WATER USE STRATEGY

NORTH JORDAN

1978

SUMMARY REPORT

Prepared for
The Government of
THE HASHEMITE KINGDOM OF JORDAN

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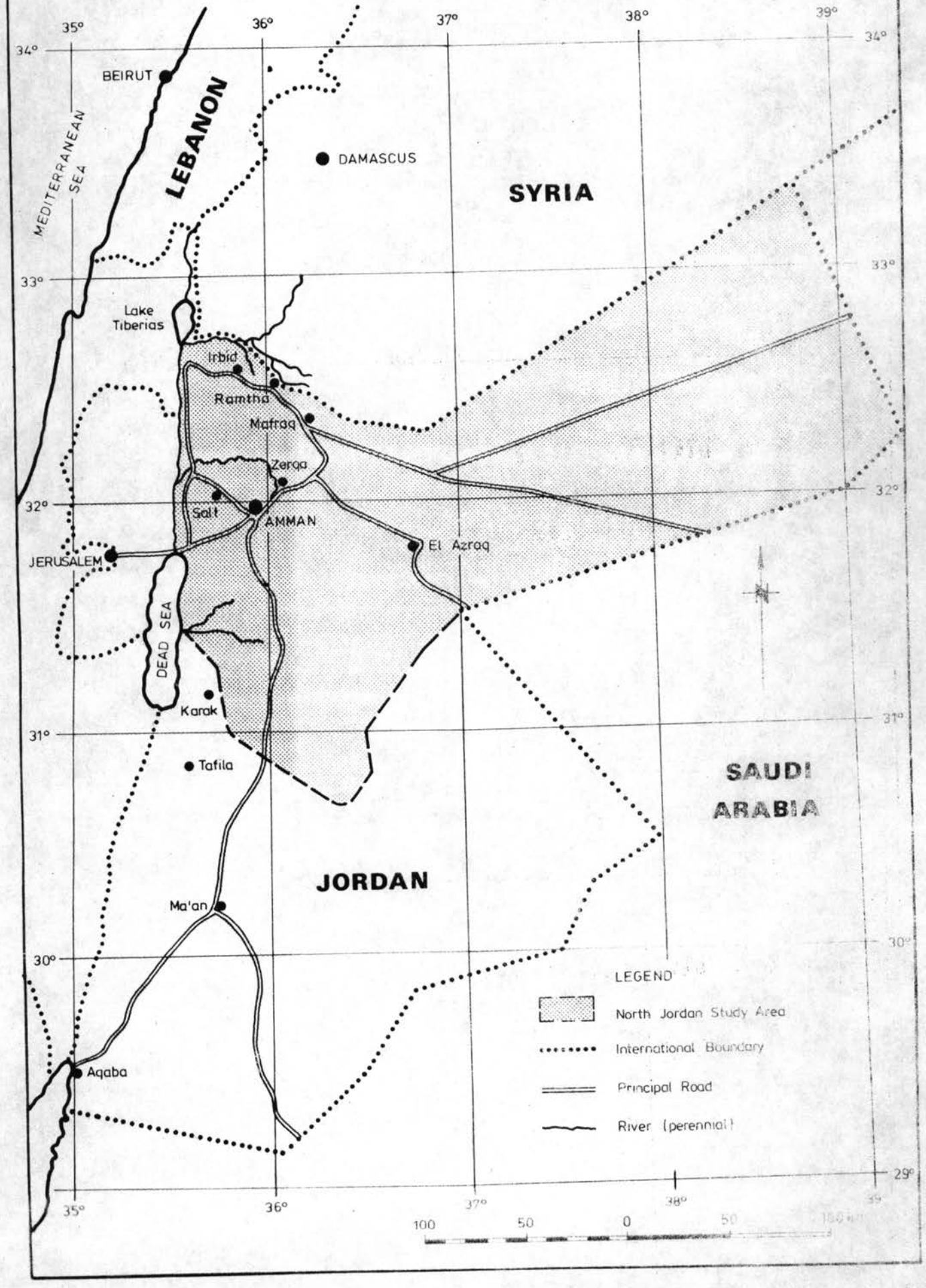
Figure 1

LOCATION MAP



INTRODUCTION

Location of Study

The study area covers the whole of North Jordan and has been defined as that area to the east of the River Jordan and extending from the Syrian border in the north to the southern limits of the Wadi Mujib and Azraq surface catchments. The area, which measures approximately 49 000 km^2, is illustrated on the location map (Fig. 1).

Background to Study

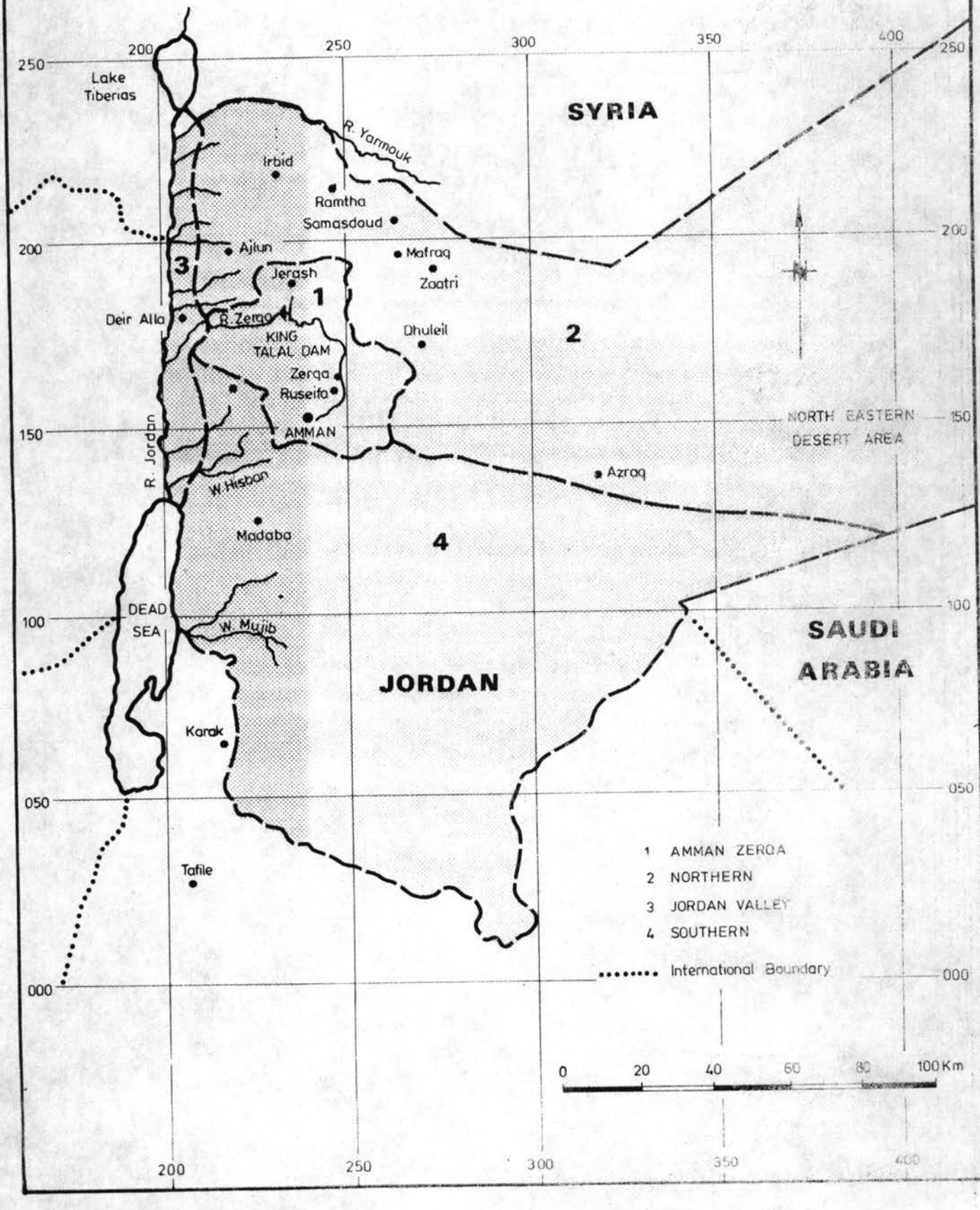
For some years now it has been recognised that water resources in Jordan are limited and eventually will not be able to provide for the increasing water demands of the municipal and agricultural sectors. A number of studies relating to regional and national resources have been carried out in the last twenty-five years, the most comprehensive being the recently completed National Water Master Plan (Agrar und Hydrotechnik, 1977). However the Master Plan only suggests an outline policy for the use of the nation's resources and does not examine the question of water supply policy in depth.

The study area includes some of the largest centres of population in the whole country. Supplies of potable water in these centres are generally insufficient, the shortage being particularly acute in the Amman-Zerqa area and Irbid. Moreover the situation will deteriorate with the continued growth of both population and the economy. The area also contains some of the most valuable agricultural land in Jordan and, given adequate supplies of irrigation water, there is considerable potential for increased development.

In these circumstances it was evident that there was an urgent need to examine the question of water supplies and, through an arrangement with the British Ministry of Overseas Development, Howard Humphreys were engaged in association with Peat Marwick Mitchell and Company and Minster Agriculture to prepare for the Government of Jordan a domestic and industrial water use strategy for the northern part of the Kingdom for a 25 year period up to the year 2002.

Figure. 2

WATER SUPPLY DISTRICTS



STUDY AREA

Geography

The study area can be divided into three geographical regions, namely the Jordan Valley, Highlands and Desert.

The Jordan Valley extends from Lake Tiberias in the north to the Dead Sea in the south and lies below sea level over its whole length. This is the hottest of the three regions with low rainfall which diminishes southwards. The economy of the region is predominantly based on agriculture and the land is assessed to have the highest potential agricultural value of any in the Kingdom.

The Highlands Region lies between the Jordan Valley and the Desert Region and flanks the west bank of the River Jordan and Dead Sea forming a well defined escarpment. The climate is cooler and rainfall heavier than in other parts of the Kingdom. Although comprising only 25% of the study area, almost 90% of the population lives in this region which includes Amman, Zerqa and Irbid. Industry and commerce is mainly centred around Amman-Zerqa with the remainder of the region comprising agriculturally based communities.

The Desert Region lies to the east of the Highlands Region and takes in the remainder of the study area. It is influenced by a continental climate with extremes of temperature and very low rainfall. The region is sparsely populated by nomadic peoples. Some agriculturally based desert resettlement schemes have been established.

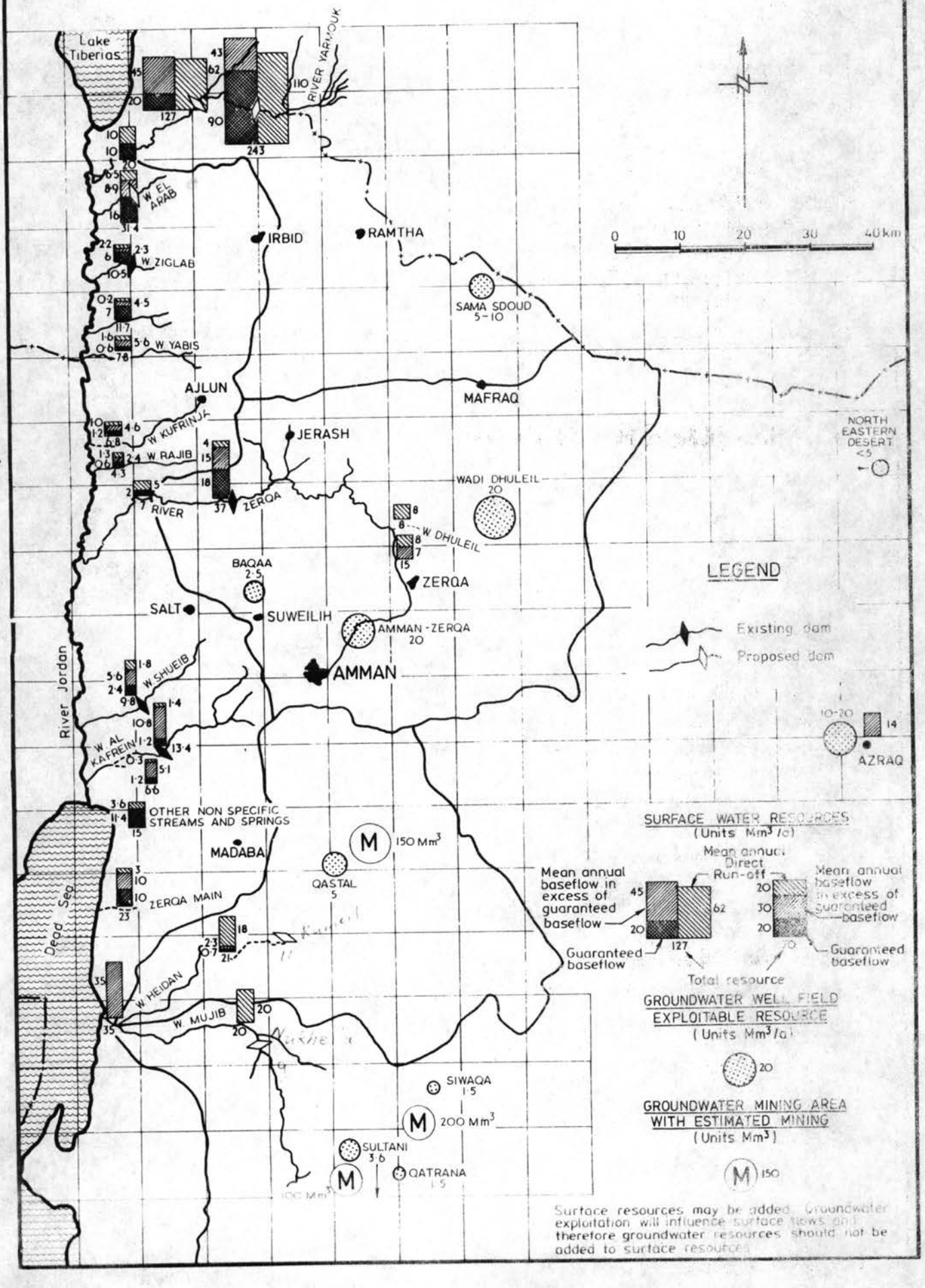
Existing Water Supplies

The Amman-Zerqa conurbation accounts for some 80% of the estimated total municipal demand of North Jordan. Existing supplies amount to about 30 Mm^3/a which is only about half of the estimated demand and in the hot summer months, supplies are available only on a zonal basis for perhaps one day per week. These supplies are drawn from local wells which are already over exploiting the resources. Firm proposals for improving the present supply situation comprise rehabilitation of existing boreholes as an interim measure to temporarily increase the output from the wellfield, and a scheme to transfer up to 22 Mm^3/a from the newly constructed King Talal Dam.

Outside the Amman-Zerqa conurbation there are two major supply systems, the larger serving Irbid and the Northern Supply District which extends across the northern part of the study area (Fig. 2). This network is served by wellfields at Azraq, Dhuleil and Samasdoud. At present there is an acute shortage in Irbid which accounts for more than one third of the total demand in the Northern Supply District and is expected to absorb more than half by the latter half of the study period. The second major distribution system, known as the South of Amman System, extends some 40 km south of Amman to include Madaba. This system is served by wells near Amman and from a newly commissioned wellfield at Qastal. Other smaller systems serve groups of towns and villages, or individual communities. Apart from some of the larger municipalities, these supply networks are generally operated by the Water Supply Corporation.

Figure 3

WATER RESOURCES



DEMANDS AND RESOURCES

Water Supply Districts

For the purposes of tabulating demands, the study area has been divided into four districts. These are shown on Figure 2 and are as follows.

1. Amman-Zerqa
2. Northern
3. Jordan Valley
4. Southern

Municipal Demands

The present national population growth is estimated to be around 3½% per annum and future projections and present levels of population for each of the four districts are shown in Table 1 below.

TABLE 1 – Estimated Population

	District	Population in 1000's		
		1977	1987	2002
1	Amman-Zerqa	1 076	1 625	2 906
2	Northern	463	573	786
3	Jordan Valley	75	148	247
4	Southern	200	213	279
	Totals	1 814	2 559	4 218

From these population projections domestic and industrial demands (termed collectively "municipal demands") have been estimated and they are summarised in Table 2.

TABLE 2 – Municipal Water Demand

	District	Demand (Mm^3/a)		
		1977	1987	2002
1	Amman-Zerqa	57	107	230
2	Northern	16	24	40
3	Jordan Valley	1	4	8
4	Southern	6	11	11
	Totals	80	146	289

It should be noted that the present (1977) demands are by no means satisfied and by 1987 the demand in the Amman-Zerqa District will be more than three times the present production and five times the safe yield of present sources used.

Agricultural Demand

Agricultural demand projections are largely based on the National Water Master Plan and are as follows:-

TABLE 3 – Estimated Agricultural Water Demands

	District	Demand (Mm^3/a) 1977	1987	2002
1	Amman-Zerqa	49	49	77
2	Northern	89	80	94
3	Jordan Valley	194	411	407
4	Southern	52	99	116
	Totals	384	639	694

It is thus evident that the agricultural sector makes by far the greatest demands on the Kingdom's water resources.

Exploitable Resources

A summary of the estimated reliable yields of known sources is given in Table 4 below, and is illustrated in Figure 3.

TABLE 4 – Known Exploitable Resources

Groundwater		Surface Water	
Source	Resource (Mm^3/a)		Resource (Mm^3/a)
Samasdoud	8	Yarmouk	390
Azraq	10	Azraq	10
Dhuleil	20	Zerqa (Deir Alla)	67
Amman-Zerqa	20	Ajlun Area	72
Baqa'a	2.5	Salt-Madaba Area	68
Qastal	5	Mujib Area	76
Qatrana	1.5	Total surface (gross)	683
Siwaqa	1.5		
Sultani	3.5	Of this gross resource the amount which could economically be exploited is:-	
Minor sources (N.E. desert)	5		
Total ground	77	Net surface resource	550

The combined resources are therefore of the order of 627 Mm^3/a of which the largest single contribution is from the Yarmouk River. In addition to these replenishable resources which may be exploited indefinitely, some 350 Mm^3 of stored water is available at Sultani and South East Qastal for mining over a limited period.

Further potential resources exist in the Eastern Sandstones which underly the study area, but this aquifer lies at depths up to 1000 m and limited available evidence suggests that water quality is poor. Extensive field investigations are required to verify this source and these are not considered justifiable for the present.

Recycling and Reuse

In circumstances of limited resources the fullest possible use should be made of all water available, including its reuse. In Amman it is probable that more than half the water supplied to domestic consumers is returned to the cycle either as surface flow or groundwater, a proportion of which will be available for abstraction for municipal and agricultural purposes. (The return from industry and agriculture is generally much less and is considered negligible in the present context).

In arid areas of the world there are a number of projects based on the direct reuse of waste water from treatment works, but these schemes have not been in operation for a sufficient period for any long term health risks to be identified. In the present circumstances it is considered that direct reuse schemes are not justified in Jordan. Indirect reuse will occur however, from waste water discharged either to ground or as surface flows impounded at King Talal Reservoir. Considerable natural purification takes place, although if dilution by natural recharge or imported water is insufficient, problems may arise with salinity, eutrophication, nitrates and pathogenic organisms.

Computer runs on a mathematical model similating the Amman-Zerqa-King Talal system have indicated that salinity concentrations will still be at acceptable levels by the end of the century. The problem of eutrophication, which occurs when nutrients in a body of water build up to a level sufficient to support prolific algal growth, can be dealt with by careful monitoring of the reservoir at all depths, by suitable positioning of the outlets and by good reservoir management and treatment. Among the nutrients occurring, nitrates are a particular problem in that in sufficient concentrations they are known to cause blood disorders in very young children. Again with careful monitoring of both reservoir and ground water the problem can be controlled, if necessary by tertiary sewage treatment or dilution with fresh water imports. Finally the presence of pathogenic organisms is not seen as a serious problem as these are virtually eliminated by normal treatment processes.

Water Balance

The availability of, and demand for, water can be compared in a water balance as shown below in Table 5. For this purpose it has been conservatively assumed that one third of the consumption of the Amman-Zerqa District will be reused.

TABLE 5 – Water Balance

Description	Water Volumes (Mm^3/a)					
	1977		1987		2002	
Resources						
Potential Resources (Table 4)	760		760		760	
Not recoverable	133	627	133	627	133	627
Re-use		5		35		75
		632		662		702
Demand						
Municipal (Table 2)	80		146		289	
Agricultural (Table 3)	384		639		694	
Yarmouk Triangle	17	481	17	802	17	1000
Surplus (Deficit)		151		(140)		(298)

If present projected demands are to be met, the above balance indicates that there will be a supply deficit by the early 1980's, and that a reduction in municipal or agricultural demand is necessary. Restrictions in domestic supplies are generally both impractical and ineffective and can give rise to serious health hazards. Also from the point of view of the economy, indications are that it is uneconomic to constrain the development of industry and commerce.

For these reasons it has been assumed in the development of water strategies that projected municipal demands will be fully satisfied although every effort should be made to avoid wasteful use and to utilise recycled water as far as possible.

DEVELOPMENT OF A STRATEGY

General Approach

In the situation where the municipal and agricultural sectors are competing for the same resource, it is not sufficient to determine the best (least cost) solution for satisfying municipal demands in isolation but rather the position must be examined on a broader basis to determine the strategy which provides the greatest benefit to the nation as a whole. Costs and benefits have been derived therefore, not only for the development of sources for municipal supplies, but also for developing where feasible these same sources for agricultural purposes. In making the final selection of development strategy for North Jordan's water resources unquantifiable aspects such as social, environmental and political have also been taken into account.

Alternative Strategies

The municipal demand for Amman-Zerqa and Irbid will represent about 85% of the total demand for North Jordan by the year 2002, and although the importance of supplies to other areas cannot be neglected it is clear that the supply of Amman-Zerqa and Irbid are the major elements influencing the formulation of the strategy. Consequently some of the resources listed in Table 4 have been excluded from the main strategy. The many small dispersed sources are not considered useful in the context of the large urban demands.

The Zerqa Ma'in source (Salt-Madaba) has also been excluded on the grounds of high pumping and demineralisation costs, along with most of the tributary wadis to the Jordan River (Ajlun and Salt-Madaba) which are used for irrigation in the Jordan Valley.

Many development strategies have been examined for the supply of Amman-Zerqa but in the final analysis these have been reduced to six. The two strategic extremes are represented by schemes using only the Maqarin and King Talal sources on the one hand, and fully exploiting the desert sources on the other. Supplies to Irbid are assumed to come from Maqarin.

With regard to allocations to agriculture, there will initially be a surplus of water available (with projected demands satisfied) but this will diminish with increasing municipal demand. The projected situation is summarised in Table 6 below.

TABLE 6 – Allocation of Resources

Allocation	Consumption (Mm^3/a)		
	1977	1987	2002
Total resource (demand) (Table 5)	(464)	645(1)	685(1)
Municipal demand (Table 2)	80	146	289
Balance to agriculture (demand)	(384)	499	396

(1) Available resource less allocation of 17 Mm^3/a to the Yarmouk Triangle.

Improved irrigation efficiencies and revised cropping patterns could largely offset the reduction in supplies available to agriculture in the second half of the study period. It is however important that account be taken in long term agricultural planning of the declining water resources available to this sector.

Some of the strategies consider the exploitation of stored non-replenishable desert groundwater resources by mining for local agricultural use. They have also been examined for municipal supplies thus making available renewable water for other sources for agriculture in the Jordan Valley.

Costs and Benefits of Alternative Strategies

The costs and benefits associated with each alternative strategy have been estimated and discounted over a 40 year period for the purposes of comparison. They showed that a strategy taking water from the Jordan Valley for municipal purposes is likely to yield the lowest return – whilst the greatest benefits are likely to be achieved by making maximum use of the desert sources for municipal supplies. Although the difference in benefits between the extreme strategies amounts to JD 65 million, this constitutes only some 10% of the gross benefits involved. It is also worth noting that the agricultural benefits calculated for the Jordan Valley are based on optimistic assumptions regarding efficiencies and failure to achieve these would reduce the benefits accrued. Furthermore, no allowance has been made for resettlement costs arising from the curtailment or abandonment of existing desert irrigation schemes caused by the diversion of resources for purely municipal supply and the inclusion of these costs would further narrow the difference between the strategies. Too much importance therefore should not be attached to the apparent economic advantages inherent in any particular strategy. Two main conclusions can be drawn however with respect to municipal supplies.

(1) The use of Maqarin Reservoir should be delayed as long as possible.

(2) The desert sources should be exploited to their fullest extent possible.

DESERT SOURCES

General Considerations

It has been shown that the retention and promotion of desert irrigation schemes will, by placing a heavier burden on the Jordan Valley water resources for municipal supplies, reduce the overall agricultural economic benefit to the nation. However, abandonment of the desert agricultural schemes would not only necessitate very substantial resettlement costs but would have serious social and political repercussions by removing the livelihood and causing disruption of many settled communities. Furthermore to centre all agricultural development on the more lucrative Jordan Valley would cause a major drift in population and would be contrary to the aims for regional development implicit in the Government's Five Year Plan. Environmental considerations are also of importance in development planning.

The various desert sources are now considered in more detail.

Azraq

The yield of this source is estimated to be 20-25 Mm^3/a. Were abstractions increased significantly above present levels (9 Mm^3/a) however, the flow in the swamps of the Azraq Oasis might dry up thereby undermining the ecological balance of the area. In this connection Azraq is considered an internationally important point on bird migration routes. It is also considered to have value as a tourist attraction and there are possibilities for fish farming. Were Azraq to be fully exploited for municipal supplies, exhaustive and expensive hydrogeological investigations would first be needed in order to verify the quantity abstractable. For these reasons it is considered that Azraq should be developed as a nature reserve and for local agricultural and municipal requirements. If however the Government feels that there are insufficient reasons for excluding the springs from the water supply strategies then it is probable, following a modest investigation, that 10-15 Mm^3/a of good quality water could be safely abstracted for use in Amman-Zerqa.

Dhuleil

The rechargeable yield of Dhuleil is estimated to be 20 Mm^3/a and at present the rate of abstraction for irrigation purposes is approximately double this safe yield. The area was originally set up as a desert resettlement scheme and to divert its resources for municipal supplies would incur large resettlement costs and much social hardship. Although Dhuleil would provide an extremely cheap source of water its use for municipal purposes is therefore considered undesirable.

Samasdoud

The reliable yield of this source is estimated to be up to 10 Mm^3/a which is adequate to satisfy the present local demands for irrigation (4 Mm^3/a) and municipal supplies (2 Mm^3/a) and for the estimated increase in municipal requirements of the Northern District east of Ramtha up to the end of the study period (4 Mm^3/a).

There are no environmental or social reasons why this source should not be exploited for municipal supply as long as present irrigation levels are not increased and it is proposed that the wellfield be fully developed for local municipal requirements.

Qastal and S E Qastal

The rechargeable yield of Qastal is assessed as 5 Mm^3/a. At S E Qastal there is no significant natural recharge but it is estimated that some 150 Mm^3 could be mined from groundwater storage.

Qastal provides about 1 Mm^3/a for local municipal supplies which are supplemented by exports from Amman. The projected demand in the area (served by the South of Amman Supply System) is estimated to rise to about 5 Mm^3/a by 2002 and Qastal could be developed to meet this demand. This would be the most economically attractive use of this source in that it makes the area independent of supplies from Amman, thereby releasing more water for use in the Jordan Valley.

The S E Qastal resources should be mined to provide a modest irrigation scheme to complement the development of the region.

Rumeil

This is an impounding scheme to store flood flows in Wadi Wala. The estimated yield is 12 Mm^3/a but due to the erratic nature of run-off in the Wadi it is probable that it would take at least five years to store an adequate volume of water to guarantee a constant supply. It is economically advantageous to transfer water from Rumeil for use in Amman, thereby releasing a like amount for irrigation in the Jordan Valley. There is no local irrigation use at present and any future schemes would not result in the economic benefits expected in the Jordan Valley.

Siwaqa, Qatrana, Sultani

The rechargeable yield of the aquifer is assessed at 6 Mm^3/a of which 4 Mm^3/a is at present used for local irrigation. In addition there is an estimated 200 Mm^3 of stored groundwater which could be mined for a short period to supply Amman and so postpone investment in the Maqarin Scheme. However a difficult and extensive site investigation would be necessary to prove the source and when the source is exhausted the capital works would be largely abandoned and major compensatory imports required from the Jordan Valley. Consequently it does not appear justifiable to exploit this resource for major municipal supplies and it is recommended instead that the area be mined slowly over a long period for local agriculture. Such a policy would be consistent with the Five Year Plan for Economic and Social Development.

PROPOSED STRATEGY

Amman-Zerqa

Taking into account not only the quantifiable aspects of the various strategies but also the social and political implications of their adoption, a recommended strategy for the Amman-Zerqa area is now presented in Fig. 4 and in Table 7. Production from the Amman-Zerqa wellfield should be maintained at its present rate (28 Mm^3/a). Immediate future supplies to Amman are based on a two-stage development to abstract the whole of the yield of the King Talal reservoir (53 Mm^3/a) together with return flows of waste water from Amman (say 16 Mm^3/a). The first stage is for 24 Mm^3/a which is double that proposed at present, but in view of the acute supply deficit an initial transfer of this proportion is necessary. This would be followed by a scheme based on Rumeil Dam in Wadi Wala (12 Mm^3/a) followed by a first stage transfer from Maqarin Dam (40 Mm^3/a). These imports would increase the return flows into the King Talal Reservoir and the Amman-Zerqa Wellfields and permit additional abstractions from them of say 35 Mm^3/a. Finally a second stage development would transfer a further 40 Mm^3/a from Maqarin to supply Amman's needs up to 2002.

TABLE 7 – Strategic Development Programme for Amman-Zerqa

Scheme	Supply (Mm^3/a) (2)		Approximate Year of Commissioning (1)	Notes
	Supply Production	Cumulative Production		
1. Existing Amman-Zerqa wells	28	28	existing	Includes undetermined elements of recycling and mining.
2. King Talal Stage I	24	52	immediate	
3. King Talal Stage II	45	97	immediate	Includes an assumed 16 Mm^3/a (3) from recycling.
4. Rumeil	12	109	1986	Investigations and preliminaries should start now to allow time to impound reservoir.
5. Maqarin Stage I	40	149	1988	
6. King Talal Stage III	25	174	1994	Represents recycled surface water (3) from Maqarin and Rumeil production.
7. Additional Amman-Zerqa wells	10	184	1997	Represents recycled groundwater (3) from Maqarin and Rumeil production.
8. Maqarin Stage II	40	224	1998	Demands satisfied to 2002.

General Notes:

(1) Commissioning dates based on theoretical date to satisfy demand.

(2) Capacities shown are not rated capacities but annual averages.

(3) Elements of recycling to be verified by monitoring programme.

Given the scale of the present supply deficit and the limitations on the rate at which new works can be constructed and commissioned it must be accepted that there will be a continuing deficit for probably the next decade.

Irbid and Northern District

Less options are available for supplies to Irbid and the Northern District and the proposed strategy is summarised in Table 8.

The future supply of Irbid and the Northern District west of Ramtha is based on abstractions from Maqarin Reservoir. Full development would be made in two main stages of 24 and 10 Mm^3/a to meet demands to the

year 2002. As an interim measure before the Maqarin Scheme is commissioned, it is proposed that the Northern Supply System be continued as at present but that Samasdoud is immediately developed to produce a further 4 Mm^3/a to help alleviate the present supply deficit. Following commissioning of the first stage Maqarin Scheme, the resources of the Samasdoud wellfield would be transferred to meet the requirements of the Northern District east of Ramtha. Unless the Government decide to exploit Azraq for supplies to Amman exports would cease from there so that the springs would satisfy only local requirements without effecting the ecology of the area. Abstraction from the Dhuleil wellfield should be reduced to the rechargeable volume (20 Mm^3/a) and water transfers from the area ceased as soon as Maqarin supplies are brought into Irbid.

TABLE 8 – Strategic Development Programme for Northern District

Scheme	Supply (Mm^3/a) (2)		Approximate Year of Commissioning	Notes
	Scheme Production	Cumulative Production		
1. Azraq	2	2	existing	
2. Dhuleil	4	6	existing	
3. Samasdoud	2	8	existing	
4. Minor sources	1	9	existing	Wells at Ramtha and Irbid
5. Samasdoud expansion	4	13	immediate	With agricultural use, fully exploited
Maqarin Stage I	24	31	1983 (1)	Azraq and Dhuleil used for local supplies only. Maqarin to serve Irbid Area. Samasdoud supplies diverted to remainder of Northern District.
Discontinued Azraq, Dhuleil	–6			
Maqarin Stage II	10	41	1993	Demands satisfied to 2002

Notes:

(1) Earliest practical date for commencing abstraction from Maqarin Reservoir assuming immediate implementation of Maqarin Project.

(2) Capacities shown are not rated capacities but annual averages.

Other Rural Areas

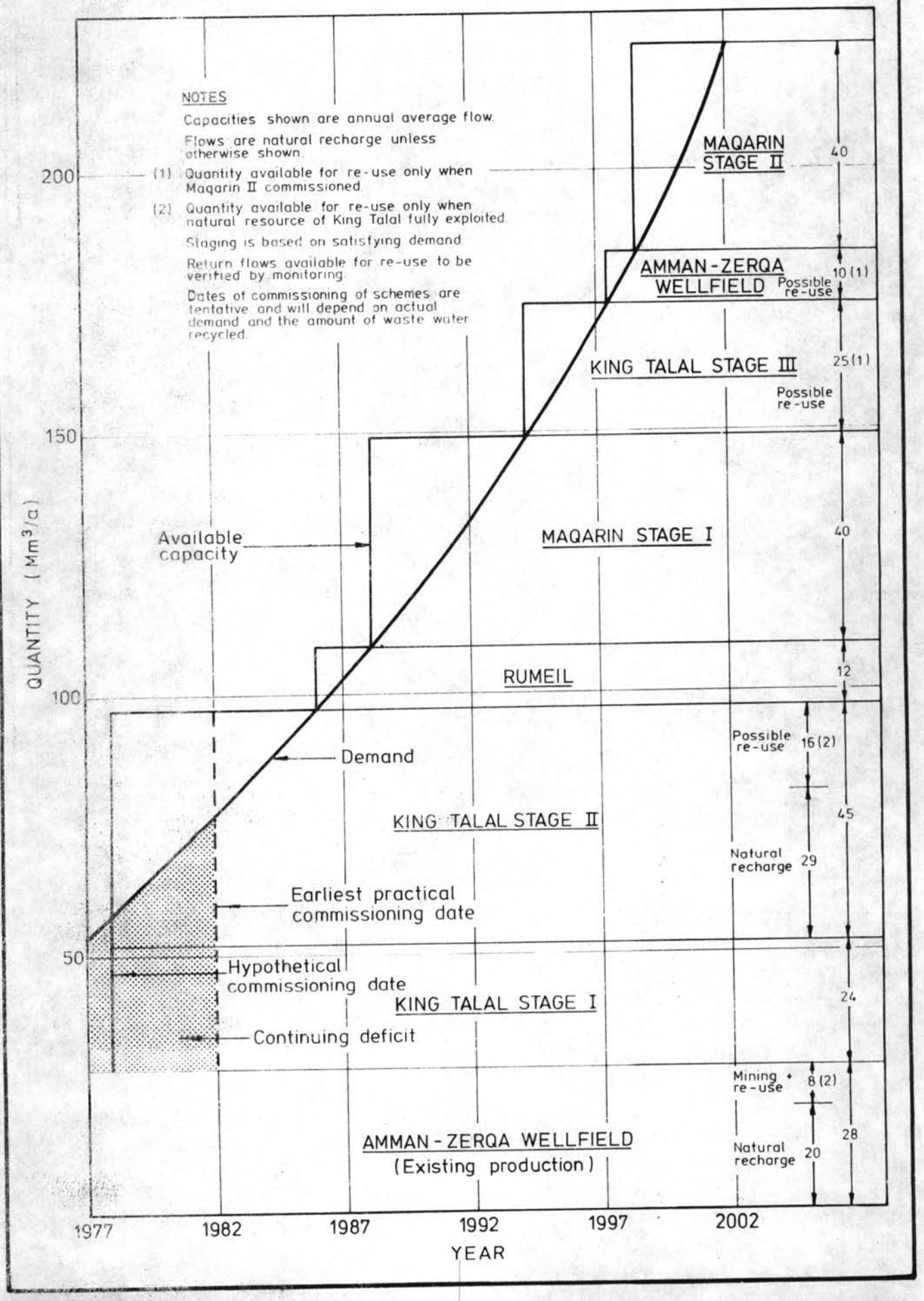
In the Southern Desert Region it is proposed that Qastal be developed (5 Mm^3/a) to supply Madaba, the southern outskirts of Amman and the surrounding villages. At the same time the S E Qastal aquifer should be mined at a modest rate of about 3.5 Mm^3/a for local irrigation.

The southern resources of Siwaqa, Qatrana and Sultani would also be developed for local municipal supplies (1 Mm^3/a) and irrigation (5 Mm^3/a) and it is suggested that the aquifer be mined at a modest rate (4–5 Mm^3/a) to supplement local agriculture.

In view of the high returns from irrigated agriculture in the Jordan Valley all available surplus resources should continue to be used for this purpose. There is a need however to improve irrigation efficiencies as much as possible to offset the reduction in irrigation water to the Valley caused by the increasing requirements of the municipal sector.

Figure 4

WATER SUPPLY STRATEGY FOR AMMAN - ZERQA CONURBATION



INVESTIGATIONS

Detailed investigations will be necessary before implementing the proposed development programme. They should be put in hand not less than two years before the start of construction except in the case of Rumeil Dam which should be commenced immediately. Hydrological and hydrogeological data collection should also be started immediately should this not already be in hand. Investigations will be required in connection with the following resource development schemes

Amman-Zerqa Basin

King Talal Reservoir

Rumeil Dam

Maqarin Reservoir

Samasdoud

Azraq

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