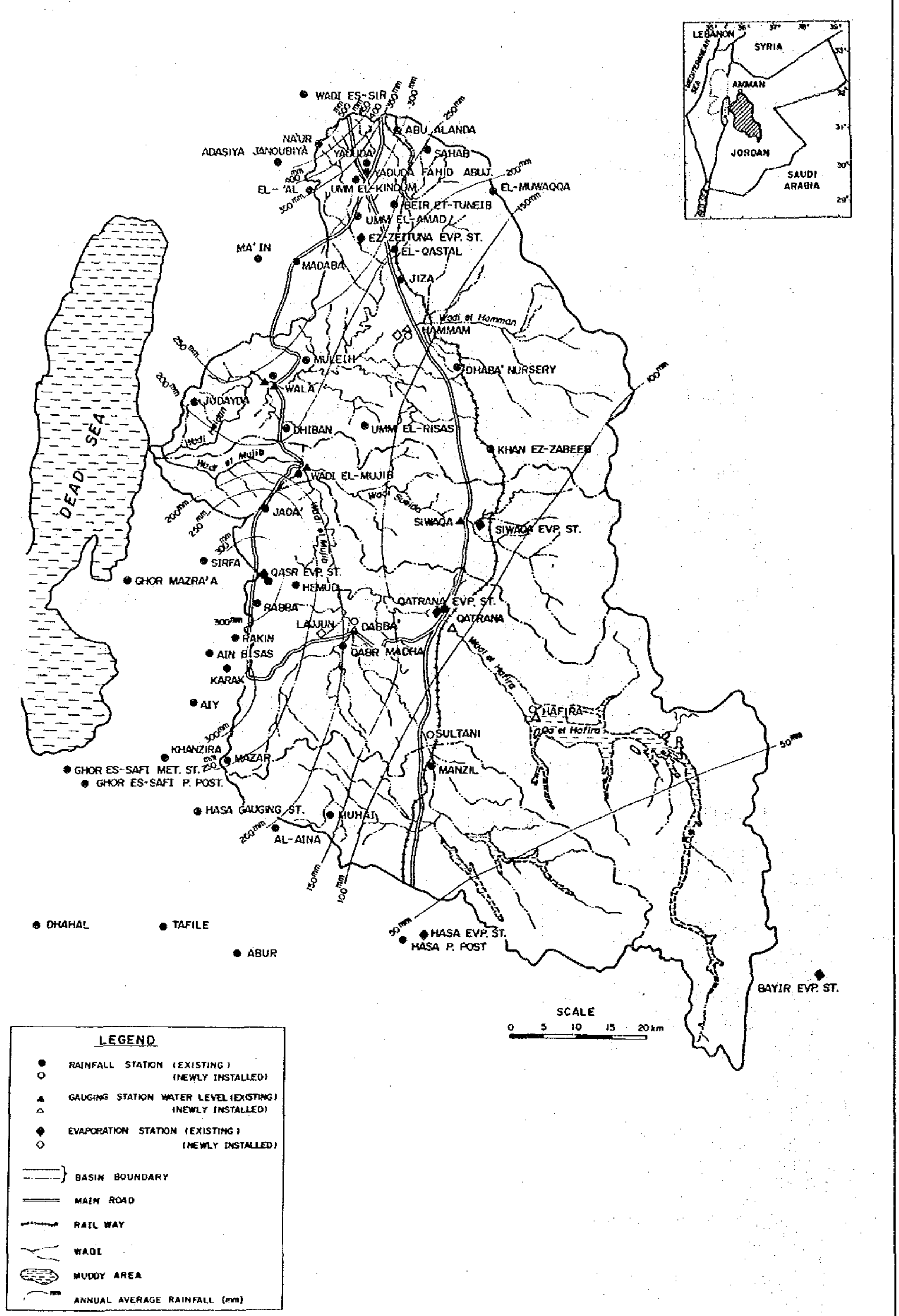

Annex M3224

Location Map of Meteorological/ Hydrological Stations

THE HASHEMITE KINGDOM OF JORDAN
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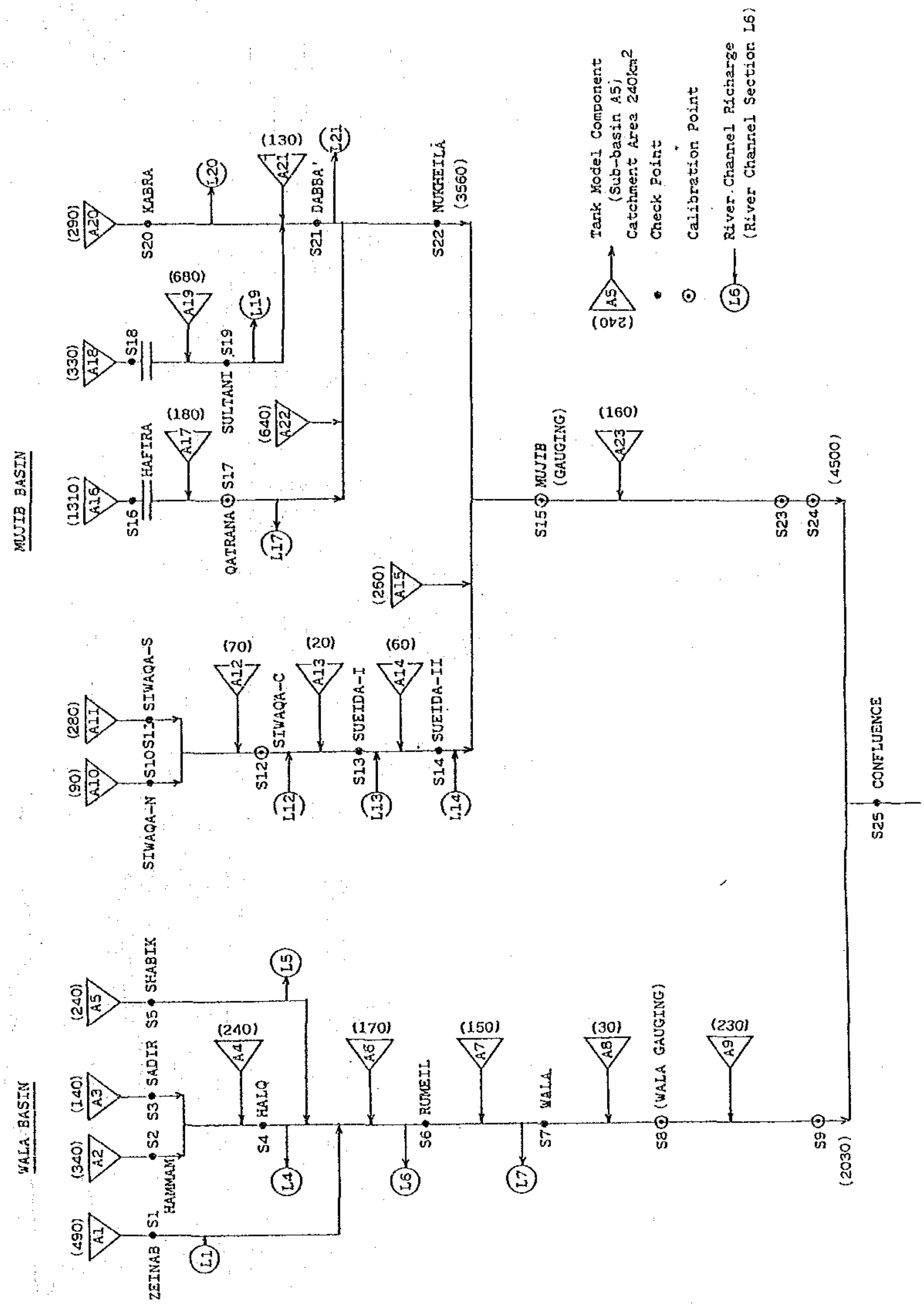

Annex M4113 Basin Model

THE HASHEMITE KINGDOM OF JORDAN
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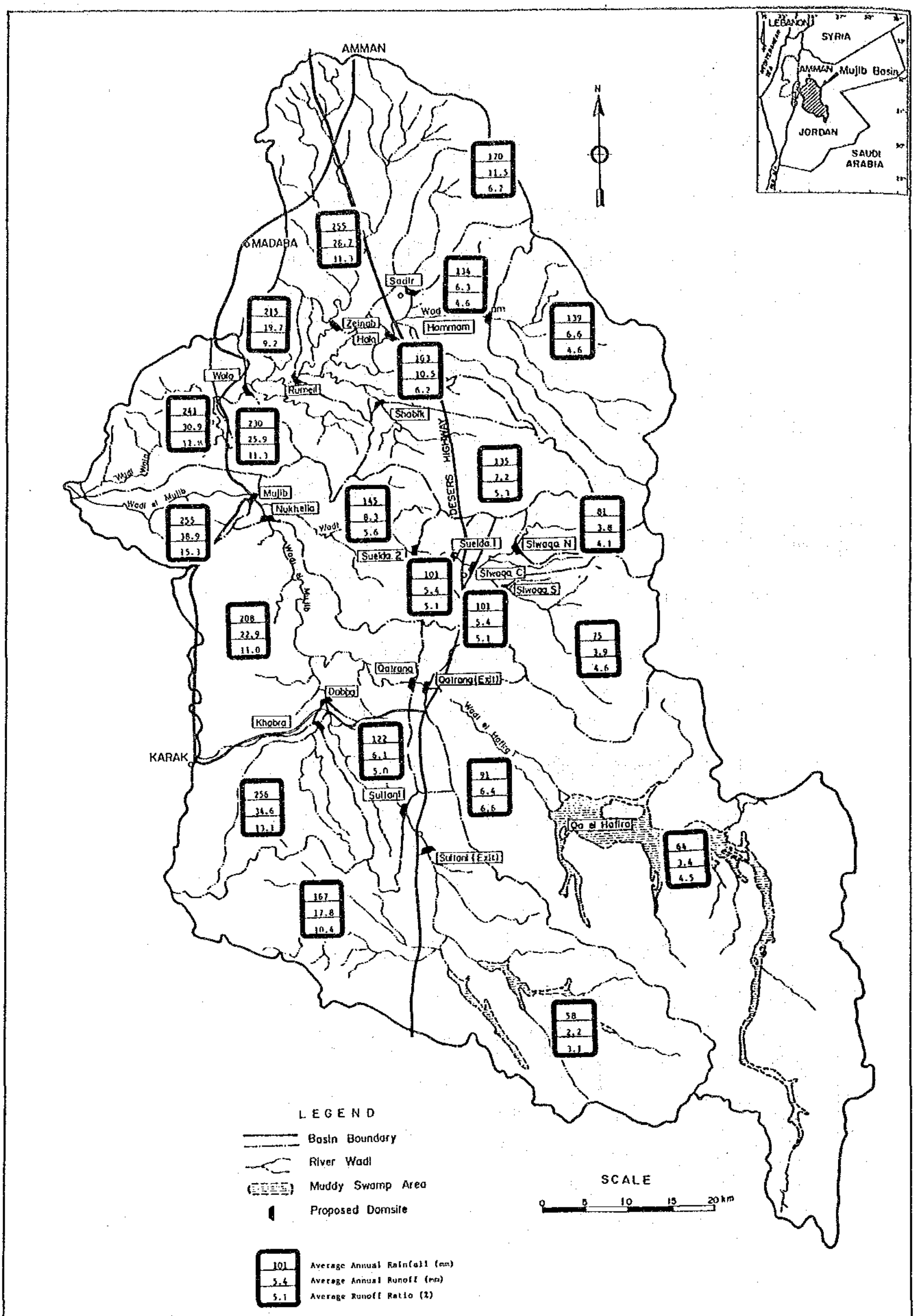

Annex M4115-1

Runoff Coefficient Distribution in the Whole Mujib Basin

THE HASHEMITE KINGDOM OF JORDAN
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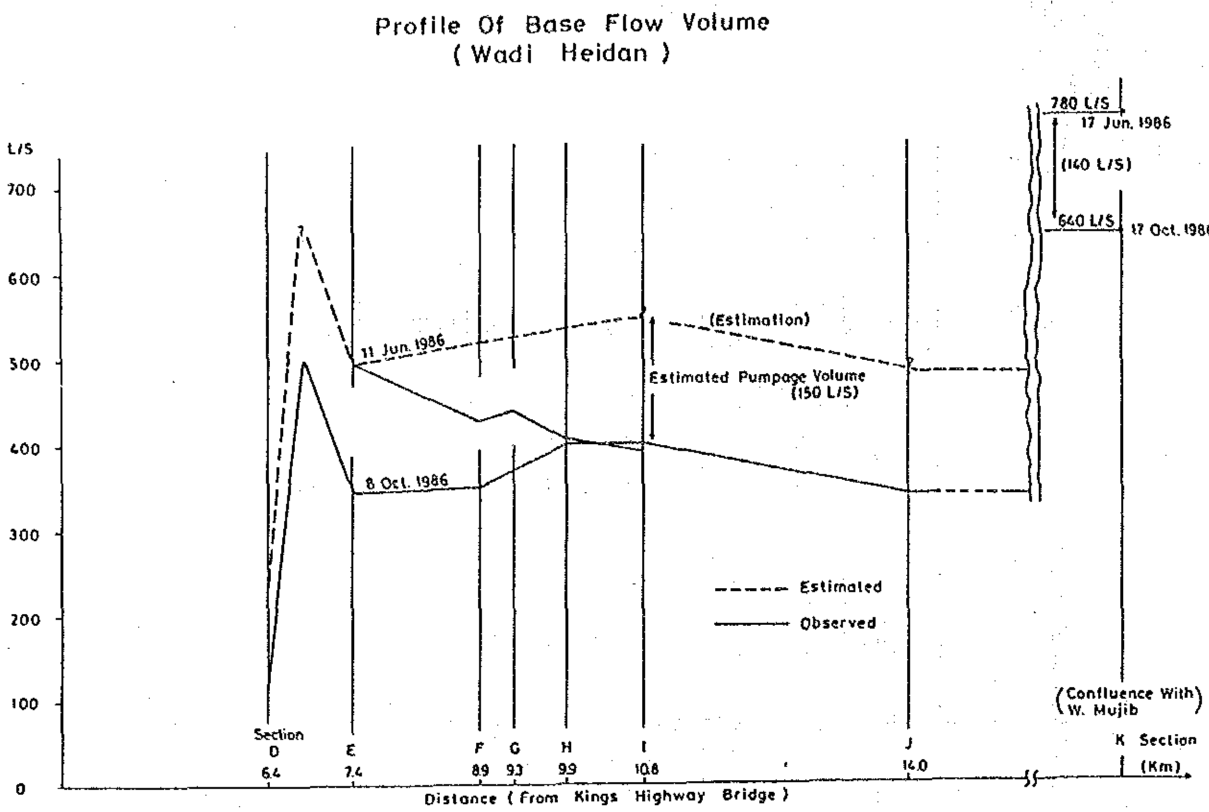
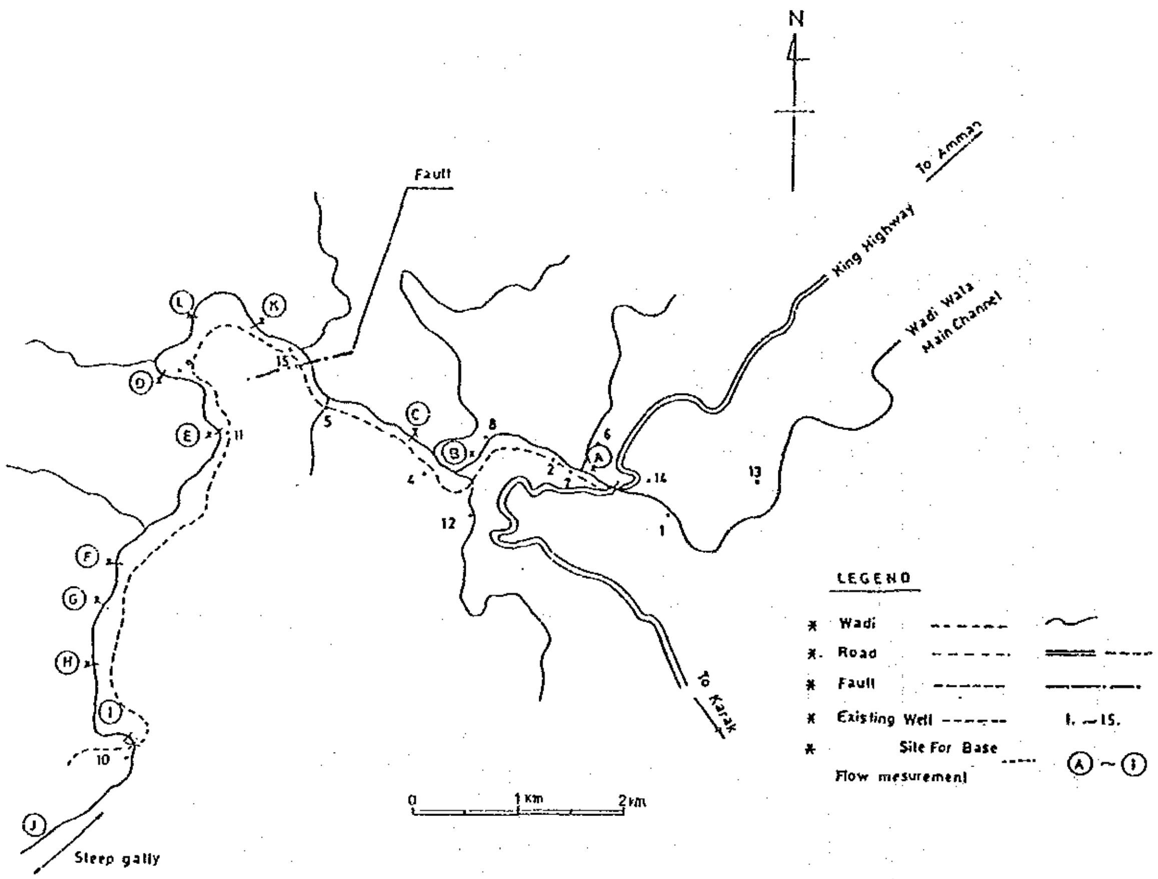
Annex M4115-2 PROBABLE ANNUAL FLOOD RUNOFF AT PLANNED DAMSITES

Damsite/ Gauging Station	Catchment Area (Km^2)	Average of Annual Flood runoff (MCM)	Return Year of Annual Runoff (MCM)							
			1.5	2	5	10	20	50	100	200
1. Zainab	490	11.23	6.04	9.86	19.27	25.50	31.47	39.20	45.00	50.77
2. Hammam	340	2.15								
3. Sodir	140	1.53	0.82	1.35	2.68	3.48	4.30	5.35	6.14	6.93
4. Halz	720	5.13	3.10	4.59	8.25	10.67	12.99	16.00	18.25	20.50
5. Shabik	240	1.67	0.80	1.44	3.02	4.07	5.08	6.38	7.35	8.32
6. Rumeil	1,620	18.99	11.41	16.99	30.71	39.79	48.51	59.79	68.24	76.67
7. Wala	1,770	21.52	13.15	19.31	34.47	44.51	54.14	66.60	75.94	85.24
10. Siwaqa N	90	0.23	0.08	0.19	0.47	0.65	0.83	1.06	1.23	1.40
11. Siwaqa S	280	0.76	0.25	0.63	1.57	2.19	2.78	3.55	4.13	4.71
12. Siwaqa C	440	1.32	0.49	1.10	2.61	3.62	4.58	5.82	6.75	7.68
13. Sneida I	460	1.40	0.53	1.17	2.76	3.81	4.81	6.12	7.09	8.06
14. Sneida II	520	1.66	0.65	1.39	3.22	4.42	5.58	7.09	8.21	9.33
16. Hafira	1,310	2.68	0.72	2.16	5.70	8.04	10.28	13.19	15.36	17.53
17. Qatrana	1,490	2.28	0.40	1.78	5.18	7.44	9.60	12.40	14.50	16.59
19. Sultani	1,010	3.19	–	2.02	10.02	15.32	20.40	30.32	31.99	36.82
20. Kabra	290	9.01	3.82	6.12	11.78	15.53	19.13	23.78	27.27	30.75
21. Dabba	1,430	11.77		8.96	28.18	40.90	53.10	65.08	80.74	92.54
22. Nukheila	3,560	26.15	5.74	20.75	57.71	82.17	105.64	136.02	158.78	181.47
15. Mujib	4,340	29.85	8.17	24.12	63.38	89.37	114.30	146.57	170.75	194.84



Profile of Baseflow Volume (Wadi Heidan)



Location of Baseflow Measurement

Annex M4122 Base Flow Profile

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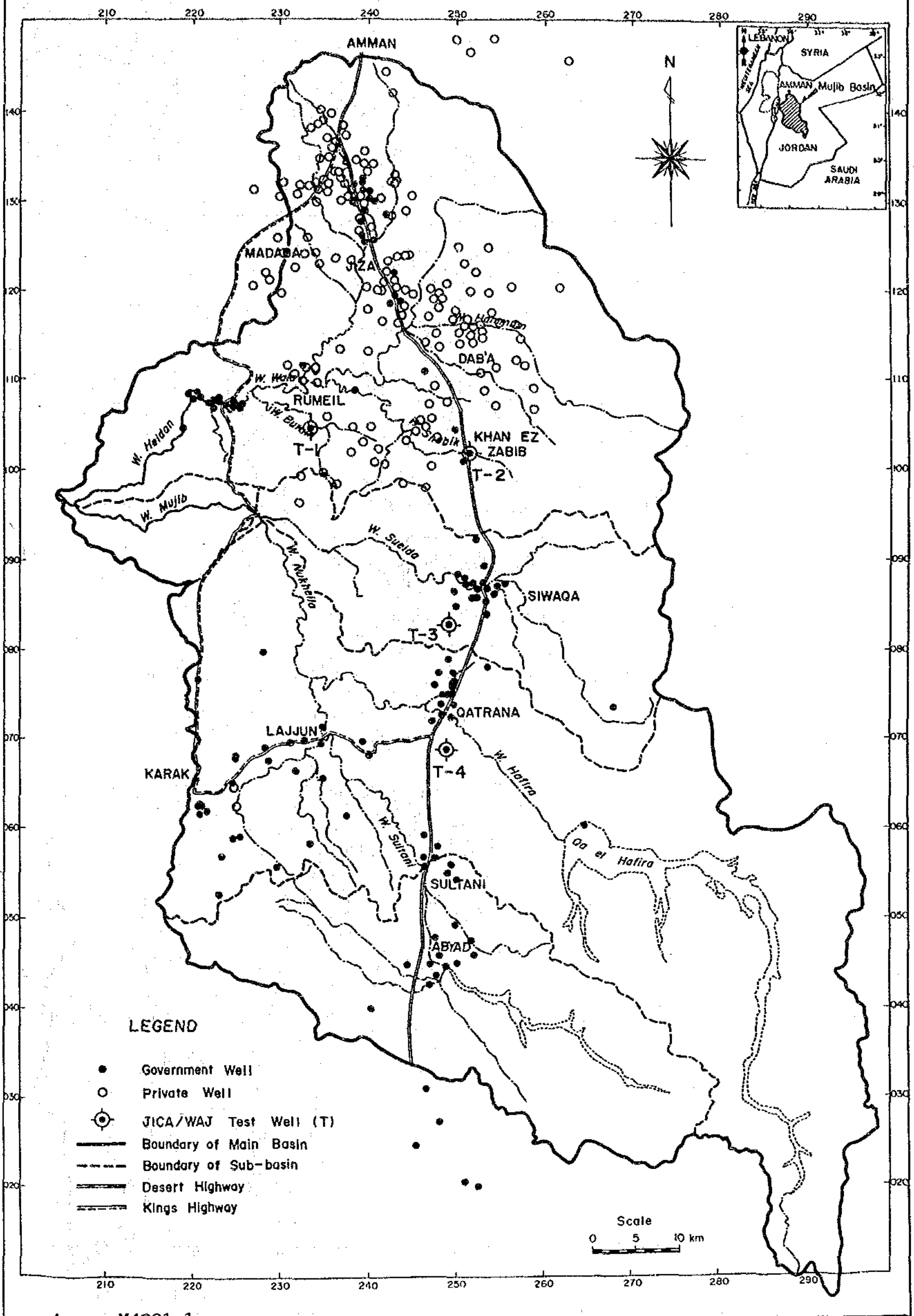

Annex M4221-1

Location Map of Groundwater Wells

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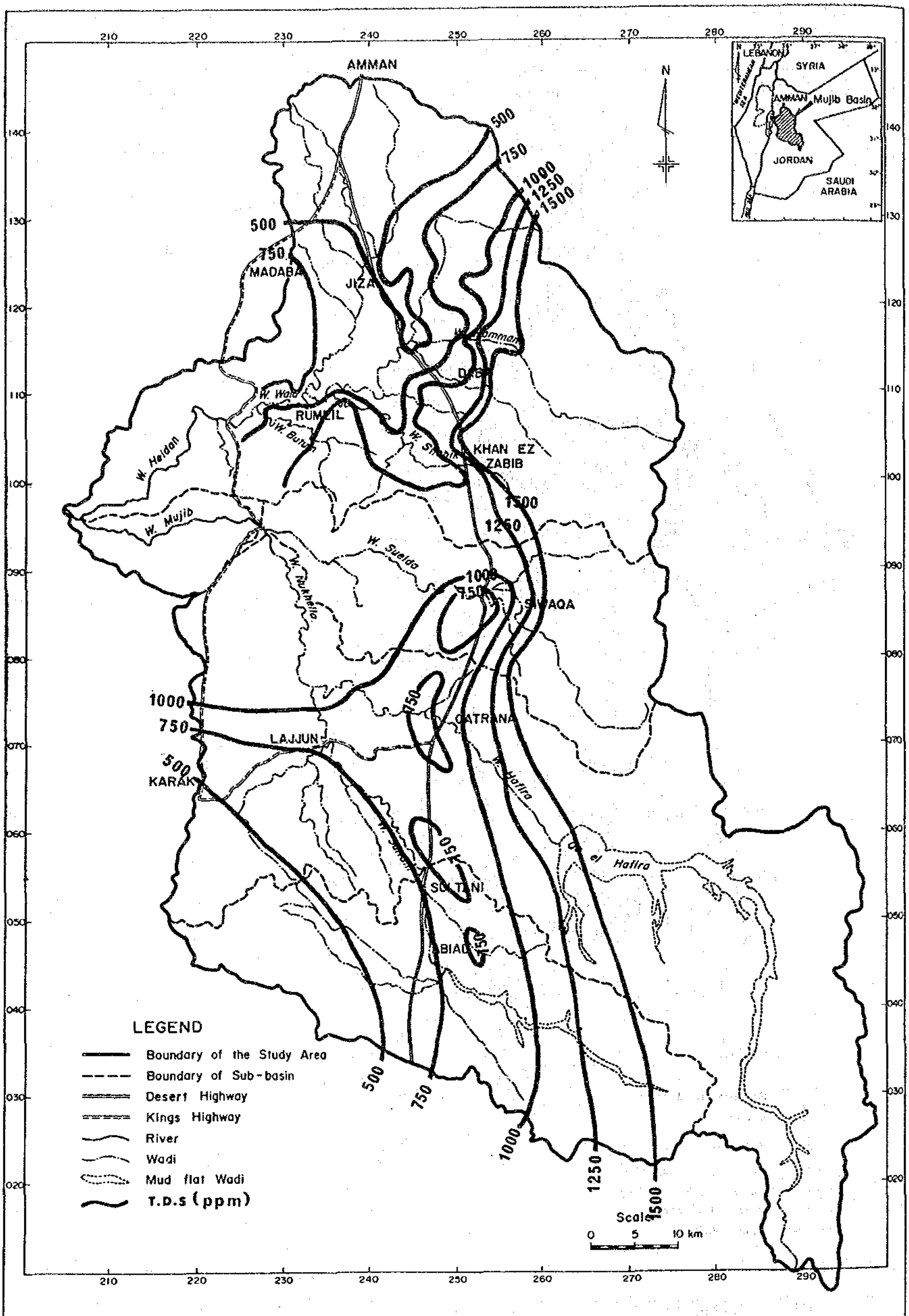

Annex M4221-2

T.D.S in the B2/A7 Aquifer

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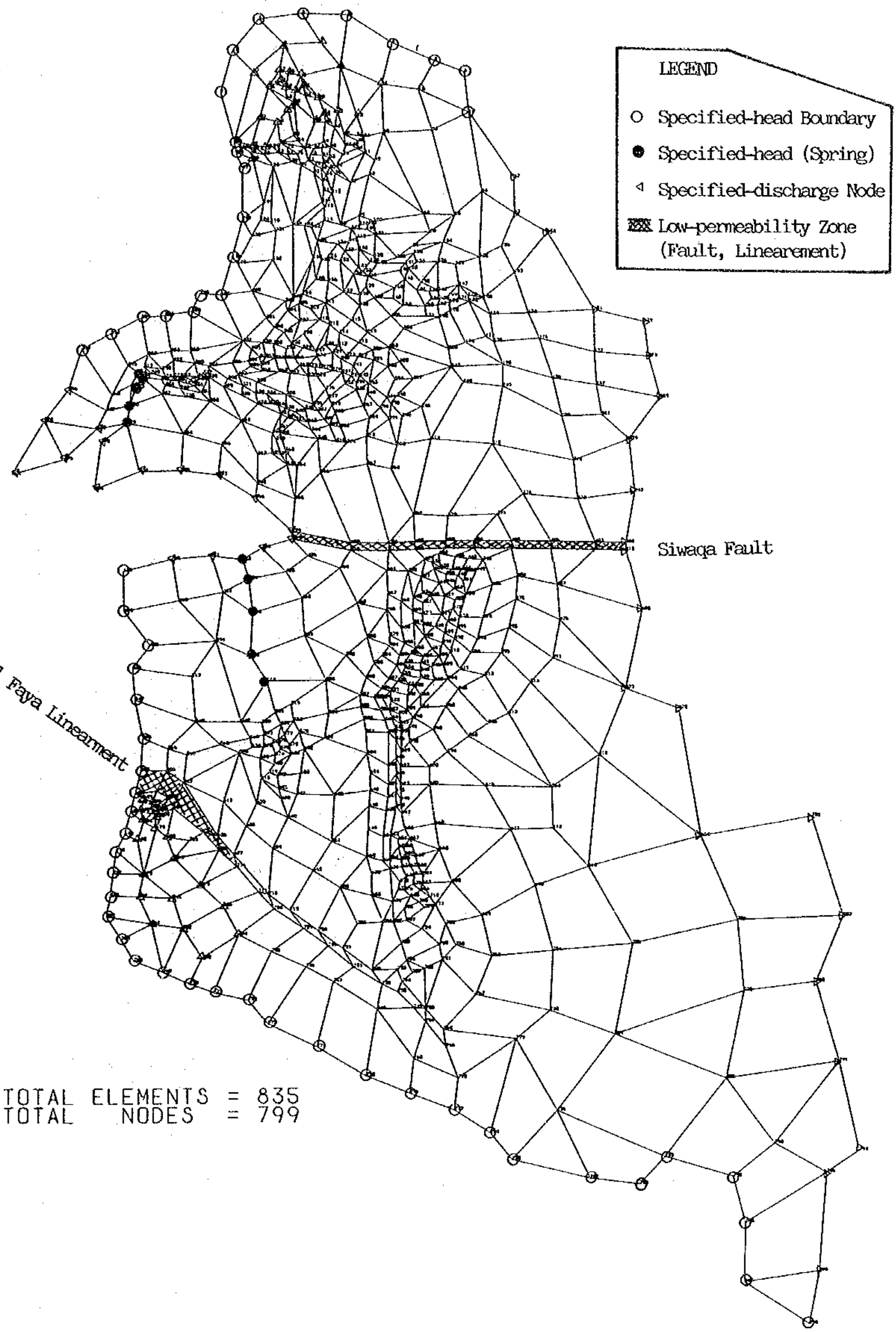

Annex M4231-1

Finite-Element Grid Showing Boundary Conditions

THE HASHEMITE KINGDOM OF JORDAN
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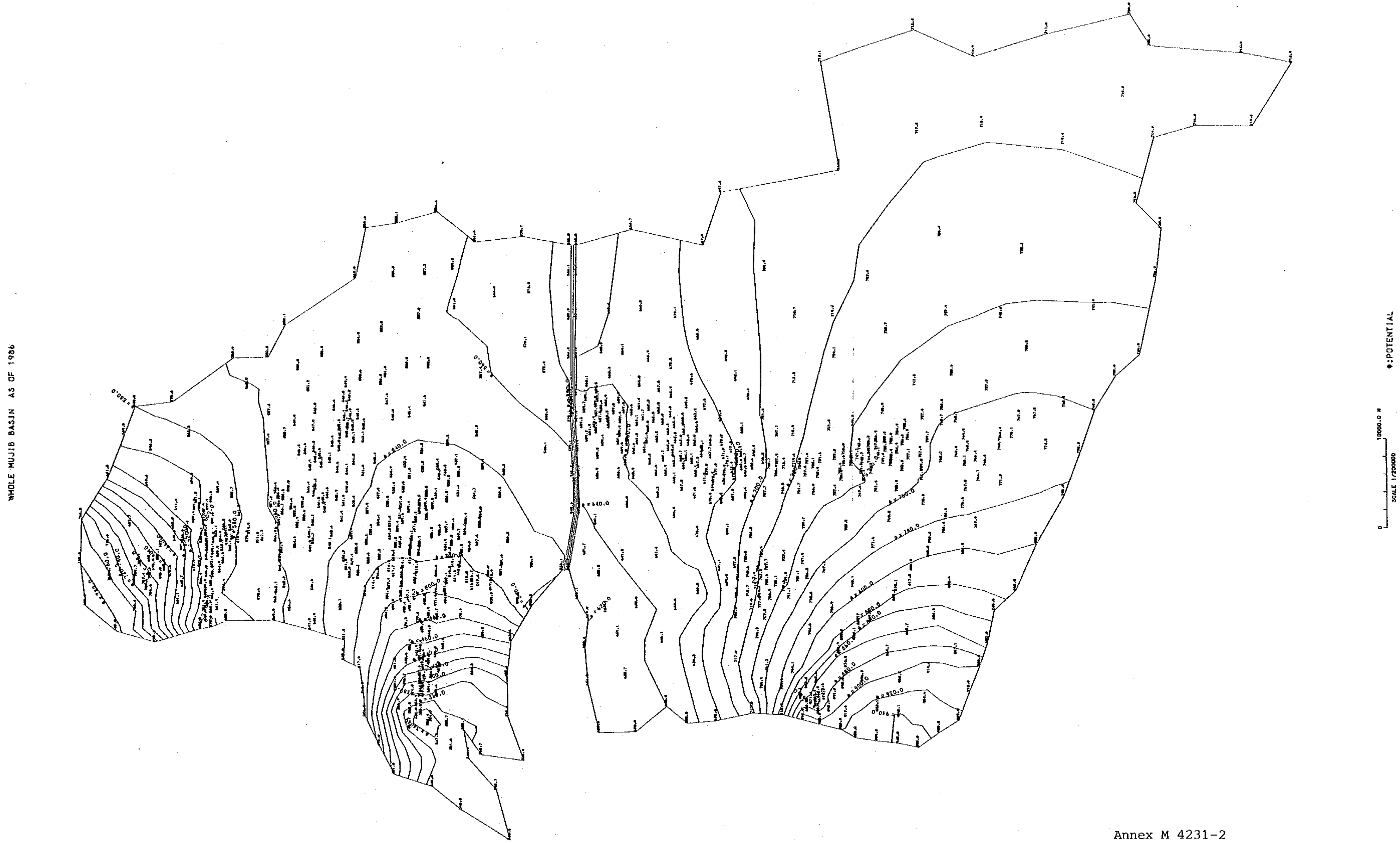

Annex M 4231-2

Groundwater Level Map of As Year 1986

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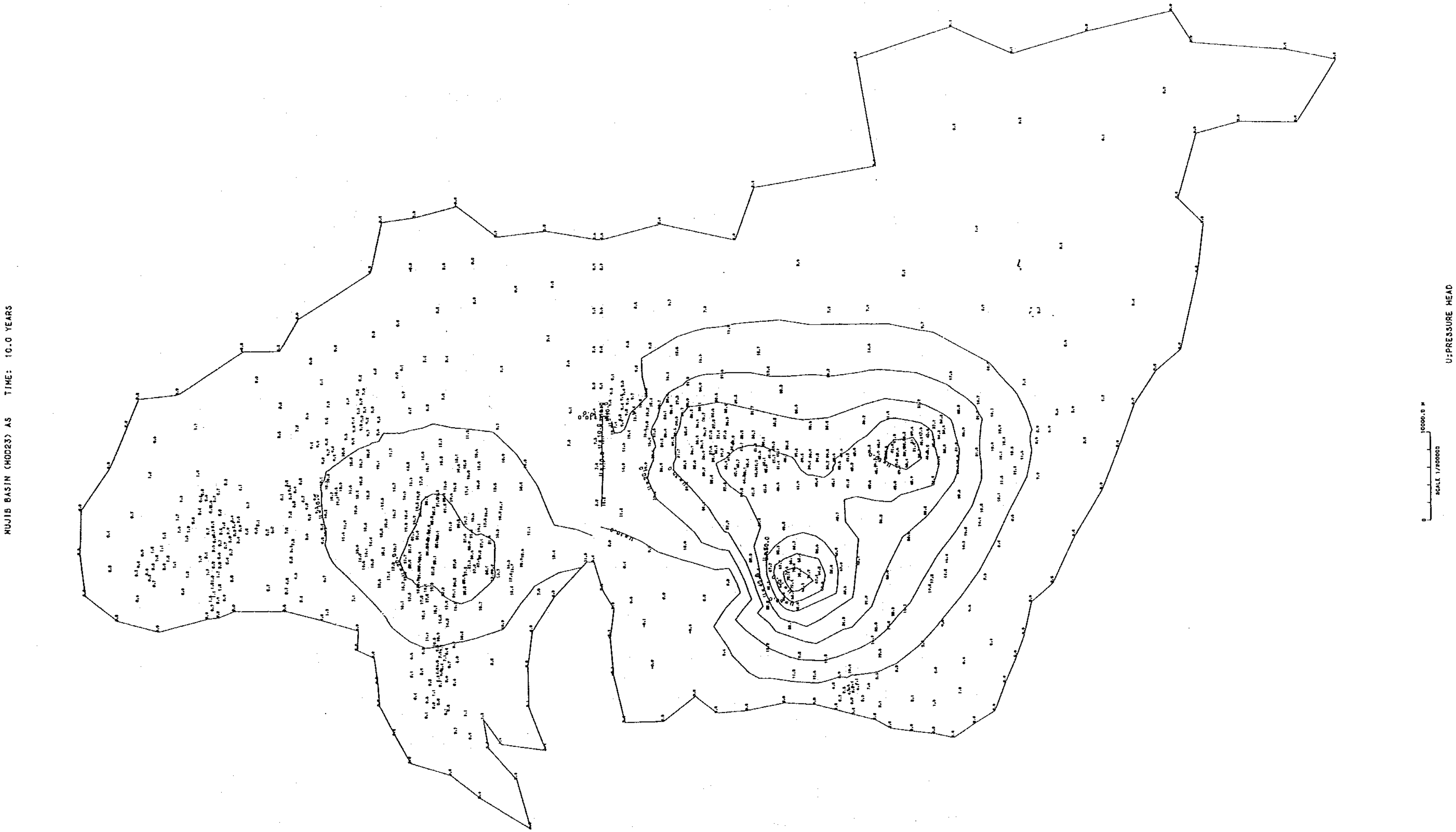
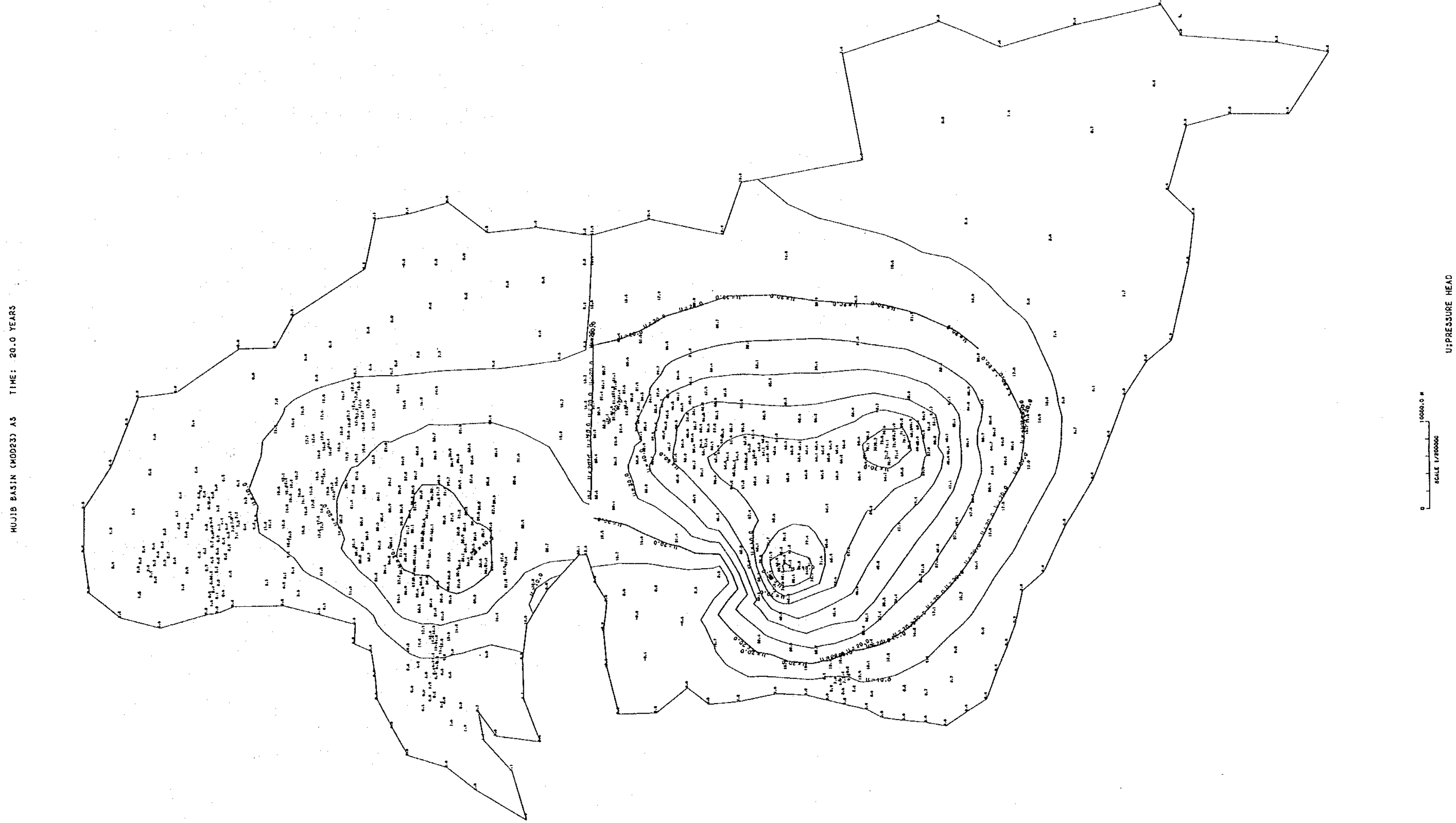


Annex M4231-3

Drawdown Map after 10 Years

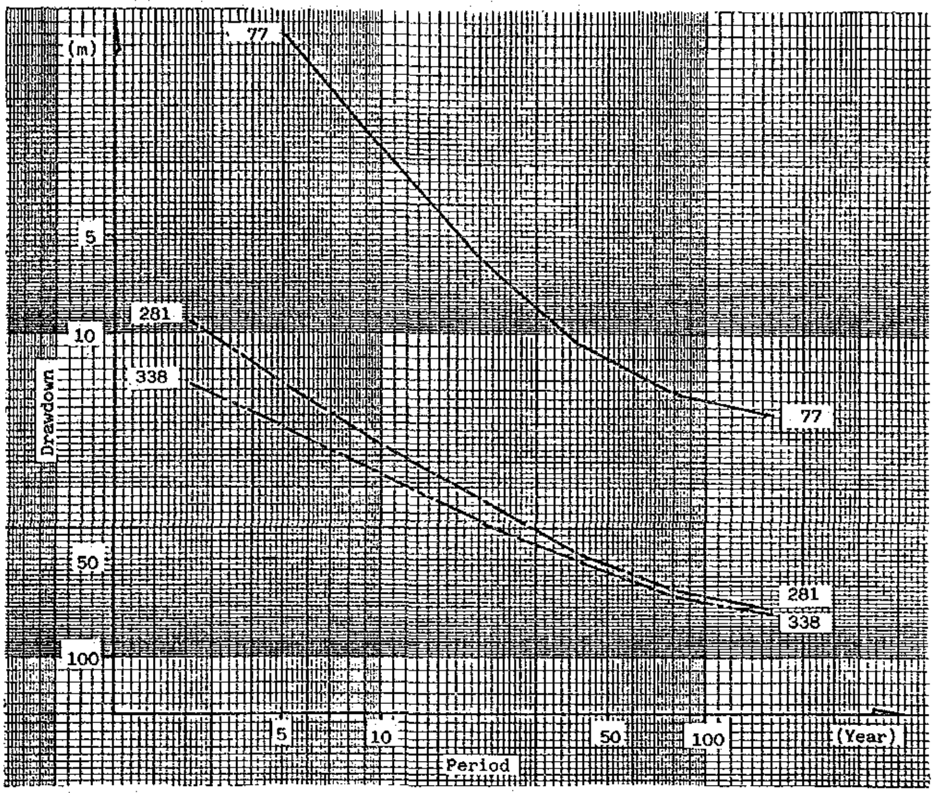
THE HASHEMITE KINGDOM OF JORDAN
HYDROGEOLOGICAL AND WATER USE STUDY OF THE MUJIB WATERSHED
JAPAN INTERNATIONAL COOPERATION AGENCY

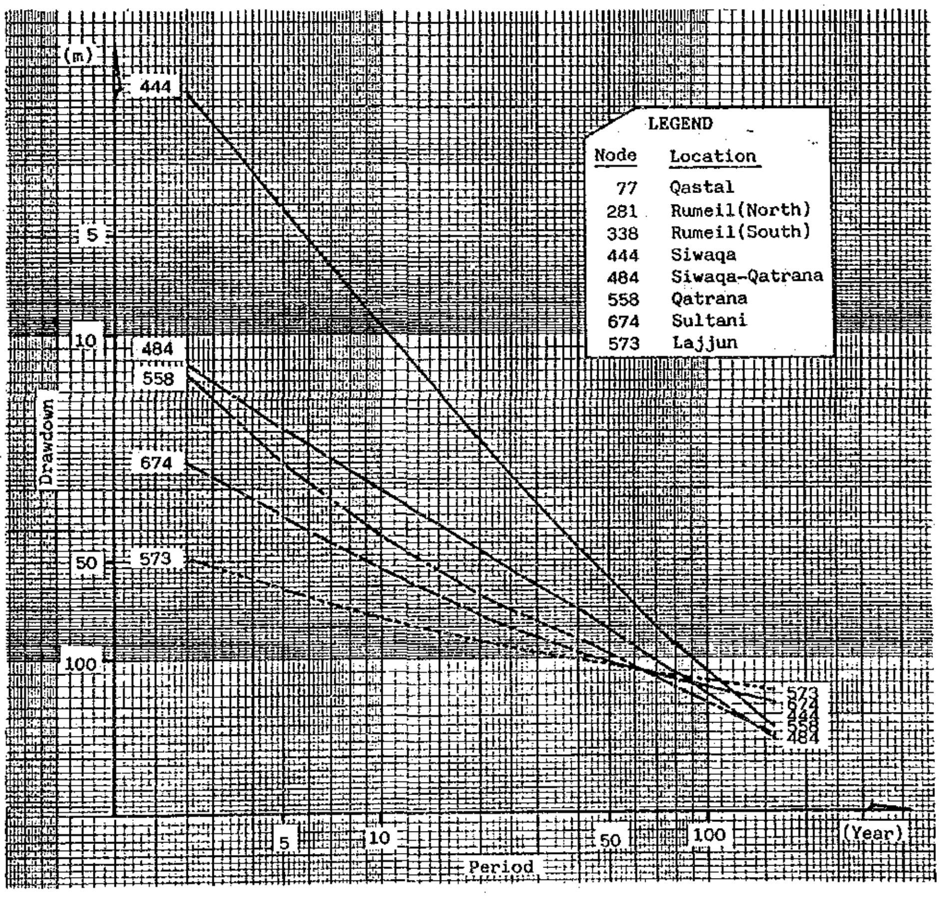


Annex M4231-4

Drawdown Map after 20 Years

THE HASHEMITE KINGDOM OF JORDAN
HYDROGEOLOGICAL AND WATER USE
STUDY OF THE MUJIB WATERSHED
JAPAN INTERNATIONAL COOPERATION AGENCY

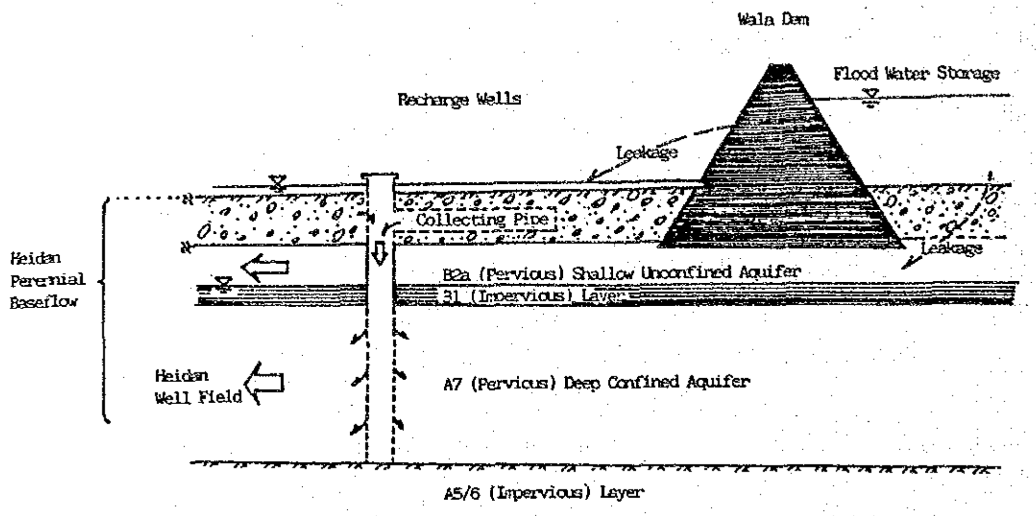


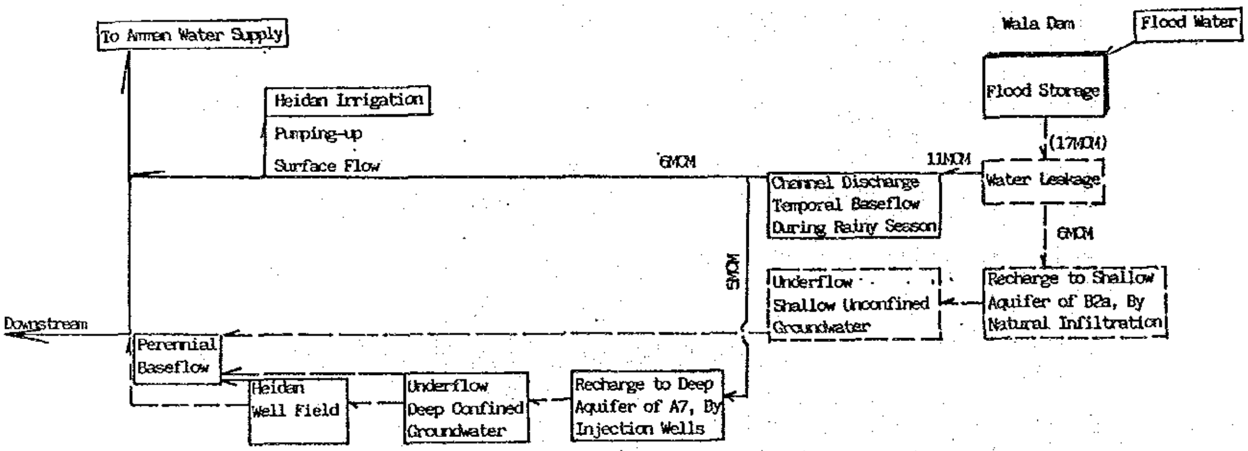


Annex M4231-5

Estimated Drawdown in Representative Wellfield

THE HASHEMITE KINGDOM OF JORDAN
HYDROGEOLOGICAL AND WATER USE STUDY OF THE MUJIB WATERSHED
JAPAN INTERNATIONAL COOPERATION AGENCY





Annex M4231-6

Schematics of Wala Artificial
Recharge Dam Scheme

THE HASHEMITE KINGDOM OF JORDAN
HYDROGEOLOGICAL AND WATER USE
STUDY OF THE MUJIB WATERSHED

JAPAN INTERNATIONAL COOPERATION AGENCY