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AN OUTLINE FOR WATER PLANNING

IN

EAST JORDAN

by

W. Barber

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1. Introduction

This report describes the result of a mission to Jordan carried out from 11th through 30th August to provide assistance in developing a National Water Plan. The work was undertaken in cooperation with Government officials. Messrs Bader Hirzallah and Omar Touqan, specialists of the Water Resources Division of the Natural Resources Authority worked with consultant throughout the mission. Numerous members of N.R.A. and other Government Agencies concerned with the development and use of water resources provided advice and information.

1.1. Objective and Scope of the Study

The objective of the study is to provide Government with preliminary evaluation of the available water resources of East Jordan in relationship to the existing and future demands, taking account of the spatial distribution of both available resources and demands. In defining future demands, only demands for domestic water which are implicit in the growth of population and improved standard of living, and demands for water for developments to which the Government is essentially committed are taken into account. In respect of the latter, developments specified in the five year plan (1976-80), and long term plans for the Jordan Valley and for Aqaba are regarded as Government commitments.

The study is based on information available at the outset of the work. The quantities of water quoted for both available resources and demands are orders of magnitude. Nevertheless it is believed that the report provides useful indicators for the future. The report does not provide a water plan. Recommendations are not made for the use of identified water surplus or for balancing future deficits, apart from suggesting possible sources from which the latter could be filled.

1.2. Methodology Adopted

In order to describe the spatial distribution of the water resources, the territory was subdivided into 24 water resources areas as shown in Figure 1. The boundaries of the areas coincide in general with natural limits of elements of the water resources systems. An attempt is made to provide evaluations of the available water resources in each area and of present and future committed demands. Areas where deficits exist or will develop and areas of net water surplus are identified. The result of the evaluation is to indicate areas where water resources appear to be available for future development.

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2. Water Resource Areas

2.1. Area 1 - The Jordan Valley

Most of this area comprises the valley floor on the east bank of the Jordan River extending from Lake Tiberius to the Dead Sea. The area also includes the foothills of the escarpment, the valley floors of the major side wadis up to the elevation of sea level and that part of the Yarmouk River Valley which can be commanded by the proposed Maqarin dam. The area functions as a line sink draining the surface water runoff and the groundwater from an extensive area in the northern part of East Jordan.
Mean annual rainfall ranges from 100mm at the southern end of the valley to 400mm at the northern end.

2.1.1. Surface Water Resources

The area draining to the east bank of the Jordan River covers about 12,000km^2 of which nearly half lies outside Jordanian territory. The major east bank tributary is the Yarmouk River with a catchment area of about 6800km^2 of which four fifths lies outside Jordan. The remainder of the flows to the area are generated within East Jordan. The surface water flows to the Jordan Valley area are summarised in Table 1.

Table 1. Surface Water Flows to Area 1.

Name Of Wadi	Annual Discharges (MCM)					
	Flood Flows			Base Flow		
	Mean	Obs. Max.	Obs. Min.	Mean	Obs. Max.	Obs. Min.
Yarmouk	250	(460)	(40)	(200)	?	?
Arab	2	5.6	0.4	34	40	18
Ziqlab	2	3.5	0.3	11	13	7
Jurm	-	-	-	12	14	8
Yabis	0.5	1	0.1	4	7	1
Kufrinja	7	14	0	6	11	2
Rajib	1	?	?	3	6	1
Zerqa	34	66	1	54	76	28
Shueib	2	3	0.5	8	13	5
Kufrein	1.5	3	0.5	8	18	4
Hisban	?	?	?	5	?	?
Totals	300			345		
Total Mean Flow:				645		

(Source: C.W.A. Technical Paper No. 33)

It should be noted that about 60% of the surface water flows to the east bank of the Jordan River are generated outside Jordanian territory.

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2.1.2. Groundwater Resources

Groundwater in the Jordan Valley area is contained in limestone aquifers which are down-faulted into the valley and in alluvial fans developed at the outlets of the major wadis. The area receives recharge by lateral flow from the escarpment and by infiltration from surface water irrigation and from floods. The following are rough estimates of recharge:

Underflow from the escarpment	60 MCM
Infiltrating irrigation and flood wadi	100 MCM
Total	160 MCM

The groundwater discharges to the Jordan River.

Despite the large recharge, the amount of groundwater which can be developed as a long-term supply is limited. The main constraint is water quality which normally deteriorates with depth and laterally towards the Jordan River. It is considered that total exploitable groundwater resource for the entire area would not exceed 50 MCM/annum. The greatest potential is offered by the downfaulted limestone aquifers which occur to the north and south of the Zerqa River outlet along the eastern edge of the valley and in the foothills of the escarpment. The groundwater potential to the north of the Zerqa River outlet is essentially unexploited.

2.1.3. Existing and Planned Facilities for Water Resource Development

Surface Water: Table 2 shows the status of surface water storage facilities to serve the Jordan Valley area.

Table 2. Status Of Reservoir Storage Facilities-Jordan Valley

River	Dam	Gross Storage (MCM)	Status
Yarmouk	Maqarin	(200)	Under study-planned for completion in 1981.
Yarmouk	Khaled	(200)	Under study
Arab	Arab	(20)	Preliminary study
Ziqlab	Ziqlab	4.3	Completed
Zerqa	Talal	56	Scheduled for completion in 1976.
Kuffrein	Kuffrein	4.3	Completed
Shueib	Shueib	2.3	Completed
	Total	487	

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The major conveyance system in the area is the East Ghor Canal which presently serves 123,000 dunums. The canal now extends from the Yarmouk outlet to Dahrat el Ramel. An extension of 18 km southwards is under construction and is scheduled for completion in 1976. A final extension of 20 km to the southern end of the valley is planned for completion by 1980. The canal presently delivers about 120 MCM/annum. The main source is a diversion of the Yarmouk base flow. Contributions are also provided from the base flows of the northern side wadis.

In addition to the area presently served by the East Ghor Canal there are about 80,000 dunums of irrigated land of which some 30,000 dunums are irrigated by groundwater and the balance by surface flows.

The long term plan for the Jordan Valley is for a fully integrated irrigation system supplying 340,000 dunums by surface water of which about 41,000 dunums will lie above the command area of the East Canal. When the system is completed it will encompass essentially all the presently irrigated lands which are not now served by the East Ghor Canal.

Groundwater: Present extraction of groundwater for irrigation is concentrated in the area from the vicinity of Karame to Sweimeh. The area served is 28,000 dunums. This area is supplied by 136 wells and the water is delivered to individual service areas. The gross extraction of groundwater is estimated to be 35 MCM/annum and the net extraction about 18 MCM/annum. It is noteworthy that with this rate of extraction, considerable declines in water level and deterioration of water quantity have occured. The system appears to be on overdraft in this area from the point of view of water quality.

2.1.4. Present and Future Demands

Irrigation Water: Table 3 shows estimates of present use and future water demands for irrigation and indicates the source from which the water will be supplied.

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Table 3. Present and Future Irrigation Water Demands - Jordan Valley (MCM/annum)

Year	Surface Water		Groundwater
	Integrated System	Other Systems	
1975[1]	130	50	35
1981[1]	370	-	-
1990[2]	560	-	-
2000[2]	560	-	-

1. Global estimates of field application is 1000mm and of all conveyance losses of 10%.

2. Global estimate of field application is 1500mm and of all conveyance losses of 10%.

Domestic Water Supply: Development plans for the area require increased population which will exceed normal growth during the early years. It is intended to attract migration of people by supplying social services among which will be reticulated domestic water supplies. It is planned to provide the domestic supplies from groundwater. Table 4 shows the forecast growth in domestic water supply demand.

Table 4. Forecast Growth in Domestic Water Supply Demand - Jordan Valley

Year	Population	Water Supply l/c/d	Water Supply MCM/annum
1975	68000	?	?
1980	115000	85	3.6
1985	142000	90	4.7
1990	165000	95	5.7
1995	191000	100	7.0
2000	222000	105	8.5

(Source - J.V.C.)

Water for Industrial and Mining Development

No major demands for water for industry or mining have been identified.

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2.5.1. Conclusions on the long-term water resource situation in the area

The estimates developed indicate that the surface water resources of the Jordan Valley will be about in balance with the demand by the year 1990. The groundwater resources may be under-exploited. However, it should be noted that there are tentative plans for development of groundwater irrigation in the foothills areas above the command of the surface water system.

When the West Bank of the valley returns to Jordanian control, it must be foreseen that there will be a heavy demand for water transfers from the resource area as defined. The area will then be in deficit.

2.2 Area 2 - The Salt Area

This area comprises the escarpment above the Jordan Valley extending from the Wadi Zerqa to the northern end of the Dead Sea. It includes the catchments of the wadis Shueib, Kufrein and Hisban. Elevations range from 800 to 1000 meters along the eastern limits to below sea level at the contact with the Jordan Valley area. Mean annual rainfall ranges from 150 to 250 mm in the foothill zones to about 650mm in the close vicinity of Salt.

2.2.1 Surface Water Resources

Surface water flows in this area discharge to the Jordan Valley. The main conduits are the wadis Shueib, Kufrein and Hisban which together contribute an annual average flow of about 25 MCM to the valley of which base flows represent 21MCM. (see Table 1). In addition, base flows are utilised for irrigation within the area and there are numerous isolated springs which provide water for irrigation and domestic supplies. Noteworthy is the Wadi Sir group of springs which discharge about 2 MCM/annum and contribute to the Amman water supply.

2.2.2. Groundwater Resources

This is a hydrogeologically complex area and the groundwater resources have not been quantified. There are however, no major groundwater bodies.

2.2.3. Existing and Planned Facilities for Water Resource Development

Irrigation facilities in the area consist of minor diversion and distribution systems on base flows in wadis and on springs. Due to the nature of the terrain, command areas are small. Development of additional irrigation cannot be foreseen.

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Domestic water supplies for villages are presently provided by springs and wadi base flows. The Salt town water supply is obtained from the wells. About 1.5 MCM/annum are exported from the Wadi Sir springs to supplement the Amman Water Supply (Area 6). Suggestions have been made to construct a small storage structure below Wadi Sir to regulate about 2-3 MCM/annum of spring and flood flows for future acquaintation of the Amman town Water Supply. While this project would decrease the supply to the Kuffrein dam (Area 1), a more difficult aspect of the development would probably be the existing water rights of the downstream users within Area 2.

2.2.4. Present and Future Demands

The demand for irrigation water is not expected to increase but an increased demand for domestic supply must be foreseen. The population in the area is presently about 90,000. Assuming a population growth rate of 3% and a present per capita demand of 50 l/s increasing to 55 l/s in 1980 and 75 l/s in the year 2000, the forecast demands for domestic water supply are as follows:-

1975	1980	2000
1.6 MCM	2.1 MCM	5 MCM

2.2.5. Conclusion on the long-term Water Resource Situation in the Area

The area as a whole has a net surplus of water which discharges naturally and is used in the Jordan Valley. Increased water demands for domestic supplies used in Area 2 will not significantly effect the situation in the valley. It is considered that Area 2 may be regarded as self sufficient in water for the future.

2.3. Area 3 - The Irbid Area

This area includes the Irbid plain, the northern slopes of the Ajlun mountains and the Jordan Valley escarpment to the north of the Zerqa River. The main population centres are Irbid and Ramtha.

2.3.1 Surface Water Resources

While considerable surface flows are generated in this area, there are few if any possibilities of mobilizing them. Table 1 (Section 2.2) indicates the flood and base flows generated on the Jordan Valley escarpment and in the Yarmouk Valley. However, these are committed for use in the Jordan Valley.

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2.3.2. Groundwater Resource

The area is underlain by the Amman Wadi Sir aquifer system and is a major recharge area. The mean annual recharge is estimated to be 110 MCM and the groundwater discharges to the Jordan Valley and the Yarmouk Valley. The base flows in the side wadis of the Jordan Valley north of the Zerqa River and part of the base flow in the Yarmouk are sustained by groundwater from this area. However, water levels are generally at considerable depth, increasing northwards towards the Yarmouk to more than 300 metres. Moreover drilling depths to tap the aquifer system also increase northwards.

Water levels of about 200 metres below ground surface are known to occur in the Husn-Nu'aima area, decreasing to less than 150 metres to the south. The potential of the area has not been estimated. Well yields are relatively low (20-50m^3/h). Nevertheless, given the general shortage for domestic water supplies in this water resource area, it is considered that a detailed investigation of the Husn-Nueima area should be carried out.

2.3.3. Existing and Planned Facilities for Water Resource Development

Irrigation Water: The Ziqlab dam and the dam planned on the Wadi Arab (see section 2.1) draw their water from Area 3 but form part of the Jordan Valley irrigation system. The only irrigation facilities which serve the area are minor diversion systems on the lower reaches of the side wadis of the escarpment and minor spring diversion in the Ajlun mountains and along the escarpment. No new irrigation developments can be foreseen to serve this area.

Domestic Water Supply: The major facility which serves the area is the Irbid pipeline system. Irbid and Ramtha towns obtain part of their supplies from independant systems based on springs and wells respectively.

The Irbid pipeline system serves a population of about 250,000 people distributed in 245 villages, towns and municipalities. The water supply is provided by wells at Sama Sdud (Area 4) and Dhuleil (Area 5) and the Azraq springs (Area 8). The domestic water supplies of Area 3 are therefore to a great extent dependant on water transfers. The quantities of water pumped to the pipeline in 1974 from the three sources were:-

Azraq	1.0 MCM
Dhuleil	2.7 MCM
Sama Sdud	0.5 MCM
Total	4.2 MCM

(Source - D.W.C.)

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The existing capacity of the main conveyance between Zatari and Haufa (which serves Area 3) is 600 m^3/h delivered through a 16" line. It is planned to increase the capacity of this part of the conveyance to 1800 m^3/h by 1977 by installing a parallel 20" line and additional pumping capacity. The distribution will also be extended to an additional 28 villages with total population of 22,000.

2.3.4 Present and Future Demands

Irrigation Water: No increase in demand for irrigation water in this area is foreseen.

Domestic Water Supply: The projected requirements for the population served by the Irbid pipeline is given in Table 5. The projection assumes a population growth rate of 3% and an annual increase in per capita demand of 1 l/sec/day. Most of the population is located in Area 3.

Table 5 Projected Domestic Water Demand from the Irbid Pipeline System (Zatari-Haufa Conveyance)

Year	Demand (MCM/Annum)
1975	Say 3.5
1980	8.5
1985	11.0
1990	13.0
1995	16.0
2000	20.0

(Source D.W.C.)

Allowing for population in Area 3 which is not catered for by the Irbid pipeline (for example parts of Irbid and Ramtha towns) the total domestic water requirement in the area may reach 25 MCM/annum by the year 2000.

2.3.5. Conclusions on the long-term Water Resource Situation in the Area

This area traditionally has been and will remain a water deficit area. It is believed that additional groundwater supplies could be developed within the area, (Husn-Nu'aime area) though these are not expected to supply more than a relatively small part of the demand. Nevertheless, it is recommended that detailed groundwater investigations should be initiated in the Husn-Nu'aime area. Deep pumping levels and relatively low yields should be expected.

The present major supplier to the Irbid pipe is the Dhuleil (Area 5). This area is believed to be on overdraft and the present rate extraction cannot be sustained in the long-term (see section 2.5).

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The Sama Sdud area (see Section 2.4) is believed to offer additional groundwater for development. The available resource has not been quantified but could be of the order of 5-10 MCM/annum. Detailed groundwater investigations should be undertaken.

A supply could be taken from the Yarmouk River but this would be to the deficit of the Jordan Valley which does not offer a long-term surplus.

The Azraq North area (Area 8) has a surplus of uncommitted groundwater (see Section 2.8). Model studies indicate that 10-20 MCM/annum of good quality water could be extracted from the area to the north and northeast of Druze Springs. Detailed investigations involving drilling and pump-testing are required to confirm this supply.

2.4. Area 4 - The Mafraq Area

This area extends from around Mafraq northwards to the border with Syria. It lies mainly with the catchment of the Yarmouk River. Annual average rainfall ranges from 150 to 250 mm.

2.4.1. Surface Water Resources

Runoff is limited and erratic and possibilities of surface storage are extremely limited. There are no important spring discharges. The surface water resources are very small.

2.4.2 Groundwater Resources

The area is underlain by the Amman-Wadi Sir aquifer system. The basalt aquifer occurs in the eastern part of the area. Recharge is mainly by underflow from the basalt aquifer. Well productivity is generally low except in the Sama Sdud area near the Syrian borders. Here well yields in the range of 100 to 200 m^3/h may be obtained and water levels are about 100 meters below ground surface. The rechargable groundwater resource has not been quantified but it is considered that the area could sustain long-term extraction of 5 to 10 MCM/annum.

2.4.3. Existing and Planned Facilities for Water Resource Development

Irrigation Supplies: The only irrigation development is on a small scale in the Sama Sdud area where the private sector has drilled 14 wells serving 1500-2000 dunums. The private sector will probably extend this development unless a decision is made to curtail drilling and allocate the water to the Irbid pipeline system.

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Domestic Supplies: Minor dams for domestic water supply have been constructed at Sama Sdud and Um Jimal with storages of 1.7 and 1.8 MCM respectively. Data are lacking on the confirmed supplies that these reservoirs yield.

A small well field (at present two wells) in the Sama Sdud area supplies water to the Irbid pipeline system. An additional two wells have been constructed to increase the capacity of the well field. Most of the villages and towns in Area 4 receive their water supply from the Irbid pipeline system.

2.4.4. Present and Future Demands

Irrigation Water: The 1974 extraction of groundwater in the Sama Sdud area was approximately 1.7 MCM. Increased development of irrigation by the private sector may be foreseen unless a decision is taken to allocate the water resource to the Irbid pipeline.

Domestic Water Supply: The domestic water requirements of the area are estimated to be 0.5 MCM at present and may be expected to increase to about 1.5 MCM/annum by the year 2000. However, it seems probable that the Irbid area will become increasing by dependant on water transfers from this area via the Irbid pipeline system. Future extraction of 5-10 MCM/annum from the Sama Sdud area may be required to serve the Irbid area.

2.4.5. Conclusions on the long-term Water Resource Situation in the Area

While the groundwater resource is more than adequate for future local domestic demands, it is believed that the requirements of the Irbid area will lead to full development of the groundwater in Sama Sdud area before the end of the century. Given this situation, Area 4 offers no long-term surplus and may in the longer term move in to deficit.

2.5. Area 5 - The Dhuleil

This area is approximately defined by the catchment of the Wadi Dhuleil. It also approximates to the subsurface catchment of the Dhuleil aquifer system. The mean annual rainfall ranges from 100 to 200mm.

2.5.1. Surface Water Resources

Flood run off to the Dhuleil catchment is sporadic and highly variable. The only spring flows occur near the confluence of the Wadis Dhuleil and Amman. A preliminary study has been carried out for a storage near Sukhna with a live storage of 18.5 MCM and a yield of 7.2 MCM. However this dam would intercept water which is committed to the Jordan Valley area via the King Talal dam.

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2.5.2. Groundwater Resources

The main aquifer of the Dhuleil area is formed by the basalt. Westwards the flow discharges into the limestone aquifers and thence to the Wadi Zerqa. A model study indicates that the net safe yield of the aquifer system is 10-12 MCM/annum. It is estimated that the rate of extraction is already being exceeded and the system is on overdraft. The groundwater reservoir is not large enough for a long-term mining operation.

2.5.3. Existing and Planned Facilities for Water Resource Development

Irrigation Supplies: The irrigated area in the Dhuleil has not been accurately measured but is in the range of 15,000 to 20000 dunums of which 5,800 dunums have been developed by the public section and the balance by the private sector. Water is provided by about 50 wells. Drilling has been prohibited with a view to curtailing water extractions.

Domestic Water Supply: The Irbid pipeline draws part of its water supply from the Dhuleil aquifer system. The village population in the northern part of the area drew water from the pipeline system. The population within the irrigated area obtain water from farm wells.

2.5.4. Present and Future Demand

Irrigation Water: The estimated gross withdrawal for irrigation during 1974 was 24 MCM. Allowing 30% for return flows provides an estimate of net extraction of 16 MCM which exceeds the safe yield at the system. Irrigation extraction will be limited by the Government restrictions on drilling. It may be foreseen that a reduction in groundwater extraction will be enforced over the next ten years by reservoir depletion and well failure.

Domestic Water Supply: The Dhuleil well field provided the largest contribution to the Irbid pipeline in 1974, supplying 2.7 MCM out of a total of 4.2 MCM. It is understood that the Irbid pipeline system has been assured 2 MCM/annum from the Dhuleil well field. The security of this supply is in question if the present rate of overdraft is continued.

2.5.5. Conclusions on the long-term Water Resource Situation in the Area

The present rate of extraction exceeds the supply The reservoir will not support long-term depletion. An equitable solution must be found for sub-division of the safe yield (10-12 MCM/annum) between irrigation supply and domestic water demands. In any event a reduction in extraction will be imposed by well failure due to aquifer depletion.

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2.6. Area 6 - The Amman-Zerqa Area

The area approximates to the valley of the Wadi Amman down to the confluence with the Wadi Dhuleil near Sukhna. It contains about 1,000,000 people-more than half the population of Jordan.

2.6.1. Surface Water Resources

Sound estimates of flood and base flows in the Wadi Amman are not available. The annual flood flows are probably in the range of 10-15 MCM. Most of the runoff is generated in the higher rainfall zone to the west and southwest of Amman. Base flows are perennial in some reaches of the wadi. Noteworthy springs are Ras el Ain, Ain Ghazal and Ain Sukhna. The first forms part of Amman water supply.

2.6.2. Groundwater Resources

There are two easily developed aquifers underlying the area, the Amman Wadi Sir and the Hummar aquifers. The Kurnub aquifer is present at depths in excess of 650 metres, and static water levels are deep (180-300 metres below ground surface).

The Amman-Wadi Sir aquifer offers the most important groundwater resource. Estimates of recharge range from 35 to 45 MCM per annum. It is believed that the recharge could be increased by proper management and that the system is presently under exploited. A problem for full development might be protection against chemical polution.

The Hummar aquifer is an artesian system with recharge of about 5-6 MCM/annum. Heavy extraction has lowered water levels over 100 metres in some areas and the system is being overdrawn.

2.6.3. Existing and Planned Facilities for Water Resource Development

Irrigation Supplies: There are about 170 wells irrigating 5,000 to 6,000 dunums along the valley between Amman and Sukhna. Thus development is controlled by the private sector. Increased development cannot be foreseen as all the land suitable for irrigation has been utilised. In fact the irrigated area may be expected to decrease as land is taken up by urban development.

Domestic Water Supplies: Most of the population within the area receives piped domestic water. The supplies are provided mainly from drilled wells within the area. The city of Amman utilises the Ras el-Ain spring (about 2-2.5 MCM/annum) and imports 1-1.5 MCM from the Wadi Sir springs (Area 2). The Madaba pipeline which provides domestic water to part of Area 10 (0.85 MCM in 1974), draws water from the Amman-Zerqa area.

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Various suggestions have been made for augmenting the domestic water supply to the area and in particular to Amman city.
These include:-

a - Increased exploitation of groundwater within the area. This would appear to have the highest priority as it offers the cheapest supply and the Amman Wadi Sir system is under-exploited.

b - Construction of a small reservoir at Abdoun upstream of Amman (estimated storage 2-3 MCM). This requires more detailed study particularly in relation ship to the regulation which might be achieved by management of the Amman-Wadi Sir aquifer system.

c - Construction of a small reservoir below Wadi Sir (estimated storage of 2-3 MCM). This would involve importing additional water from Area 2 and water rights could present difficulties.

d - Construction of wells in the area to the south of Amman in area 10. This appears feasible though the hydrogeological conditions are difficult and water levels are deep (circa 150 metres). However a rapid increase in demand may be foreseen in this area due to the construction of the new airport. There may in fact be no long-term surplus of groundwater for transfer.

e - Construction of a dam on the upper Wadi Wala (Area 10). A preliminary investigation indicates that a dam at Rumeil with storage of 75 MCM would yield about 25 MCM/annum. The development would depend on flood flows which are presently uncommitted.

f - Construction of a pipeline from the King Talal dam on the Zerqa River. This would involve about 45 kms of pipeline over difficult country and a lift of about 800 metres. Moreover, the water of the Talal dam is committed to the Jordan Valley and only a short-term, temporary surplus can be foreseen.

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Water Supply for Industry and Mining: The Ruseifa phosphate development and the Zerqa refinary control their own water resource facilities based on groundwater. Several small industries have private wells.

2.6.4. Present and Future Demands

Irrigation Water: Gross extraction of groundwater for irrigation is estimated to 12 MCM/annum. Allowing for return flows, net extraction is probably about 6 MCM/annum. Increased demand is not foreseen and, as stated previously, demand will probably decrease due to land being taken up for urban development.

Domestic Water Supply: Estimates have been developed by V.B.B. of the future gross water demand for domestic water for Amman city. They assume a population growth rate of 5% to 1982 and 3% in subsequent years, and an increase in per capita supply from 85 l/d/c in 1975 to 140 l/d/c in the year 2002. Estimates have also been developed by Government based on a 3.5% population growth rate and an increase in demand from the actual net per capita use of 38 l/d/c in 1974 to 100 l/d/c in 2002.
Government estimates assume a gradual decrease in transmission losses from 54% in 1975 to 30% in 2002. The forecasts are compared in Table 6.

Table 6 - Domestic Water Supply - Amman City (in MCM)

Year	VBB Estimate	Government Estimate
1975	19.2	19
1982	29	29
1990	45.5	
2002	84	78

The population of Area 6, excluding Amman city, is about 400,000 of which some 200,000 live in Zerqa. Assuming a population growth rate of 3.0% and a net per capita demand of 55 l/d/c in 1980 and 75 l/d/c in 2000, the domestic water demand will be as follows:-

1980 Net demand assuming	55 l/d/c	9.3 MCM
1980 Gross " "	50% loss	18.6 "
2000 Net demand "	75 l/d/c	23 "
2000 Gross " "	30%	30 "

The estimates developed indicate that the gross water demand for domestic water in the Amman-Zerqa area may be about 110 MCM by the year 2000.

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Water Supply for Industry and Mining: The major user of water is the phosphate plant at Ruseifa which requires 2.5 MCM/annum. Demands for other industries are not known but could total 2 MCM/annum. It is not possible to forecast growth in industrial demands but they will be small compared to domestic demands.

2.6.5. Conclusions on the long-term Water Resources Situation in the Area

The Amman-Zerqa area will become a deficit area during the 1980's. Developments due to the construction of the new airport in the northern part of Area 10 plus normal population growth in that area will probably utilise much of the groundwater which can be obtained from the Jiza area. Recirculated sewage water could meet the demands of agriculture and supply a considerable part of the domestic requirements, if this can be made acceptable to the population. Possible sources of imported water are:-

a - Storage on the upper Wadi Wala (say 25 MCM/annum). This supply is uncommitted.

b - The base flow of the Wadi Zerqa Ma'in (about 17 MCM/annum). This supply is uncommitted but would require desalinization (probably reverse osmosis) and would involve a very high lift. (1000m)

c - Groundwater from Area 8, Azraq north (say 10-20 MCM). This supply may be required for the Irbid area.

d - The Talal dam.. This water is committed in the long-term to the Jordan Valley.

2.7. Area 7 - The Lower Zerqa Catchment Area

This area includes the valley of the Zerqa River below the confluence of the Wadi Dhuleil and Amman, the southern slopes of the Ajlun mountains, and the northern slopes of the Salt mountain block. The mean annual rainfall ranges from 250mm on the lower reaches of the Zerqa River to over 650mm in the Ajlun mountains.

2.7.1. Surface Water Resources

A large proportion of the runoff to the Wadi Zerqa is generated within this area in the form of flood and base flows. There are in addition a large number of springs. The total runoff to the Zerqa Dam averages 97 MCM/annum. This runoff is committed to the Jordan Valley.

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2.7.2. Groundwater Resources

This is a hydrogeologically complex area and there are no major aquifer systems for groundwater development. Minor groundwater bodies occur in some localities on the higher slopes and groundwater may be obtained from the Wadi Zerqa alluvium. The resources have not been quantified.

2.7.3. Existing and Planned Facilities for Water Resource Development

Irrigation Water: Apart from Talal Dam and its associated distribution system which form part of the Jordan Valley development, there are no major surface water irrigation facilities in the area. The dam will serve about 11,000 dunums between the outlet and the East Ghor Canal as well as some 40,000 dunums below the canal.
There are numerous minor irrigation systems based on diverted spring flows and base flows. Increased development of surface water irrigation facilities is not foreseen.

A few wells have been drilled by the private sector for irrigation. Such scattered development of groundwater may be expected to continue.

Domestic Water Supply: Most of the towns and villages within the area obtain their water from springs. An important except is the refugee settlement (reputed to contain 60,000 people) in the Baq'a valley which is supplied from groundwater. A few small pipeline systems have been constructed to deliver water to some villages.

2.7.4. Present and Future Demands

Irrigation Water: The demands for irrigation water have not been quantified. The water available is sufficient for present requirements and future large scale development of irrigation is not foreseen.

Domestic Water: The population of the area is probably about 200,000 including a large proportion living in refugee camps. Present domestic water requirement is probably about 3-4 MCM/annum. As a large part of the population is not permanently settled, long-term water requirements cannot be forecast. However the requirement will probably not exceed 6 MCM/annum by the end of the century. This can be assured from within the area.

Water for Industrial and Mining Developments: No important requirements under this heading have been identified.

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2.7.5. Conclusions on the long-term Water Resource Situation in the Area

This area is and will remain self sufficient for water supplies. The only major supply for transfer has been committed to the Jordan Valley via the Talal Dam.

2.8. Azraq North

This area lies within the northern part of the Azraq basin extending from the most southerly of the Azraq springs to the Syrian border. The mean annual rainfall ranges from 50mm at Azraq to about 200mm at the border.

2.8.1. Surface Water Resources

The only perennial surface water supply is provided by the Azraq springs. The flood runoff in the area is negligible. The discharges of the Azraq springs are tabulated below together with date on water quality.

Table 7. Discharges and Water Quality - Azraq Springs (1963 data).

Spring Name	Annual Discharge (MCM)	Maximum Monthly (m^3/h)	Minimum Monthly (m^3/h)	Quality (ppm)
Druze	2.5	316	265	330
Shishan	6.3	754	680	780
Soda	6.0	625	514	1300

2.8.2. Groundwater Resources

The basalt aquifer underlies almost the entire area and provides the most important groundwater resources. The Amman-Wadi Sir and Kurnub aquifers are present at depth but contain poor quality water.

A model study indicates that 10 to 20 MCM/a of good quality water could be developed from the area immediately to the north and northeast of the Azraq Druze springs. The rate of water extraction would eventually kill the Druze spring and reduce the flow rate of the southern springs.

2.8.3. Existing and Planned Facilities for Water Resources Development

Irrigation Water: About 40 wells have been constructed by the private sector mainly in the area to the north and northeast of Qa' Azraq. However many of these wells are not utilised and the area actually irrigated does not exceed a few hundred dunums. Drilling of additional irrigation wells has been prohibited.

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Domestic Water Supply: The Azraq springs (Druze) supply water to the Irbid pipeline via the Azraq pumping station and a 16" pipe. A branch line takes water to the H5 area.

2.8.4. Present and Future Demands

Irrigation Water: Present gross extraction for irrigation does not exceed 2 MCM/annum. Future extraction will depend on whether the Government permits development in the area.

Domestic Water Supply: Local demands for domestic water are very small. About 1 MCM was pumped to the Irbid pipeline system in 1974. Future demands will depend mainly on whether Government decides to develop additional water for the northern districts from this source.

2.8.5. Conclusions on the long-term Water Resources Situation in the Area

The area presently offer a large surplus of water for development. A decision is required on whether the resource is allocated for agricultural development in the area or whether it is reserved for domestic use in the northern districts.

2.9. Area 9 - Azraq South

The area lies within the southern part of the Azraq basin. The average annual rainfall ranges from less than 50 to about 100mm.

2.9.1. Surface Water Resources

The only surface flows occur as occasional flash floods in wadis. The water flows to Qa' Azraq and evaporates. Conservation does not appear feasible except by induced recharge to groundwater.

2.9.2. Groundwater Resources

Groundwater is contained in the Rijam limestone aquifer at shallow depth but is generally of poor quality except in the Kherane area where water with about 600 ppm of dissolved solid occurs. The recharge is believed to be 5-10 MCM/annum. The Amman Wadi Sir aquifer and the Kurnub aquifer are present at depth but contain poor quality water.

2.9.3. Existing and Planned Facilities for Water Resource Development

The only facilities within area are wells equipped as desert watering points. No additional developments are planned.

2.9.4. Present and Future Demands

Present demands are minimal and are not expected to increase appreciably in the future.

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2.9.5. Conclusion on the long-term Water Resources Situation in this Area

This is an area of generally poor quality groundwater which also has low potential for irrigation due to the soils. Though the area has a water surplus, it is considered to have a low priority for development.

2.10. Area 10 - The Madaba Area

This area approximates to the catchment of the Wadi Wala. The mean annual rainfall ranges from 200 to 500mm.

2.10.1. Surface Water Resources

The mean annual flood flow in the Wadi Wala at the Madaba-Karak road crossing near the outlet to the area is 43 MCM with a range of 9.5 to 92 MCM (MacDonald data). Most of the base flow in the Wala occurs below the crossing into Area 23. Preliminary studies indicate that a dam at Rumeil with storage of 75 MCM would yield about 25 MCM/annum. This water is presently uncommitted.

2.10.2. Groundwater Resources

The groundwater resource of this area is contained in the Amman-Wadi Sir aquifer system. The recharge over the entire area is estimated to average about 35 MCM/annum. The groundwater discharges to the Dead Sea, mainly as base flow in the Wadi Mujib. The exploitable resource is much less than the recharge. It is considered that no more than half of the recharge could be recovered. Water levels are deep on the plateau (about 150 metres in the Jiza area and on the Daba Plain). Shallower levels may be obtained in the lower part of the Wadi Wala catchment but there is little demand in this area.

2.10.3. Existing and Planned Facilities for Water Resources Development

Irrigation Supplies: Irrigation facilities consist of minor base flow and spring flow diversion in the lower part of the Wala catchment and few wells, two of which are in the Jiza area. Increased development of irrigation is not foreseen.

Domestic Water Supplies: The main domestic water supply facility is the Madaba pipeline which presently obtains its water from wells in the Amman-Zerqa area (Area 6). A pipeline facility is planned to supply the villages in the Dhiban area. A number of wells have been drilled in the Jiza area with a view to obtaining additional water supplies for Amman.

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2.10.4. Present and Future Demands

Irrigation Water: The use of water for irrigation has not been quantified but is small. The main source of supply is from springs and base flows in the lower Wala catchment. Demands are unlikely to increase.

Domestic Water Supplies: Pumping to the Madaba pipeline was 0.85 MCM in 1974. Total domestic water use in the area was probably in the range of 1-1.5 MCM in that year. With normal population growth, this demand may be expected to increase to 1.5-2 MCM in 1980 and 3-4 MCM by the year 2000. However accelerated growth may occur due to the construction of the new airport in this area. Transfer of stored surface water from this area (Rumeil dam) to Amman may be solution for the developing water shortage in area 6.

2.10.5. Conclusions on the long-term Water Resource Situation in this Area

The area has presently an unused surplus of both surface and groundwater. Accounting only for identified growth in demand within the area, a long-term surplus may be foreseen. However, demands for water transfers to the Amman-Zerqa area may absorb much of the available surplus of surface water.

2.11. Area 11 - The Qatrani-Sultani Area

This lies within the eastern part of the Wadi Mujib catchment. The mean annual rainfall is in the range of 100 to 300mm.

2.11.1. Surface Water Resources

The flood flows leaving this area by the Wadi Mujib average 24 MCM/annum with a range of 0.5 to 84 MCM/annum (MacDonald data). Base flows in this area are small and are either consumed by irrigation along the wadi or reinfiltrate to groundwater. A possible dam site at Nukheila with live storage of 5.5 MCM and an annual yield of 5.5 MCM/annum has been investigated.

2.11.2. Groundwater Resources

The Amman-Wadi Sir aquifer system underlies the entire area. The mean annual recharge is probably in the range of 20 to 30 MCM/annum. The groundwater discharges to the Dead Sea, mainly as base flow in the Wadi Mujib. The reservoir storage is very large and there is the possibility for controlled depletion in this area. Potential development areas are Siwaqa, Qatrani, Sultani & Abyad where water levels are in the range of 60 to 100 metres below ground surface.

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2.11.3. Existing and Planned Facilities for Water Resource Development

Irrigation Supplies: The irrigation facilities in the area consist of small scale spring and base flow diversion by the private sector and a Government developments of 1700 dunums of irrigation by groundwater at Qatrana and 500 dunums at Abyad. Increased facilities for use of surface water are not foreseen. Designs have been made for extending the irrigated areas at Qatrana and Abyad and for irrigation developments at Siwaqa and Sultani.

Domestic Water Supplies: Minor storage dams have been constructed at Qatrani and Sultani (4.2 and 1.3 MCM storage respectively) but these do not provide a firm supply and are little utilised. Qatrani village obtains its domestic water supply from groundwater and there is a desert watering point at Siwaqa.

2.11.4. Present and Future Demands

Irrigation Water: The quantity of surface water utilised for irrigation has not been quantified but the demand is not expected to increase due to lack of command area. The gross requirement for the existing groundwater irrigation facilities at Qatrana and Abyad is about 3.0 MCM/annum.

Domestic Water Supplies: Present use of water for domestic supplies in the area is very small and will remain so in the future unless developments draw population to this area.

2.11.5. Conclusions on the long-term Water Resource Situation in the Area

This is a water surplus area. The possibilities for mobilising the surface water in this area are limited and flood runoff to the Dead Sea will continue. Groundwater resources could be exploited in the Siwaqa, Qatrana, Sultani and Abyad areas at relatively low cost.

2.12. Area 12 - The Karak Area

This area lies mainly within the western part of the catchment of the Wadi Mujib. A small part of the area drains to the Wadi Karak. The mean annual rainfall ranges from 200 to 350 mm.

2.12.1 Surface Water Resources

There appear to be no opportunities for mobilising flood runoff within this area. There are few springs except along the Mujib.

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2.12.2. Groundwater Resources

The area is underlain by the Amman-Wadi Sir aquifer system. The mean annual recharge is about 30 MCM of which 7 MCM discharges to the Wadi Karak and the balance to the Wadi Mujib. The exploitable resource is probably of the order of 10-15 MCM/annum.

2.12.3. Existing and Planned Facilities for Water Resource Development

Irrigation Supplies: Irrigation facilities consist of spring and base flow diversions along the Mujib and an area of 500 dunums irrigated by groundwater at El-Ghuwair. The area irrigated by surface water is not expected to increase. Designs are available for extension of the groundwater irrigated area around El-Ghuwair.

Domestic Water Supplies: A pipeline system based on a well at El-Ghuwair supplies the villages in the northern part of the area. The Mazar pipeline system supplies the southern villages. Karak town is supplied from a spring on the Wadi Karak.

2.12.4. Present and Future Demands

Irrigation Water: The quantity of surface water utilised for irrigation has not been quantified but the demand is not expected to increase. The groundwater extraction required for irrigation at El-Ghuwair is in the range of 200,000 to 250,000m^3/annum. Extension of the area irrigated by groundwater could increase the demand to 2-2.5 MCM/annum.

Domestic Water Supplies: The 1974 pumping for the El-Ghuwair and Mazar pipelines totaled 0.6 and 0.2 MCM respectively. The water used by Karak town is not known but probably did not exceed 0.5 MCM. Assuming a population growth of 0.3% and allowing for an increase in per capita demand, the domestic water supply required could be about 2 MCM in 1980 and reach 4 MCM by the year 2000.

2.12.5. Conclusions on this long-term Water Resource Situation in the Area

The area has a relatively large, groundwater surplus.

2.13. Area 13 - The Dead Sea Escarpment

This area extends from the Wadi Udheim at the northern end of the Dead Sea to the northern limit of the Wadi Hasa catchment on the escarpment. The eastern limit is the crest of the escarpment and the western limit is the Dead Sea coast. The rainfall ranges from less than 100mm to about 350mm.

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2.13.1. Surface Water Resources

The Wadis Zerqa Main, Mujib and Karak traverse the area and most of the catchments of the Zerqa Main and Karak lie within the area. Table 3 summarises the surface water discharges in the major streams of the area.

Table 8 - Surface Water Discharges in the Main Wadis Crossing the Dead Sea Escarpment

Name Of Wadi	Mean Discharges (MCM/Annum) Flood Flows	Base Flows
Zerqa Main	(5)	(15)
Mujib	64	50
Karak	(1)	(5)

The floods and base flows of the Wadi Zerqa Main are not utilised. It would be possible to mobilise part of the base flow but the water is highly mineralised and would require dilution for agricultural use and dilution or treatment for domestic use. Part of the flood flows in the Mujib could be regulated on the Wadi Wala and upper Wadi Mujib (Areas 10 and 11 respectively). There are no storage sites on the Mujib within the escarpment zone and thus loss of flood flows to the Dead Sea are inevitable. Studies have been made for diversion of about 40 MCM/annum from the Mujib to Ghor Safi for irrigation. This will be provided mainly from base flows but some upstream storage in Areas 10 or 11 will be required to ensure the supply. The base flows on the Wadi Karak are partly utilised for domestic water supplies for Karak town and for irrigation, part escapes and infiltrates to the gravel fan at the outlet onto the Lisan peninsular. There are no storage possibilities on the Wadi Karak.

2.13.2. Groundwater Resources

There are no exploitable groundwater resources of any consequence in this area.

2.13.3 Existing and Planned Facilities for Water Resource Development

Irrigation Supplies: The only irrigation facilities are small diversion works, mainly on the Wadi Karak. The diversion of the Mujib base flow to Ghor Safi is planned.

Domestic Water Supplies: Karak town obtains about 0.5 MCM/annum by pipeline from springs on the Wadi Karak.

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2.13.4. Present and Future Demands

Irrigation Water: The present demand for irrigation water has not been quantified but is exceeded by the supply. The only major planned increase in demand is the diversion of about 40 MCM/annum from the base flow of the Mujib to Ghor Safi.

Domestic Wadi Supply: Adequate water is available for the small village in the area from springs. The increase in demand for Karak town, which may reach 1.5 MCM by the end of the century, can probably be met from the Wadi Karak base flow. Alternatively, it could be produced from wells in Area 12.

2.13.5. Conclusions on the long-term Water Resource Situation in the Area

The major uncommitted resource is the base flow on the Wadi Zarqa Main which averages about 15 MCM/annum. However, this is poor quality water. The springs occurs at elevations ranging from sea level to -125 metres below sea level. The resources would be very expensive to mobilise. Losses of flood flows from the area to the Dead Sea appear inevitable.

2.14. Area 14 - The Hasa Area

The area occupies most of the catchment of the Upper Wadi Hasa to the east of the Wadi Araba escarpment. The main settlement is El-Hasa. The mean annual rainfall ranges from about 100 to 300mm.

2.14.1. Surface Wadi Resources

The surface water discharges within this area consist mainly of floods in the Wadi Hasa. Base flows in the river on this reach are very small. There are some isolated springs.

The mean annual flood runoff from the area in the Wadi Hasa averages 30 MCM/annum with a range of 1.5 to 127 MCM/annum. The only storage sites identified (at Tannur, five kilometres downstream of the Karak-Tafila road crossing, and at Ruweihi, about seven kilometres downstream of El-Hasa) are intended for flood control on Ghor Safi and could not be operated to provide water continuously through the year.

2.14.2. Groundwater Resources

The main aquifer system underlying the area is the Amman-Wadi Sir system. The mean annual recharge is estimated to be about 25 MCM/annum, most of which originates in the higher rainfall zone around Tafila. The most advantageous area for groundwater extraction is around El-Hasa where water levels are shallow and the well yields are high. In the mountain zone, the yields are lower but are usually adequate for domestic water supplies. It seems probable that extractions of up to 10 MCM/annum could be taken from near El-Hasa.

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2.14.4. Existing and Planned Facilities for Water Resource Development

Irrigation Supplies: Minor spring diversions near Tafila serve irrigation. Expansion of this area is not foreseen.

Domestic Water Supplies: The Tafila pipeline supplies Tafila town and a number of villages from groundwater. Groundwater supplies are delivered to the population of El-Hasa village and the new village housing workers on the phosphate development.

Mining Water Supplies: The phosphate development at El-Hasa is supplied from groundwater. An enlargement of this facility will be required to support expansion of the phosphate plant.

2.14.4. Present and Future Demands

Irrigation Water: The use of irrigation water has not been quantified but increased demands are not foreseen.

Domestic Water Supply: Pumping to the Tafila pipeline was 0.3 MCM in 1974. The requirements for the area may reach 1 MCM by the end of the century.

Mining Water Supplies: The 1975 demand for water at the phosphate plant is 3.2 MCM, increasing to about 8 MCM by 1980 and 10 MCM in the year 2000.

2.14.5 Conclusions on the long-term Water Resource Situation in the Area

The main demand will be met from groundwater. Supplies are adequate for increased domestic water demand. The demand for irrigation is not expected to increase. The limits of the supply from the El-Hasa area for the phosphate mines may be reached when the mines are fully developed. The available water is about in balance with the long-term future demand.

2.15. Area 15 - The Husseiniya Area

This area extends from the Fujeij region near the escarpment to the vicinity of Tell Burma. The mean annual rainfall ranges from less than 50mm on the desert to about 300mm near the escarpment.

2.15.1. Surface Water Resources

This area offers no surface water resources.

2.15.2. Groundwater Resources

The area is underlain by the Amman-Wadi Sir aquifer system. The mean annual recharge is about 6 MCM. It is considered that about this quantity of water could be exploited.

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2.15.3. Existing and Planned Facilities for Water Resources Development

Irrigation Supplies: There is about 1000 dunums of irrigation by groundwater in this area. The area could be extended to 4000 dunums.

Domestic Water Supplies: The only domestic water supply facilities are desert watering points and a piped supply to Husseiniya village.

2.15.4. Present and Future Demand

Irrigation Water: The present demand for irrigation water is about 1.5 MCM/annum. The future demand will depend on the decision whether to expand the groundwater irrigation area. The demand for 4000 dunums would be about 6 MCM/annum.

Domestic Water Supply: The present domestic water supply demand is very small. Large increases in demand are not foreseen.

2.15.5 Conclusions on the long-term Water Resources Situation in the Area

The area presently offers a surplus of groundwater for development. No developments, apart from increasing the irrigated area, are foreseen to utilise the surplus.

2.16. Area 16 - The Shaubak-Ras en Naqb Area

This area extends from the top of the escarpment between Shaubak and Ras en Naqb, eastwards to the longitude of Ma'an. The mean annual rainfall ranges from less than 50mm on the desert to 350mm in the vicinity of Shaubak.

2.16.1. Surface Water Resources

This area offers no surface water resources apart from a few minor springs.

2.16.2. Groundwater Resources

The Amman-Wadi Sir aquifer system underlies the area. The mean annual recharge is estimated to be 18 MCM/annum. A model study indicates that it is possible to extract about 15 MCM/annum from the area without incurring unacceptable water level declines.

2.16.3. Existing and Planned Facilities for Water Resources Development

Irrigation Supplies: There are minor areas of irrigation based on spring water. These areas cannot be extended. There is a small area irrigated by wells in the Shaubak valley and a small pilot development at Arja. The government plans to develop about 7500 dunums of irrigation by groundwater under the 1976-1980 plan.

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Domestic Water Supplies: The town of Ma'an is supplied by a pipeline from Talhouni well. Minor pipelines serve Udroh and Shaubak areas.

2.16.4. Present and Future Demand

Irrigation Water: The existing use of irrigation water from wells does not exceed 0.5 MCM/annum. The demand will increase is about 7 MCM/annum when the new development schemes are completed.

Domestic Water Supplies: The domestic water requirement for Ma'an is in the range of 0.5-1MCM/annum. The remainder of the population require about 0.5 MCM per annum. The total domestic requirement may be about 3 MCM/annum by the year 2000.

2.16.5. Conclusions on the long-term Water Resources Situation in the Area

The area at present offers a surplus of groundwater for development. Taking account of planned projects and population growth, a surplus of about 5 MCM/annum is available.

2.17. Area 17 - The Northern Wadi Araba Escarpment

This area extends from Wadi Hasa to about 25 km south of Wadi Musa. It forms a region of extremely broken country between the crest of the escarpment and the floor of the Wadi Araba. The mean annual rainfall ranges from 100mm on the foothills to 200-300mm at the top of the escarpment.

2.17.1. Surface Water Resources

The only major drainage system which traverses this area is the Wadi Hasa. The base flow in the Hasa at the outlet to Ghor Safi averages about 25 MCM/annum. The flood flows average about 30MCM/annum with a range of 1.5 to 127 MCM. There are no reservoir sites for regulation of either base flows or flood flows along the Hasa gorge in this area. Sites for two flood control regulators on the Wadi Hasa have been identified in Area 14.

A number of small catchments are contained within the escarpment area. The flood discharges are small and cannot be controlled. They flow to the Wadi Araba and infiltrate to groundwater.

The spring flows in this area total 10 MCM/annum, the most important springs being in the areas of Dana & Feifa, Ain Musa, at the head of water Musa discharges about 1 MCM/annum.

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2.17.2. Groundwater Resources

There are no important groundwater resources in this area. Locations might be identified for wells in the foothill zone.

2.17.3. Existing and Planned Facilities for Water Resources Development

Irrigation Supplies: All irrigation supplies in this area are provided by spring diversions. These facilities cannot be appreciably extended.

Domestic Water Supplies: The villages of the area obtain domestic supplies from springs.

2.17.4. Present and Future Demand

The demands for this area have not been quantified. Domestic demands are small and large increases cannot be foreseen. The irrigation demand will remain fixed at its present level. There may be future demand to divert spring flows from the Dana area for use of the copper developments.

2.17.5. Conclusions on the long-term Water Resources Situation in the Area

The supplies from springs and base flows will provide adequate water supplies for use within the area for the future. The base flows on the Hasa are committed for development of irrigation at Ghor Safi. The question of a possible demand for the copper mining development is unresolved.

2.18. Area 18 - The Southern Wadi Araba Escarpment

The area includes the mountain range of Shafat Ibn Jad extending from near Ras en Naqb to the frontier with Saudi Arabia south of Aqaba. The mean annual rainfall in the range of 50-100mm.

2.18.1. Surface Water Resources

The only permanent flows of water are provided by a few small springs. Flood flows are usually small and very erratic. The area offers no possibilities for mobilising surface water.

2.18.2. Groundwater Resources

The area is underlain by crystalline rocks of very low permeability. Groundwater may be contained in wadi bed alluvium. The major alluvial body is in the Wadi Utum gorge. The estimated recharge to the Wadi Utum alluvium is about 3.5MCM/annum and the safe yield is about 2.4 MCM/annum. The supply is committed to Aqaba.

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2.18.3. Existing and Planned Facilities for Water Resources Development

Irrigation Water: Water is not used for irrigation in this area. There is no possibility for future development.

Domestic Supplies: The Aqaba pipeline from the Wadi Utum gorge is the only domestic water supply facility.

2.18.4. Present and Future Demands

The only existing important demand is for Aqaba. The present rate of pumping is about 2.4MCM/annum. It is considered that the lower Wadi Utum alluvium cannot produce additional water supplies.

2.18.5. Conclusions on the long-term Water Resource Situation in the Area

The samll amount of groundwater which can be developed in this area has been mobilised.

2.19. Area 19 - The Quweira Area

The area forms a narrow strip of territory extending from the foot of the Ras en Naqb escarpment is the head of the Wadi Utum gorge. The mean annual rainfall is in the range of 50-100mm.

2.19.1. Surface Water Resources

The area offers no possibilities for surface water development.

2.19.2. Groundwater Resources

The area is underlain by a sandstone aquifer of the Disi Group. Mean annual recharge is about 3MCM/annum. It is considered that about this amount of water could be extracted on a safe yield basis. This rate of extraction would in the very long term effect the existing well field in the lower Wadi Utum gorge.

A recent model study has shown that the volume of water stored in the aquifer would support a long term depletion programme.

2.19.3. Existing and Planned Facilities for Water Resource Development

A small pipeline facility supplied by groundwater serves about 400 houses in Quweira village. Two wells have been drilled for the pipeline one of which is presently in operation. There is in addition one well providing water for stock and nomads.

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2.19.4. Present and Future Demands

The D.W.C. records show that 0.1 MCM were pumped to the Quweira pipeline in 1974. A large demand from the population in this area cannot be foreseen.

2.19.5. Conclusions on the long-term Water Resources Situation in the Area

The area presently offers a water surplus. Future local demands are not expected to exceed the supply. Water could be transferred to Aqaba. The amount and duration of the supply would demand on the rate of groundwater depletion accepted.

2.20. Area 20 - The Qa' Disi-Mudawara Area

This area occupies most of the Southern Desert of Jordan. The mean annual rainfall is less than 50mm.

2.20.1. Surface Water Resources

There are no perennial surface flows. Floods are generally small and extremely erratic. There are no possibilities for mobilising surface waters.

2.20.2 Groundwater Resources

The major aquifer system is formed by the Disi Group sandstones. This underlies the entire area. Minor aquifers are contained in the overlying Khreim Group sediments in the area around Mudawara. The groundwater resources in the Tubaik mountains to the east of Mudawara have not been investigated.

The Disi Group sandstone aquifer receives an average annual recharge of about 70 MCM. The reservoir storage in the system is immense and would support a long-term depletion programme. The most advantageous areas for exploitation of the resource, taking account of water levels and drilling depths are around Qa Disi, Sahl es Swan and Qa Ghal. Very shallow water levels occur around Mudawara but the drilling depths would exceed 600 metres. Well yields in excess of 200m^3/h can be obtained.

A model study has shown extraction of about 50 MCM/annum from the Qa Disi-Sahl es Swan - Qa Ghal area would cause water level declines of about 100 metres in the pumping area over a period of 50 years.

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2.20.3. Existing and Planned Facilities for Water Resources Development

The only important existing facilities are Government financed groundwater irrigation schemes serving 7500 dunums in the Qa Disi and Sahl es Swan areas.

It is planned to supply water for developments in Aqaba by water transfers from a well field in this area.

2.20.4. Present and Future Demands

The design requirement of the existing irrigation schemes is 15 MCM/annum. Bearing in mind the demand for Aqaba (see below and Section 2.21) it would appear that extension of the irrigated area should not be undertaken.

The demand for Aqaba may be in the range of 15 to 25 MCM by 1990 depending on the scale of the development actually implemented and the projected per capita demand accepted for the forecast (see section 2.21). The long-term source of most of this water supply will be the Qa Disi area.

2.20.5. Conclusions on the long-term Water Resource Situation in the Area

The area presently offers a large water surplus. However, the requirements of the existing irrigation systems and the future demands for Aqaba from the Qa Disi area will induce considerable head declines over the next 50 years. The declines will be most marked during the early stages of pumping and the system will not be in equilibrium by 2025. The future pumping levels will be acceptable for domestic and industrial supplies but will become marginal for agriculture. It is recommended that no further demands than those planned for Aqaba and the existing irrigation should be planned until the actual response of the system to withdrawals has been observed.

2.21. Area 21 - The Wadi Araba

This area covers the floor of the Wadi Araba from the southern end of the Dead Sea to the head of the Gulf of Aqaba. The narrow strip along the coast of the Dead Sea to the Lisan peninsula is included. The mean annual rainfall is in the range of 50 to 100mm.

2.21.1. Surface Water Resources

The only surface water flows which can be utilised occur at the northern end of the area around Ghor Safi where Wadi Hasa and a number of minor wadis discharge to the Wadi Araba and the Dead Sea coastal zone. The most important source is the Wadi Hasa with a base flow of 25 MCM. The mean annual flood flow on the Hasa is about 30 MCM/annum with a range of 1.5 to 127 MCM. Two small reservoirs have been identified on the Wadi Hasa in Area 14 but these would function as flood regulators to provide protection to the irrigated areas on Ghor Safi. It would appear inevitable that flood water losses to the Dead Sea must be accepted in high run off years.

The base flows in the Wadis Khuneizira, Feifa and Hudeira total about 5.4 MCM/annum. The total base flows from side wadis on the Dead Sea coastal strip to Lisan total about 7 MCM/annum.

It is planned to divert about 40 MCM/annum from the base flow of the Wadi Mujib to the southern ghors.

2.21.2. Groundwater Resources

The groundwater resources of Wadi Araba have not been investigated. A study is presently being initiated. In general the groundwater is of poor quality. However, good quality water should be present in the fans of wadis which discharge into the area.

2.21.3. Existing and Planned Facilities for Water Resources Development

Irrigation Supplies: The existing irrigated areas are concentrated at the northern end of the Wadi Araba on Ghor Safi and Ghor Feifa, extending intermittantly along the coastal strip on the Dead Sea as far north as the Lisan Peninsular. The area presently irrigated has been estimated as 34,000 dunums but the intensity is very low. The areas of irrigation are subjected to flood damage. The Government plans to develop irrigation facilities on a gross area of 54,000 dunums. The water sources will be from the Wadi Hasa and the small side wadis adjacent to the development area and a diversion from the Wadi Mujib. At full development, storage may be required on the Mujib and flood control will be required on the Hasa (see Sections 10, 11 and 14).

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Domestic and Industrial Water Supplies: The only important domestic water supply facility is for Aqaba town. The town presently obtains most of its water from wells in the lower Wadi Utum (Area 18) though poor quality water is obtained from wells adjacent to the town. Developments in the Aqaba area will demand additional water supplies for the resident population, for tourism, for the port and for industrial developments. It is planned to import the bulk of the water required by pipeline from the Qa Disi area (Area 20). An alternative source for part of the supply would be the Quweira area (Area 19).

Possible future facilities are for the potash development at the southern end of the Dead Sea and a copper development near the Wadi Dana.

2.21.4. Present and Future Demands

Irrigation Water: The present irrigation requirements have not been quantified. The long-term plan for irrigation of the southern ghors will require about 80 MCM/annum. This will utilise all the base flows of the Hasa and adjacent side wadis plus a diversion of about 40 MCM from the base flow of the Wadi Mujib Storage on the Wadi Wala and Upper Wadi Mujib may be required to ensure the security of the Mujib diversion supply. There may therefore be competition for water should the Rumeil Dam supply on the Wadi Wala be required for the Amman Area.

The Aqaba Development: The plans for the Aqaba area include tourism, the extension of the port facilities and provision of a free trade zone, and development of industry. The last will consist of a phosphate fertilizer plant in the early stages- a refinery may be added at a later stage. Table 9 and 10 summarise the low and high projected demands developed by Tippets, Abbet, McCarthy and Straton, Consulting Engineers for the proposed Aqaba development.

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Table 9. Demand for Water - Aqaba Development
Low Projection (in MCM)

Year	Domestic Water	Phosphate Plant	Refinery	Port FTZ	Other	Tourism	Total
1975	1.8	-	-	0.1	-	0.1	2.0
1980	3.7	1.8	-	0.4	0.2	0.1	6.2
1985	4.7	1.8	-	0.4	0.3	0.3	7.5
1990	6.5	3.0	-	0.5	0.5	0.4	10.9

Table 10. Demand for Water - Aqaba Development
High Projection (in MCM)

Year	Domestic Water	Phosphate Plant	Refinery	Port FTZ	Other	Tourism	Total
1975	1.8	-	-	0.1	-	0.1	2.0
1980	3.9	2.4	-	0.4	0.3	0.1	7.1
1985	6.6	4.4	1.7	0.4	0.5	0.4	13.9
1990	8.8	5.0	1.6	0.5	0.7	0.7	17.3

The projections provided in Tables 9 and 10 are based on per capita demands 110 m^3/cap/year-78 100m3/cap/year, in 1979 and 90m^3/cap/year thereafter. Allowing 20% for losses, the supply must be 13.7 MCM to meet the 1990 low projection and 21.6 MCM to meet the 1990 high projection.

Assuming 120m^3/cap/yr demand and 20% losses, the low projection supply will be 16.4 MCM in 1990 and the high projection will reach 25.3 MCM in that year.

The above supplies cannot be obtained from the Aqaba area or from the Lower Wadi Utum gorge, which has a safe yield of 2.4 MCM/annum. Part of the supply could be obtained from the Quweira area (Area 19) but extractions in excess of about 3 MCM/annum would involve long-term mining of this supply. The long-term, firm source of supply is Qa Disi (Area 20).

Possible Demands for Copper and Potash Development

The possible development of copper mining and smelting based on the ore body near Dana would have a water requirement of about 6.5 MCM/annum in 1980 rising to 15 MCM in the year 2000. The source of the water supply has not been identified Possible sources are spring water in the escarpment area (Area 17) and groundwater from the Wadi Araba.

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Extraction of potash from Dead Sea water may be undertaken. The demand for water would be 1.75 MCM/annum, exclusive of flushing water. The supply could probably be obtained from groundwater in the Ghor Safi area. An assured source would be an allocation from the base flow of the Wadi Hasa.

2.21.5. Conclusion on the long-term Water Resource Situation in the Area

The proved surface water resources of this area have been committed. Water transfers are necessary to support the planned developments. Groundwater exploration should be undertaken as a matter of high priority.

2.22. Area 22 - The Jafr Area

This is a small area around the Jafr oasis. The mean annual rainfall is less than 50mm.

2.22.1. Surface Water Resources

There are no possibilities for storing surface water. The occasional floods discharge to the Qa Jafr and evaporate. The possibility of inducing recharge to groundwater by check dams and flood spreading should be investigated.

2.22.2. Groundwater Resources

Groundwater is contained in a shallow aquifer system formed by the Rijam Formation. Water quality has deteriorated below the presently irrigated area. The mean annual recharge is about 6 MCM.

The Amman- Wadi Sir system underlies the area at depth. Static water levels are 75-100 metres below ground surface. Water quality is fair (about 1000 to 1200 ppm). Well construction costs will be high due to the presence of loose, fine sand in the aquifer. The recharge is small and occurs as underflow from adjacent areas. The reservoir capacity is large. Controlled aquifer depletion could be envisaged.

2.22.3. Existing and Planned Facilities for Water Resources Development

The Government irrigation facility at El-Jafr is based on groundwater and serves about 3000 dunums

It has been suggested that the new phosphate plant at Shadiya to the southwest of Jafr in Area 2 may obtain water from the Jafr area.

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2.22.4. Present and Future Demands

The 1974 pumping for irrigation at Jafr is reputed to have been 2.4 MCM. This is insufficient for full development of 3000 dunums. The requirement for the existing irrigation facility may increase to between 4.5 - 6 MCM/annum.

The demand for the Shadiya phosphate plant may reach 6 MCM/annum by 1980 and 10 MCM/annum by the year 2000. It is very doubtful whether this supply can be assured from the shallow aquifer system at Jafr, even on the basis of long-term depletion.

2.22.5. Conclusions on the long-term Water Resources Situation in the Area

A large part of the rechargeable groundwater in the shallow aquifer system has been committed. An attempt to extend the irrigated area or meet the demands of the Shadiya phosphate plant would probably put the system on overdraft. Given the importance of the phosphate development, the effects of various rates of extraction from the Jafr area require detailed study.

2.23. Area 23 - The Eastern Desert Plateau

The area includes essentially the entire desert plateau of east Jordan to the border with Saudi Arabia excluding the Azraq South area (Area 9) and the Jafr Oasis area (Area 23). The mean annual rainfall ranges from less than 50 mm in the east to 100-150mm in the west.

2.23.1. Surface Water Resources

The area offers no possibilities for development of surface water.

2.23.2. Groundwater Resources

The Amman-Wadi Sir aquifer system underlies the entire area. Recharge is small and occurs mainly as underflow from adjacent areas. The reservoir storage in the aquifer system is very large and would sustain a long-term depletion programme. Water levels are generally less than 150 metres below ground surface in the west of the area (areas with less than 100 metres water levels occur) but water levels increase fairly rapidly to the east. Drilling depths also increase to the east. Well construction costs will be high in the south eastern segment of the area embracing the Jafr oasis. Well productivity deteriorates in this segment. The water quality is generally better than 1000 ppm in the western part of the area.

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The western part of the Sirhan basin is included in the area. Groundwater of variable quality can be obtained from shallow aquifers in this region. The quantity of water available is not known, but the recharge will be small.

2.23.3. Existing and Planned Facilities for Water Resources Development

The only existing facilities are a few desert watering points.

The new phosphate plant at Shadiyah will require water. As the water cannot be obtained from the Shadiyah area, a pipeline conveyance will be necessary.

2.23.4. Present and Future Demands

Existing demands are minimal. The only large scale future demand identified is for the phosphate plant at Shadiyah which could require 6 MCM/annum by 1980 and 10 MCM/annum by the year 2000.

2.23.5. Conclusions on the long-term Water Resources Situation in the Area

It is unfortunate that, while the area as a whole offers surplus groundwater, the Shadiyah phosphate development is located in that part of the area where groundwater resources are minimal. Wells in the Amman-Wadi Sir aquifer near Ma'an railway station would have water levels of about 130 metres below ground surface and exploration extending south-eastwards from Ma'an migh be justified. The shallow aquifers of the Jafr area (Area 22) appear to provide an uncertain supply, but his should be verified. Deep wells near Jafr to the Amman-Wadi Sir aquifer would be expensive to construct. Given this situation, the water supply for the Shadiyah phosphate plant requires careful investigation.

2.24. Area 24 - The H4 - H5 Areas

This includes the entire "Panhandle area" to the east of Areas 8 and 9. The mean annual rainfall is less than 50 mm.

2.24.1. Surface Water Resources

This area offers no possibilities for surface water development.

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2.24.2. Groundwater Resources

The groundwater resources of the area have not been quantified but the rechargeable resource is believed to be small . The groundwater is contained in basalt aquifers in the western half of the area and in limestone aquifers in the eastern half. Water levels are generally deep and the water quality is usually poor.

2.24.3. Existing and Planned Facilities for Water Resources Development

The existing water supply facilities consists of a number of single well installation to supply nomadic people and army encampments. A branch of the Irbid pipeline extends to H5. No major developments are foreseen.

2.24.4. Present and Future Demands

Present demands in this large area are relatively small. Estimates indicate that current pumping from all wells for domestic supplies and stock watering totals 0.6 MCM/annum. Large increases in demand are not foreseen.

2.24.5. Conclusions on the long-term Water Resources Situation in the Area

This area offers very limited groundwater resources and no surface water resources. Nevertheless it should be possible to supply the demands for domestic and stock water from wells in the area, though poor quality water may have to be accepted.

3. Recapitulation on Important Areas

3.1. The Jordan Valley

The planned developments for irrigation on the east bank of the valley commit essentially all the available water resources. If large demands are made in the future for developments on the west bank of the valley, the area will be in deficit.

3.2. The Northern Districts

Provision of domestic water supplies will continue to provide problems. Larger water transfers will be required. The possibility of obtaining groundwater from the Husn-Nu'aime area should be investigated though high lifts and relatively low yielding wells will have to be accepted. The water resources available from the Sama Sdud area should be properly evaluated and supplies allocated to the Irbid pipeline. In the longer term, greater reliance may have to be placed on imported supplies from groundwater at Azraq. This source of supply should be properly evaluated. The Azraq water is presently uncommitted. A firm supply could be obtained from surface water in the Yarmouk but this would be to the detriment of the Jordan Valley.

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3.3. The Amman-Zerqa Area

This area will probably move into deficit during the 1880's. Meanwhile, the Amman-Wadi Sir aquifer of the valley is believed to be under-exploited. The first priority is to make a proper assessment of the safe yield of this system. Insofar as a large proportion of the water supplied for domestic use is not consumed, provision should be made for recycling reclaimed sewage water, probably through the aquifer system. Polution control for industrial effluents may be necessary.

Possible major sources of imported water should be evaluated and their costs of mobilization compared.

These include:-

a. Groundwater and/or surface water from the Wadi Wala catchment. A possible storage reservoir yielding about 25 MCM/annum has been identified at Rumeil at an elevation of about 600 metres M.S.L. and about 40 km from Amman.

b. Groundwater from the Azraq area (10-20MCM/annum). This supply is at an elevation of about 500 metres and about 80 km from Amman. The supply may be needed for the Northern Districts.

c. The base flow of the Zerqa Main (about 15 MCM/annum). This supply is at 125 metres below sea level and at a distance of 50 km from Amman over rugged terrain.

d. The King Talal dam. The dam is at an elevation of about 75 metres and at a distance of about 40 km from Amman over rugged country. The water has been committed to the Jordan Valley.

3.4. The Hasa Phosphate Development

The future demands for water (8MCM in 1980 - 10 MCM in 2000) must be met from groundwater. The available supply within the vicinity of El-Hasa should be properly evaluated.

3.5. The Shadiyah Phosphate Development

Provisions of water for this development will present difficulties. The possibility of obtaining supplies from the Amman-Wadi Sir aquifer in the Mean area should be investigated. The exploitable resource from the shallow aquifer system of the Jafr area should be properly evaluated.

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3.6. The Aqaba Development

The supply for developments in the Aqaba area is assured from Qa Disi. Part of the supply could be obtained by depletion of the aquifer system below Quweira. Desalinization of sea water at Aqaba or brackish water from the Wadi Araba are not economically comperative with mobilising groundwater from either Disi or Quweira.

3.7. Irrigation of the South Ghors

The first phase plan for irrigation of the South Ghors will utilise the base flows of the Hasa and the smaller wadis in the vicinity of the irrigated area and the base flow of the Mujib by diversion.

3.8. Possible Potash Development at the Dead Sea

The relatively small water requirement for this development could be supplied by an allocation from the Hasa base flow or possibly from groundwater. The latter requires investigation.

3.9. Possible Copper Development at Dana

This development, if undertaken, will have a large water requirement (6.5 MCM in 1980; 15 MCM in 2000). The source of the supply has yet to be identified.

Amman 28/8/1975

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WATER RESOURCE AREAS

28/8/1975

FIG. 1