THE WATER MASTER PLAN OF JORDAN

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1. Objectives of Nation-wide Water Resources Planning

1.1 Basic Targets

The increasing demand for water in almost all countries is confronted with more and more problems which are related to the availability of natural water resources on the national or regional level and the progressive reduction of these resources due to pollution effects. If not balanced through highly efficient water planning and management, many countries may sooner or later reach the limits of their socio-economic development. Water planning means to determine the most appropriate allocation of the resources to the various water users and to formulate medium- and long-term policies and guidelines for the exploitation and the utilization of the water resources; the subsequent water management should aim at the best use of the available resources (water, funds, manpower, and other relevant means), the most suitable methods and operations, and - as far as practicable - the renewal of the resources.

These basic objectives and targets were made the topics of a number of international and UN-sponsored conferences; the last one, a year ago, in Mar del Plata in Argentine. A rational management of national and regional water resources is indispensable whenever adequate water needs are to be secured or when problems of conflicting water requirements are to be solved in development programmes. However, all water allocation policies and management plans are closely related to corresponding considerations of economic and human development, health and environment protection, and of financial, legal, and organizational aspects. Many countries took account of this relationship. They established organizations and procedures for water management and river basin planning. Frequently, the operations helped to cope

with regional or local shortages of water supply; they facilitated the control of the water resources utilization, and they made people and water users aware of the requirements regarding water saving practices and control of water pollution. The great number of these experiences suggested to promote training/research and documentation centres on water management at high policy- and decision-making level. In early 1977, e.g. in Valbonne (France) one of such centres started its activities. Among the various objectives, the centre is placing first priority on the dissemination of information on the methods for the preparation of national water plans. The programmes deal thoroughly with the governing aspects (like demography, national economy and potentials, health, environment, water quantity and quality) in order to establish and maintain the consistency between the different objectives.

In line with the definitions, "national water plans" provide a quantitative and qualitative description of the water resources and of existing and potential works for the utilization of the resources; they evaluate water quantity and quality requirements of the different water users (under present conditions and in view of medium and long-term development plans), and they outline potential recycling techniques. They formulate water allocation programmes which take account of alternative objectives, resources, and requirements, and they establish policies and general management rules, which form the basic guidelines for all the subsequent water resources development strategies, detailed project studies, and implementation/investment programmes at regional or even individual project level.

Thus, the necessary arrangements for the administrative and legal structure related to water resources planning and control are to be seen as integral part of each national water plan. At government and decision-making level, these

arrangements should primarily serve an effective guidance and implementation of the programmes and policies, once the plan has been approved. Any decisions, also immediate ones to solve urgent water shortage problems or resources protection in quantity and quality, should be in line with the established strategies and consistent with the medium and long-term development targets. Development forecasts and projections, of course, do seldom meet with the expectations. They are nevertheless to be made to the best of the available knowledge and information, and to be reviewed at regular intervals in order to improve the programmes and strategies and to adapt them to the actual development. The permanent updating and control activities depend substantially on the effectiveness of the organizational arrangements for the flow of information and data between all concerned. For example, projections on annual water requirements in the year 2000 in the Federal Republic of Germany which were made in 1972 and reviewed in 1976, showed considerable differences:

	Water Demand in Year 2000	
	projected in 1972	projected in 1976
Private Households	4,700 MCM	3,900 MCM
Industry (excl. internal recycling operations)	22.100 MCM	16.100 MCM
Powerplants	14.500 MCM	48.600 MCM
Small industries, public utilities agriculture	1,100 MCM	1,100 MCM
Total	42,400 MCM	69,700 MCM

Quite obviously, the revised projections regarding electric power demand (thermal power plants) caused the very significant increase in water requirements; for most of the

specific demand centres the local problems can only be coped with through transfers of water over large distances, and they force the authorities to delineate water production and protection areas which are in conflict with the interests of other users and development plans of the areas.

1.2 Specific Approach Applied in Jordan

The Government has realized that the achievement of the national development targets is very much dependent on well coordinated policies and strategies for the utilization of the country's scarce water resources. Appropriate management and exploitation of these resources have been given high priority in order to cope with the immediate and projected water demand in the country. The authorities concerned, however, are aware of a number of constraints, and in the documents of the current Five Year Plan for Economic and Social Development (1976-1980) they identified the characteristics, problems, goals, and organizational measures related to water resources planning and management in the Kingdom. Accordingly, the formulation of a national water plan and of a water resources policy was made one of the development programmes within the scope of the Five Year Plan. The specific targets and principal outlines of the approach may be quoted from some of the relevant statements in the Five Year Plan documents:

> "Water requirements of the various sectors are constantly on the increase as a result of population growth, expansion of irrigated areas, and establishment of new industries. Although potential water resources are limited and will barely meet the demand expected by the end of the century, there is no coordination or overall-policy regarding the development of water resources and their utilization in the light of priorities and basic needs. Should this situation continue, an acute water

crisis in some regions of the Kingdom is eventually bound to arise. Signs of this are already apparent....

The aim of this project is to carry out a comprehensive study to assess, with a certain degree of precision, potential water resources and evaluate requirements in the light of the distribution of population, industry, agricultural areas, and development programmes. As a result of the study, an overall-water policy will be entrusted to the Higher National Water Council which will coordinate between the various sectors and follow up all matters of execution ...."

These statements reflect to a large extent the scope of work carried out since April 1976 by a Jordanian-German working group for the preparation of the National Water Master Plan of Jordan. The joint efforts resulted from a technical cooperation agreement between the Government of the Hashemite Kingdom of Jordan and the Government of the Federal Republic of Germany. The Natural Resources Authority (NRA) in Amman acted as the responsible counterpart organization and assigned professional staff to the team; Agrar- und Hydrotechnik GmbH, Consulting Engineers, Essen, and the Bundesanstalt für Geowissenschaften und Rohstoffe (the Federal Institute for Geosciences and Natural Resources), Hanover, provided their professional services for the German side on behalf of the German Agency for Technical Cooperation Ltd. (GTZ).

A systematic approach taking account of all the most significant aspects of nationwide water resources planning was adopted; the documentation which is now available provides an overall-picture of the water resources and water demand in Jordan. It is intended to serve as a guideline which may facilitate the necessary policy decisions at the top level of the Government, and the implementation of these decisions

for an appropriate allocation and utilization of the water resources. The scarcity of water in Jordan certainly requires a more resource-oriented approach to government control and management. When constraints present serious problems to an attainment of objectives and goals, then changes in laws, policies, and regulations may become necessary, or objectives and strategies may have to be modified. Thus, the formulation of the National Water Master Plan is incorporated in a sequence of activities:

- definition of objectives;
- quantification of needs and demands;
- appraisal of available and potential resources;
- determination of policies and criteria for the evaluation and selection of projects;
- establishment of an appropriate institutional framework for detailed planning, implementation, and operation in accordance with the policies and strategies for water resources allocation.

The recently completed documentation is based on existing data and information; the various development projections take account of development potentials and medium-term (1985) and long-term (2000) development plans. Particular attention was paid to an analysis of socio-economic and regional development trends, in order to assess their effects on projections and to facilitate the identification of development priorities in cases where available water resources and their regional distribution constitute constraints.

In this way, the framework and procedures for the formulation of the National Water Master Plan of Jordan have been established. The findings of the studies and reviews - although they have had to be based on a number of estimates and assumptions because of insufficient data sources - are considered to be adequate for realistic first conclusions.

2. Water Resources and Water Demand in Jordan

2.1 Basic Approach

In recent years, several efforts were made to obtain an overall-picture on the country's water resources and water requirements. Such assessments were considered necessary in view of the various development projections established for Jordan by a number of Government authorities and other agencies. The data sources and available background information, however, were scarce. Only tentative conclusions could be drawn. From the reviews, nevertheless, it appeared that a number of water resources development projects were conceived and implemented without full consideration of implications resulting to other water users.

As stated before, the formulation of any regional or national plan and strategy for the utilization of the water resources is to be supported by adequate information on the available resources, the development trends, and the resulting water demand projections. In fact, such data do exist to a very limited extent only. Information on regional development programmes is inconsistent; a number of projections were made individually for selected areas or project schemes, but they seem to disclose discrepancies. The outlines given in the current Five-Year-Plan for Economic and Social Development refer to the various sectors and their projects. They are, however, not necessarily reflecting integrated programmes at national level.

Therefore, it was decided to apply a systematic approach and to incorporate all the relevant aspects, at least as far as available data and information permit. A systematic - and nevertheless for obvious reasons pragmatic - approach was considered necessary to outline sound planning principles and procedures, and to establish a realistic framework for

the formulation and for all future updating National Water Master Plan.

According to standard practices, national or regional water master plans aim at a comparative review of the available water resources and of their potential utilization to comply with needs and demands. The comparative identification of resources and demands required a corresponding analysis of the conditions in the individual river basins and surface catchment areas. A similar and to some extent separate analysis was made for the various groundwater basins of the country which do not necessarily coincide with the existing surface basins. The combined information served the delineation of appropriate "balance areas", which cover the country and which provide the overall-picture on the regional distribution of resources and water demand.

The approach started with an analysis of the present situation in order to assess the water resources and the extent of their present exploitation. The next step referred to the medium-term development projections. They were based mainly on existing plans of Government agencies, and they assume that the various targets outlined in the current Five-Year-Plan would have been achieved until 1985. Thus, the situation envisaged for 1985 was compared with regard to the water resources and to possible development constraints originating from limitations in exploitable resources. Particularly for that purpose, a methodology for the review and identification of project priorities was introduced.

A corresponding approach was applied for the tentative formulation of long-term projections. Data on the development of the water demand until the Year 2000 were estimated under consideration of the socio-economic trends and regional development potentials, though closely related with the assessment of exploitable water resources. Primary attention was paid to the projected demand of potable water supply.

Finally, the data compiled for the delineated "balance areas" allowed to formulate recommendations and guidelines for a water resources allocation strategy, and to identify the areas for which the implementation of a coordinated strategy should be given high priority under the National Water Master Plan.

2.2 Background Information and Data

In accordance with the plan of work agreed for the preparation of the National Water Master Plan, it has been acknowledged by all concerned that the available data base is scarce but sufficient for the very necessary first approach to the formulation of the Plan. A number of assumptions and estimates had to be introduced, but they have been marked in the documentation. This applies to data used for the assessment of the water resources as well as to data related to water demand. The Plan therefore outlines procedures and methodologies for improved data collection and processing of information in order gradually to eliminate estimates and assumptions from the documentation and to update the Plan in due course. The employment of computer facilities for processing and interpretation of water resources data and development priorities has been initiated and is intended to be pursued and refined by the Jordanian agencies.

The details on the data sources and the results of the evaluations are compiled in separate volumes of the recently completed documentation; they deal with

"Surface Water Resources"
"Groundwater Resources"
"Irrigation Water Demand"
"Domestic/Industrial Water Demand"
"Socio-Economic Aspects",

and are supplemented by the most important data and findings.

2.3 Study Areas

It was decided to use the surface drainage areas as the basic reference system for the analysis of the regional distribution of water resources and demands. The existing layout of the administrative units in Jordan differs very much from the pattern of hydrological areas, and the absence of any other binding or suitable area delineation in Jordan suggested. This approach which corresponds with practices usually applied for the preparation of regional or other large-scale water master plans. Some modifications became necessary for the interpretation of the groundwater resources the resources of groundwater basins, however, could adequately be related to the surface water catchments.

The layout of the hydrological areas was developed from the existing system of drainage basins and river catchments and refined for the specific purposes of the Water Master Plan investigations. Accordingly, an Index (giving locations, code numbers, and acreages of the individual areas) has been established. It serves the identification of the areas and subareas which cover some 94,500 km^2, i.e. the East Bank territory, and it turned out to be an adequate base for the comparative review of resources and demands. It should therefore be maintained during the follow-up services related to the implementation of the National Water Master Plan. But supplements to the Index may well be introduced in due course in order to adapt it to new information.

2.4 Water Resources

Surface Water Resources:
The limited data base and the specific objectives of a nationwide assessment supported the decision to identify the annual flows rather than their monthly or seasonal flow patterns. Available hydrological records were reviewed and used for interpretations as far as practicable, frequently combined with a theoretical approach to estimates for

ungaged areas. Most of the recorded flows needed to be adjusted in order to take account of present uncontrolled flow abstractions serving various water users in the catchment areas. Such adjustments were based on estimates developed from information on present water use for irrigation and domestic/industrial water supply. It was the target of these adjustments to define the potential annual water resources in gaged areas, to relate the data to rainfall records, and to assess characteristic relationship which could be adopted for estimates in ungaged catchments. Rainfall records proved to be the most reliable long-term data base and were used for a statistical definition of annual rainfall in average, dry, and wet "hydrological years". Accordingly, the corresponding annual surface water resources in the different areas were estimated.

Assuming average annual rainfall conditions, the East Bank catchments (including the Syrian area of the Yarmouk River Basin) would receive a rainfall volume of about 8,065 MCM. About 75 per cent (or 6,000 MCM) of this annual rainfall can be related to Jordanian territory. The corresponding total annual streamflow of about 880 MCM is small compared to the rainfall volume and characteristic for the particular conditions of the surface water resources in Jordan. It is to be noted that 400 MCM of the annual streamflows are to be attributed to the resources in the Yarmouk River at Adasiya. They originate primarily from catchments in Syria. Thus, only some 480 MCM can be considered as annual resources of the streams in Jordan, and the analyses indicate that considerable parts of these flows result from groundwater discharge (baseflow) rather than from direct rainfall runoff during the annual rainy season.No consideration was given to the flows in the Jordan River. Quality constraints, in particular, seem to eliminate these flows from the resources suitable for exploitation.

The estimates of potential annual streamflow reflect the general tendency of decreasing resources, when comparing the catchments from the north to the south of Jordan. Although a number of assumptions had to be introduced for the assessments, the results provide a realistic picture of the annual surface water resources. This applies particularly to the flow estimates of average-year conditions. The statistical interpretation of the data indicates possible variations which may have to be taken into account for certain planning aspects; they should be the subject of future reviews, together with a more specific interpretation of the probable seasonal fluctuations of the surface flows.

Groundwater Resources:
The assessment of the groundwater resources based on water balances established for defined groundwater basins. Abstractions owing to groundwater exploitation, as well as groundwater recharge components and underground flows were taken into account through either recorded data or estimates. Particular attention was paid to a realistic interpretation of the relationship between groundwater exploitation and baseflow discharge in the river courses, in order to identify these two resources separately.

In line with the objectives of the investigations, the assessment aimed at the determination of such groundwater resources which seem to be exploitable with reasonable means. Generally acceptable criteria were therefore applied in this first approach, in order to define reasonable limitations in the resources which can be considered as available. These criteria, of course, are not necessarily applicable to all types of projects and water users which envisage the exploitation of groundwater resources. The various specific aspects would have to be studied and decided individually for the detailed layout of each groundwater supply scheme. Such considerations exceeded the scope of an overall-assessment of the potential re-

According to the definitions and criteria introduced during the investigations, and based on the review of present and potential exploitation constraints (water quality, accessibility), the determination of the resources in the various areas distinguishes:

-"available annual groundwater resources" as the volume of groundwater which is recommended for exploitation at defined locations, and locally characterized by certain constraints; (to a large extent this volume corresponds to the difference between the average total annual groundwater recharge and the average annual surface baseflow discharge of the area); and
-"available groundwater storage" as the estimated exploitable volume of groundwater retained in the area in aquifers down to a depth of 150 m below ground surface.

The estimated volumes of these resources have been related to the defined areas. They indicate the regional distribution of the groundwater resources, and among the number of map presentations information has been compiled also regarding

- areas of present and potential groundwater exploitation
- areas proposed for groundwater protection
- areas with restrictions for groundwater exploitation

On the average, from the total amount of annual groundwater recharge in East Jordan of about 580 MCM, some 220 MCM seem to be available as annual groundwater resources, in addition to the streamflow and the stored groundwater. The volume of stored groundwater is estimated

to be in the order of about 12,000 MCM. Locally, water retained in depths greater than 150 m below ground may prove to be exploitable additionally for specific purposes. Surveys should be related to particular project studies in due course.

The estimates on present and future groundwater resources take account of probable exploitation effects, particularly as far as mining of stored groundwater and the interrelation with groundwater flow and surface water baseflow are concerned.

2.5 Socio-Economic and Regional Development Aspects

Because of the reasons mentioned earlier, the integrated approach to the preparation of the National Water Master Plan included an analysis and tentative interpretation of the present and potential socio-economic and regional structure of the country. These studies did not attempt to determine regional development plans. It was their main objective to outline some of the most significant development aspects at regional level, and to provide background information with regard to water demand projections and development priorities. Thus, data have been established which indicate the potential development of the population numbers in the various areas delineated for the purposes of the Water Master Plan, and which indicate potential centres of future sectoral development.

The findings and projections, of course, need to be reviewed in due course, particularly with regard to the development trends of population numbers and their consequences on the demand of potable water supply in the various areas. They may further form a base for the formulation of official regional development plans in coordination with the water resources allocation programmes of the National Water Master Plan.

Population Development:
Available data sources were the Agricultural Census of 1975 and the 1961 Census of Population. The information was not fully conclusive. A number of adjustments became necessary to prepare a consistent data base related to the areas defined for the Water Master Plan, and to estimate realistic projections.

The present (1975) population number of Jordan is in the order of 1,950,000 inhabitants. About 1,100,000 people live in the Amman Governorate, including the Amman Sub-District with some 685,000 inhabitants. The heavy concentration of the population in the greater Amman-Zarqa area is obvious.

The projected population numbers for 1985 base on an annual growth rate of 3.5 per cent as ceiling for the total population of Jordan. A detailed review of consequences resulting from growth rates which had been envisaged for individual areas like Amman, Irbid, Jordan Valley, showed considerable discrepancies and deviations from the projected overall-population growth. Reasonable adjustments were therefore introduced in order to obtain consistent and realistic projections for the different areas of the country. Thus, individual growth rates for the population development were estimated and applied for each area. They range between 7 per cent (Jordan Valley) and 4 - 5 per cent (Zarqa/Irbid/Amman Municipalities) annually in the major development centres, and they go down to rates of less than one per cent (and negative growth rates even) in other areas.

A similar approach was made to long-term projections of the population number (year 2000). The population is expected to increase to about 2,740,000 persons in 1985, and to about 4,445,000 persons in the Year 2000. The greater Amman-Zarqa area will remain the main population centre in Jordan; more than 60 per cent of the total population will presumably remain in this area. The data on present

and projected population numbers formed a background information for the assessment of potable water supply requirements.

Socio-Economic and Regional Development:
Based on available data sources, the investigations of the population development were supplemented by an analysis regarding the present (1975/76) situation of

- the agricultural production and its regional distribution;
- the industrial production and its regional distribution;
- the technical infrastructure (transport system, electric power supply);
- the social infrastructure (educational and health services); and
- the adminstrative system and services.

The interpretation of the results allowed a tentative delineation and assessment of existing socio-economic regions and regional structures in Jordan. Accordingly, some outlines on the regional development trends and potentials were formulated, considering "harmonic socio-economic development" as the primary long-term development objective, in line with the main target of the current Five Year Plan. The outlines on trend and potentials refer to the key-sectors agriculture, mining and manufacturing industry, and services. It is to be noted, that the socio-economic regions do not coincide with existing administrative units or the hydrological areas which were selected for the purposes of water resources planning. The reasons are obvious. Regional development plans as definite basic guidelines for water demand projections and water resources development do not exist as yet. Projections were therefore primarily based on other development programmes and plans. The review of socio-economic trends and the tentative delineation of regions may be considered

decisions regarding the allocation of the water resources and the priority of projects.

Priority of Development Projects:
The formulation of strategies for the allocation of the water resources can be confronted with the problem to set priorities for the use of water if the available resources are limited. Tentatively, the "benefit-value analysis" has been introduced as a suitable method to facilitate decisions concerning the ranking of water use. It allows a comparative evaluation of the relative utility of project and water use alternatives in relation to the target objectives of regional and national development. It applies a goal system and measurable attributes which indicate the relative importance of the various goals and socio-economic aspects. Accordingly, tests have been made for a number of selected economic development projects, and for projects related to domestic water supply. The particular priority of potable water supply was taken into account.

The comparative review area-wise of the available water resources and the projected water demands did not reveal particular problems which would have required to decide on priorities already. The allocation of the water resources, suggested in the present documentation, however, may not entirely meet with the policies considered by the Government. The "benefit-value analysis" could then be adopted for final conclusions regarding specific projects and water allocation plans. It will also serve future reviews of the Plan, when the goal system and measurable attributes have been refined with more detailed data and information.

2.6 Water Use and Water Demand

Water use and water demand in Jordan result dominantly from the requirements of domestic and industrial water supply and from irrigated agriculture. Consideration of hydropower

potentials is of secondary importance, and aspects related to water use for navigation do not exist. Long-term plans, however, will have to take account of the maintenance of adequate water quality and minimum flows in river courses of areas which require particular standards of environmental protection. A similar approach will certainly have to be made regarding flood protection measures as part of water resources development projects. At present, specific overall-outlines on flood protection requirements cannot be defined from the available information.

Domestic/Industrial Water Supply:
At present (1975 - situation), the annual water production - primarily from groundwater resources- for the water supply of communities and industries is in the order of 46 MCM. Related to the population number, this figure proves the considerable deficiencies, particularly in the existing systems for domestic water supply. Assuming proper water supply conditions, the potential present water demand would require a water production of about 82 MCM/year.

The data computed for the individual areas demonstrate the regional distribution of the present domestic and communal water use and potential demand. Industries with independent water supply were considered separately. Corresponding to the pattern of the population density, the Amman-Zarqa area requires about 60 per cent of the annual water production. The supply gaps in most of the areas are obvious and have been identified as objectives of major concern for the allocation of water resources and for the implementation of water supply projects.

The investigations regarding water demand projections paid particular attention to a realistic assessment of unit demand figures covering domestic water use, water requirements for commerce and small industries, and allowances

for water losses in the water distribution systems. Such unit demand figures (representing the overall-demand of water per day and head of population) were estimated for specified types of communities, ranging from large cities down to villages. The projections which differ considerably from the data of the present water use, assume that adequate standards of domestic water supply should gradually be achieved in future water supply schemes throughout the country. In the Year 2000, such water supply schemes should serve about 95 per cent of the population.

Separate projections were made for the water requirements resulting from the implementation of industrial development projects with own water supply facilities. The data have been based on available information or estimates.

Accordingly, the projected annual water demand was computed and mapped for the defined areas. The particular future demand centres are obvious and indicate the importance of a well-coordinated water resources strategy which allows to satisfy the domestic water supply in first priority. The total water demand for domestic and industrial purposes in 1985 is estimated to be in the order of about 190 MCM/year, and will most likely increase to about 300 MCM in the Year 2000. Compared to the estimated present annual water use of about 46 MCM, these projections might be considered as too ambitious. They should, however, be taken into account as targets, and they reflect the present low standard of the domestic water supply.

Domestic and industrial water supply is closely related to a control of water quality and water pollution. Existing information on the quality of groundwater was therefore evaluated and interpreted within the assessment of the groundwater resources. Data on the quality of the stream-flows are scarce and still inconsistent, but they indicate the particular pollution hazards resulting from uncontrolled waste water discharges and waste deposits along the river

courses at major communities and industrial centres. At present, apart from initial operations in Amman, there is hardly any treatment of sewage. The projections, however, assume the implementation and further extension of existing plans for the operation of sewage treatment plants. Return-flows of treated sewage contribute significantly to the very necessary maintenance of acceptable water quality in the river courses, and they are to be considered as potential future water sources in addition to the natural annual water resources. Accordingly, estimates of such return-flows in certain individual areas were incorporated into the projections. They envisage that large communities and industries will eventually avail of full-scale sewerage system and treatment facilities. Applicable standards and recommendations for follow-up works, which should help to establish urgently policies and procedures for the control of water quality and water pollution, have been formulated in the present documentation.

Irrigation Water Supply:

The development of water resources for irrigated agriculture as a basic component of Jordan's economy, is given a high rating. Present irrigation schemes - both public and private are scattered throughout the country and cover a total area of about 336,000 donums (or 33,600 hectares). The average annual water use is in the order of 405 MCM. Most of this volume (approx. 230 MCM) is taken from river flows; 100 MCM are pumped from groundwater resources, and some 75 MCM originate from spring flow diversions. These data are based on estimates to a large extent. Available background information and records are incomplete or inconsistent. The results of the assessment, nevertheless seem to provide a realistic picture of the present water use for irrigation in the individual areas, and of the deficiencies in most of the existing schemes.

Projections regarding future water demand for irrigation were made under consideration of plans and programmes formulated by the Government. The projections envisage an extension of irrigated areas as well as improvements in technical means, cropping patterns, and irrigation practices. Thus, data of medium-term projections have been established. They assume that public irrigation schemes in 1985 will cover about 471,000 donums (i.e. 47,100 hectares), in addition to about 112,500 donums (i.e. 11,250 hectares) under private schemes. Compared to the present situation, the area of irrigated lands would be extended by about 75 per cent. Accordingly, the average annual water demand is estimated to require a water production of about 730 MCM. In line with the projections and adopted assumptions, 455 MCM would have to be diverted from river flows and about 200 MCM to be pumped from groundwater resources, while springflow diversions for obvious reasons would remain in the present order of about 75 MCM. Some 350 MCM of the average annual demand of irrigation water result from the development programmes for irrigated agriculture in the Jordan Valley.

The formulation of specific long-term water demand projections for irrigation was not considered reasonable. Developments going beyond the 1985 - projections depend on exploitable water resources and related economic aspects rather than on available land resources. It appears at present that no significant extensions of areas and water supply can be expected after 1985. This will apply primarily to the major centres of irrigated agriculture like Jordan Valley and the Southern Ghors, which depend on the available surface water resources. Individual small-scale schemes based on exploitation of groundwater resources in desert or highland areas may, however, prove to be feasible for additional long-term development programmes. Realistic long-term projections should therefore preferably be established in accordance with the water allocation policies which will finally be determined by the Government and which will take

account of the available resources and the priorities attributed to adequate domestic water supply.

As mentioned earlier, the data base for the assessment of the present water use for irrigation was insufficient. A theoretical approach, including a number of assumptions, had to be adopted, and a computer programme was prepared to facilitate the computation of the estimated water use in the individual projects and study areas. The results show the sources of the irrigation water supply, and the annual volumes of water, related to conditions of years with average and low rainfall. Because of the insufficient data base and considering the objectives of the overall-review for the purposes of the National Water Master Plan, no attempts were made to identify the seasonal or monthly variations of the irrigation water supply in the different areas. They should be the subject of specific studies for the detailed layout of schemes and water management works.

With modified input data, the computer programme was applied also for the computation of the medium-term water demand projections. The results regarding the sources of irrigation water were reconsidered and adjusted during the subsequent comparative review of the resources and demands in the various areas. The computer programme, nevertheless, proved to be an adequate base for the projections. It can be refined and adapted to improved information and thus serve all the future reviews of the present documentation.

Water Use for Other Purposes:
At present, there is no significant use of water for purposes other than domestic/industrial water supply and irrigation. A few small-scale hydro-power installations (e.g. at Wadi Jurum) do not affect the availability of the local surface water resources.

According to the present plans and programmes, this situation is not likely to change in future. The hydro-power plants envisaged at the King Talal Dam (Zarqa River) and at the projected Maqarin Reservoir (Yarmouk River) will presumably be operated in coordination with the priorities and water requirements of irrigation and domestic water supply schemes. The same will certainly be taken into account for other plants which may be projected in combination with the future construction of reservoirs. Therefore, a particular consideration of potential water demands for power generation is not necessary; the operational programmes of hydro-power plants, however, should finally correspond to the water resources allocation policies established by the Government.

Some attention may have to be paid to an assessment of the future water requirements related to the maintenance of minimum river flows in certain areas. Aspects of environmental and water quality control may ask to determine such requirements during the coming years and to arrange for the relevant water management strategies and measures. Present data and information do not yet allow a reasonable interpretation; most likely, the Zarqa River between Amman and the King Talal Reservoir will have to be considered with some priority.

2.7 Summary

Based on the data evaluation, the average annual surface water resources in Jordan (East Bank) seem to be in the order of 880 MCM. They include some 400 MCM as average annual flow of the Yarmouk River at Adasiya. Additionally, some 220 MCM seem to be available as annual groundwater resources; exploitable groundwater resources stored in aquifers all over the country appear to exceed a volume of 12,000 MCM.

Compared to these resources, the assessment of the present water use and the projected future water demand in Jordan outlined the following main annual requirements:

	Domestic and Industr. Supply (MCM)	Irrigation (MCM)	Total (MCM)
Present Use	46	405	451
Demand 1985	190	730	920
Demand 2000	300	(800)	(1100)

The overall-figures indicate that the resources are not fully exploited at present, and that the projected long-term demand could be covered by the annual resources. The figures, however, cannot serve final conclusions. The exploitable resources are not necessarily located in or near the areas of particular demand centres. The allocation and management of the water resources in order to satisfy the potential water demand throughout the country will therefore depend to a large extent on technical and economic aspects related to the implementation of water resources projects.

This suggested to extend the investigations to a comparative regional review of resources and demand, based on the data established for each of the individual study areas. Thus, the effects of the regional distribution of water resources and water demand were identified more specifically. The results of the analyses enabled to delineate areas with particular problems or conflicting interests regarding the allocation of water resources, as well as areas with a surplus of water resources.

3. Regional Balances of Resources and Demand

3.1 Balance Areas

For the regional review of the present utilization and the potential allocation of the water resources, 15 "balance areas" have been distinguished:

I	Yarmouk Area
II	Jordan Valley
III	Northern Riftside Wadis of the Jordan River
IV	Southern Riftside Wadis of the Jordan River
V	Zarqa River Basin
VI	Dead Sea Riftside Wadis
VII	Mujib River Basin
VIII	Wadi Hasa Basin
IX	Wadi Araba North
X	Wadi Araba South/Wadi Yutum
XI	Southern Desert Area/Qa Disi
XII	Jafr Basin
XIII	Wadi Sirhan Basin
XIV	Azraq Basin
XV	Wadi Hammad Basin

The delineation of these areas was guided primarily by the defined surface catchments and groundwater basins, to some extent also by aspects of the present water management and water resources development (e.g. areas supplying water into the Jordan Valley).

The "balance areas" are composed of hydrological subareas with similar characteristics and form units of adequate size. A satisfactory coordination with the tentative "socio-economic regions" could not be achieved for various reasons; the findings of the socio-economic data interpretation, however, were taken into account as far as practicable during the review of the balances.

3.2 Determination of Area Balances

The "area balances" do not represent hydrological balances; they rather compare the water resources and the water demand in the delineated "balance areas".

Basically, average-year conditions have been considered. This corresponds to the approach adopted for the preparation of the National Water Master Plan. Demand data of defined dry and wet years do not differ significantly from those of average years, and the data on water resources as yet do not provide a sufficient base for a specific differentiation of dry and wet year balances in all the areas. Such detailed analyses are the subject of individual project studies, e.g. in connection with a survey of the potential effects of "over-year" storage in reservoirs in order to compensate variations of the annual flows.

For each balance area, the estimated quantities of water resources and water use/demand have been compiled in form of lists. They separate the present situation and the conditions envisaged in line with the medium-term and long-term development projections. The direct comparison of the annual quantities of resources and water use/demand identifies areas which, as far as their resources are concerned, are basically to be considered as surplus or as deficit areas. More important, however, is the subsequent analysis regarding the utilization of the water resources. It shows for each area the extent of the present or potential future use of water, satisfying the requirements in the area itself or in adjacent areas.

It is to be noted that the area balances take account of potential surface returnflows. As outlined earlier, these are primarily the estimated future effluent from sewage treatment plants. They constitute supplementary sources to the annual natural water resources.

3,3 Interpretation of the Area Balances

Present Situation:
Although many of the data concerning water use and water resources originate from estimates, the results of the balance computations appear to reflect the present situation with reasonable accuracy. They also provide a very instructive picture of the present technical water transfers between various areas. Not all of the existing water supply systems seem to make the best use of the available water resources.

The Yarmouk Area (Area I) definitely is the most important region of potential water resources for Jordan. Considering rights of other water users in Syria and the Yarmouk Triangle and the estimated present diversion of irrigation water for the Jordan Valley, on the average some 200 MCM of annual surface flows are still available for exploitation. As regards the rights of water users outside Jordan, no final information is available as yet. These water rights, however, seem to be applicable only in case of a future storage of the Yarmouk flows.

The situation in the Jordan Valley (Area II) is completely different. Apart from some 12 MCM of groundwater with acceptable quality, the water resources of the Valley region are not suitable for exploitation. The irrigation schemes, covering about 17,300 hectares of agricultural lands in the valley, depend almost entirely on water diverted from the adjacent areas (Yarmouk Basin, Riftside Wadis, and Zarqa River Basin). Practically, all the present water use in the Jordan Valley is related to irrigation. The estimates of annual quantities range between 135 MCM and 185 MCM, because there are no reliable and conclusive data sources of the present actual water use. A comparison of diversion data and estimated use of irrigation water indicates that locally excess water is being discharged

through the schemes into the Jordan River. This observation results also from operational records of the Ziqlab-Reservoir, and from statements of staff in charge of the irrigation services. A detailed identification of the actual figures of the present water use in the Jordan Valley, however, is not considered to be so much important. The estimates outline the prevailing conditions and tendencies adequately; the Jordan Valley will remain a region which depends on the water resources of neighbouring areas, but a more effective management of these resources will have to be achieved in future.

The area balances of the Northern Riftside Wadis (Area III) show a considerable surplus of water resources. On the average, some 40 MCM annually could be exploited in addition to the estimated present water use. The surplus of water resources in the Southern Riftside Wadis (Area IV) is small. Considerable quantities of the available surface and groundwater flows serve water users in the very area. The balance computations are not fully conclusive with regard to the estimated surface resources and diversions of the Wadi Shueib and Wadi Kafrein catchment; the records of the existing reservoirs do not allow a proper evaluation. The operational constraints of the reservoirs are known. It appears, however, that surface flows not used at present (approx. 8 MCM) are primarily originating from uncontrolled floods. Additionally, some 6 MCM have been estimated as unused groundwater flow.

The comparative review identifies the Zarqa River Basin (Area V) as a region which requires particular attention. The greater Amman-Zarqa area is the centre of domestic and industrial water use in Jordan. The balance computations indicate that apart from flood flows the available annual water resources are used to a large extent throughout the river basin. Locally (Wadi Dhuleil area), the water production results from a considerable mining of stored

groundwater resources. Although some 62 MCM of annual surface and groundwater flows, in addition to more than 1,800 MCM of stored groundwater, could still be exploited, the findings of the balance computations give reason to certain concern. The present water use for municipal water supply does not meet with acceptable standards. Any improvements or future extensions should first draw on the development of the present surplus resources. The recently completed King Talal Reservoir started to control the unused surface flow at the lower course of the Zarqa river. This is a great advantage for the management of the resources, the flood flows in particular.

The area balance of the Dead Sea Riftside Wadis (Area VI) outlines the northern catchments (north of the Wadi Mujib gorge) as a region with a considerable surplus of suitable water resources. These are dominantly baseflows originating from springs and discharge of groundwater. The present water use in the area is small compared to the resources. In the southern subareas the situation is very much different. There is a significant water use in irrigation areas. They are estimated to consume some 30 MCM of the annual surface water resources. Groundwater is hardly being exploited.

The Wadi Mujib Basin (Area VII) is a major "surplus area". Less than 10 MCM are at present exploited for purposes of domestic water supply and irrigation, while the average annual surface water flow is estimated to be in the order of 78 MCM, in addition to considerable groundwater resources which include more than 1,100 MCM of groundwater stored in the region. The rather limited present water use is caused by constraints in the access to the water. The average perennial baseflows of about 41 MCM are available along the lower courses of the Wadi Mujib and Wadi Wala/Haidan, where the topographic conditions do not allow an extensive irrigation development. The balance computations are affected to some extent by the interrelationship between groundwater

flow and baseflow in the wadis, and by the unidentified extent of actual groundwater mining. Nevertheless, it can be assumed that on the average some 75 MCM of annual surfac flows (including about 37 MCM of sporadic floods) are not yet used, and that available groundwater resources in the order of 15 MCM annually could be exploited in the area, in addition to a further mining of stored groundwater.

The interpretation of the area balance determined for the Wadi Hasa Basin (Area VIII) allows a conclusion similar to that drawn for Area VII. The estimated annual water resources compared to their present utilization indicate that more than 30 MCM are still available for development and annual use. Further, almost 1,700 MCM seem to be stored as exploitable groundwater in the upper Wadi Hasa Basin.

In the southern and eastern regions of the country, any further water resources development will depend on the potentials of an exploitation of stored groundwater rather than on those of annual water resources which at present are not used. The area balances indicate, that limitations in the present use of the available resources result primarily from technical and operational problems related to access and control of the water. Additionally, economic aspects are involved. The area balances, however, also indicate that regions with limited water resources have made use of these resources as far as possible. These observations have to be taken into account. Water resources which are estimated as available for further use in the various balance areas, are not necessarily exploitable with reasonable technical and economic means. The final identification will have to become the subject of detailed surveys and studies in the areas of particular interest.

Projection 1985:
The projected water demand data compiled in accordance with the delineated balance areas identify three main demand centres:

- the Jordan Valley with a projected annual water demand of about 360 MCM, primarily for irrigation purposes;
- the greater Amman-Zarqa area with a projected municipal/ industrial water demand of about 100 MCM per year; and
- the region of the Southern Ghors with a projected annual irrigation and industrial water demand of about 85 MCM.

Further, the projected increase of municipal water demand in the northern population centres is to be taken into account. Some 28 MCM per year will have to be produced and distributed in order to provide adequate domestic water supply for these communities. A significant increase of annual water demand (about 11 MCM) is also to be satisfied in the Aqaba area. All other demand projections are less significant or related to existing plans which envisage the exploitation of specific local water resources.

According to the approach applied for the assessment of the natural water resources, most of the estimated data regarding average-year conditions seem to remain valid for the consideration of the projected area balances. This conclusion was drawn after an assessment of the possible implications resulting from the present water use and particularly from the exploitation of groundwater resources. Among other areas, the conditions to be expected in the Zarqa River Basin were reviewed.

In the northern regions of Jordan, the Jordan Valley (Area II) remains the dominant centre of water demand. Some 353 MCM will have to be supplied to meet the projected irrigation requirements in line with the medium-term development plans covering the irrigation of about 33,200 hectares. For domestic water supply, an annual demand of 3 MCM has

been envisaged. Compared to these demand projections, the suitable water resources of the very valley region are practically negligible but increasing water logging problems will nevertheless arise and require the implementation of specific drainage works to control the groundwater tables.

The Yarmouk Area (Area I) remains the main source of water supply for the northern regions of Jordan. Water demand projections related to the area itself show increased annual water requirements for municipal water supply (8 MCM compared to about 2.3 MCM at present), but no changes are envisaged with regard to the water use in the existing irrigation areas of the Mafraq-Ramtha region. The plans for the development of some 2,200 hectares of irrigated lands along the southern banks of the lower Yarmouk rivercourse are to be considered separately. They are part of the Stage II - Jordan Valley Development Project. The projected annual water demand of about 19 MCM is therefore to be seen together with the projected operation of the Maqarin Reservoir.

Provided the Maqarin Reservoir is completed in 1985, on the average an annual surface flow of 273 MCM will be controlled at that site. Use can further be made of about 55 MCM of average annual baseflow (at Adasiya) originating from Yarmouk catchments downstream from the Maqarin site. The estimated average annual flood flows (72 MCM) of the lower catchment (including the Wadi Raqqad area) do not seem to be exploitable in 1985. As regards the groundwater resources, the exploitation projected for 1985 indicates a surplus of available annual groundwater flow (approx. 8-10 MCM), in addition to the considerable quantities stored in the area. The area resources exceed by far the water demand of the area. The allocation of the surplus resources is therefore to be coordinated with existing project plans and the area balances of the adjacent regions. Allowances for Syrian water rights

(assumed as 5 per cent of the surface flows stored in the Maqarin Reservoir) and for irrigation purposes in the Yarmouk Triangle are to be taken into account.

The projected area balances of the Northern and Southern Riftside Wadis (Areas III and IV) indicate a surplus of resources, although there is a significant increase of municipal water demand in the areas. Measures for control of water pollution will become important here.

For the Zarqa River Basin (Area V), the comparison of resources and projected water demand confirms the particular problems to be expected in the greater Amman-Zarqa area.

This overall-review of the situation in the northern regions of Jordan suggested an allocation of the water resources under consideration of the following aspects and plans:

- the projected water demand of the Jordan Valley to a large extent is related to the completion and operation of the Maqarin Reservoir;
- appropriate water supply conditions are to be achieved for the communities of the northern population centres (including the Jarash region);
- the water resources of the Zarqa River Basin should primarily serve the water requirements in the very area;
- the projected water demand of Area IV (Southern Riftside Wadis) should be given priority in the allocation of the area water resources.

The suggested arrangement of an integrated "northern central system" for municipal water supply is supported by existing project plans. It is thought reasonable to extend the present pipeline systems practically into all the nortnern communities, and to include also those of Jarash region. Such scheme, however, is to be based on an economic exploitation

of reliable water resources. The resources which serve the domestic water supply at present cannot satisfy the projected demand. Therefore, in line with plans formulated by the Government, use should in first priority be made of the Yarmouk water resources. The allocation is to be seen also in the light of the projected demand in the Year 2000. The domestic water supply should not be curtailed for the benefit of other water use. It is to be noted that the incorporation of most of the population centres of Area III (Northern Riftside Wadis) into the "northern central system" will save considerable quantities of the local resources. These are exploitable for irrigation purposes in the Jordan Valley. A future elimination of the present water use for irrigation in Area III is not considered reasonable. The existing private irrigation schemes should be maintained for reasons of regional development. The water used there would not contribute significantly to the resources which are to be conveyed into the irrigation areas of the Jordan Valley.

As outlined in the area balance of the Yarmouk Area (Area I) it seems to be appropriate to allocate 275 MCM of the Yarmouk resources for the Jordan Valley irrigation schemes. 55 MCM would result from diversion of baseflow at Adasiya, and 220 MCM (including 19 MCM for the projected water demand of the irrigation areas at the lower Yarmouk) would have to be released from the water stored in the Maqarin Reservoir. The projected annual water demand of the communities envisaged to be covered by the "northern central water supply system" is estimated in the order of 24 MCM. It is assumed that the Summayya well fields operated by the Water Supply Cooperation at present, or other new well fields in the Ramtha-Mafraq area, can be extended to an annual groundwater production of about 2 MCM, by 1985. The balance of 22 MCM represents the quantity to be allocated from the Yarmouk flow at Maqarin. No further import of water resources

from Azraq and Dhuleil (at present about 3.5 MCM per year) is planned under these conditions; it is nevertheless to be continued in near future until the suggested new lay-out is operational.

The projected area balance of Area I leaves 31 MCM at Maqarin to serve rights and purposes of other water users. This figure as well as the other figures related to the allocation of the Maqarin Reservoir resources base on the assumed average-year conditions. The potentials resulting from "over-year" storage were not taken into account as yet. The final project studies may eventually justify higher figures regarding diversions into the Jordan Valley. Basically, however, the allocation programme seems to make reasonable use of the available resources. The limited surplus of groundwater resources (including some 600 MCM of stored groundwater) is not considered a significant base of further extensive development in the area; but the uncontrolled annual flood flows (about 72 MCM) of the lower Yarmouk and Wadi Raqqad are to be seen as a potential long-term supplementary resource for the Jordan Valley, provided they could be retained in a reservoir.

The area balance of the Northern Riftside Wadis (Area III) shows that approximately 66 MCM of the available water resources can be diverted for use in the Jordan Valley (Area II). This should be achieved through a coordinated water management, incorporating the operation of the projected Wadi Arab Reservoir and the Ziqlab Reservoir, an exploitation of available baseflows, and locally also the implementation of small flood retention basins. The projections assume further the exploitation of groundwater flow (about 7 MCM) at the foothill areas. Only some 8 MCM of the groundwater and surface flows were estimated to remain unused because of technical and economic reasons. Based on the available information and an assessment of

the local conditions, the assumed allocation programme appears to be realistic. It is, of course, to be reviewed in connection with the relevant findings of future detailed and specific surveys in the area.

The projections regarding the municipal water supply in Area III envisage the majority of the communities to be served through the "northern central system". Accordingly, 14,4 MCM of the total estimated domestic water demand will be satisfied from the Yarmouk resources, while 2.8 MCM will be produced in the area itself for individual water supply schemes of communities located in the lower reaches of the riftside catchments. The increased demand of domestic water supply, combined with the plans to establish sewerage systems and treatment plants, is likely to yield significant sewage returnflows. The importance of adequate treatment for control of water pollution is obvious. By 1985, such returnflows in the order of 3 MCM may be expected from the Irbid area. Controlled through the Wadi Arab Reservoir, they could contribute to the supply of irrigation water, if they were not reused in the Irbid area itself.

The area balance prepared for the Southern Riftside Wadis (Area IV) takes account of the priority of domestic and industrial water supply, but by 1985 the present transfer of water (from Wadi-es-Sir) into the water supply system of Amman should no longer be maintained. The available resources should serve primarily the demand in the area. Sewage returnflows are considered to be negligible, although important with regard to pollution control. Water use for irrigation purposes in Area IV is not envisaged to increase significantly, compared to the present situation. Accordingly, assuming that improved operation of the Shueib and Kafrein Reservoirs would be achieved in 1985, about 13 MCM of groundwater and surface flow have been estimated as available

to irrigation and/or domestic water supply schemes in the Jordan Valley. This allocation programme corresponds to a large extent to existing schemes and plans and appears to make full use of the resources. As far as the estimated data regarding the resources are concerned, however, the background information showed a number of discrepancies, which should become the subject of specific surveys and studies in the near future.

The balances established for the Areas I, III and IV provide for annual water transfers into the Jordan Valley (Area II) in the order of 336 MCM. This volume and the estimated suitable groundwater resources (about 12 MCM) in the valley area itself stand against the projected water demand of 356 MCM for irrigation and domestic water supply in the Jordan Valley. Provided the development plans and the envisaged irrigation efficiencies can be realized, the annual supply gap of about 8 MCM will have to be filled through water resources transferred from the Zarqa River Basin. The water requirements after the implementation of the irrigation schemes may exceed the projected demand figures; if so, temporary and local adaptations regarding cropping and irrigation intensities may become necessary. It is unlikely that considerable supplementary water resources can be made available to the valley region.

These aspects reflected into the considerations regarding the projected area balance of the Zarqa River Basin (Area V). The particular situation of the present and presumably also future groundwater exploitation in the Wadi Dhuleil area suggested a separate analysis of the conditions expected there. The continued large groundwater production for the irrigation schemes in the Dhuleil region will deplete the stored groundwater resources and may eventually be affected by technical and economic constraints. This appears to apply also to the Dhuleil well field presently operated by the Water Supply Corporation for purposes of domestic water

supply in the northern communities around Irbid. The resources are not reliable for extended development and therefore not taken into account in the projected water allocation for the proposed "northern central water supply system". The expected continued depletion of the groundwater resources, however, is not likely to cause a significant reduction of the water resources estimated for the other subareas of the Zarqa River Basin. This allows to regard the Wadi Dhuleil area as a separate unit where irrigation activities and development will continue as long as technical and economic aspects justify an extensive groundwater production.

Taking the Wadi Dhuleil area out of further consideration, the area balance of the Zarqa River Basin is governed primarily by the projected water demand to be satisfied in the greater Amman-Zarqa area. Compared to the present annual water use of about 28 MCM, the estimated municipal and industrial water demand of 1985 would require to provide a supply of about 98 MCM. This projected figure may appear to be excessive; nevertheless, it should be seen as the target in the layout of water allocation programmes. The greater Amman-Zarqa area will remain the most significant growth centre in Jordan, and arrangements for a reliable and full-scale water supply are of first priority. For the other areas of the Zarqa River Basin, the projected demand data in the fields of irrigation and domestic water supply do not differ very much from the estimated data of the present water use.

Considering average-year conditions, the balance computations indicate that surface baseflows and available groundwater resources will be exploited to a large extent by the various water users in the area. Some 42 MCM, primarily floodflows, which cannot be diverted for direct use, will be retained in the King Talal Reservoir. A supplementary

source of water is assumed to originate from returnflows of treated sewage. According to present plans, in 1985 about 26 MCM of such returnflows will presumably be released into the Zarqa River from treatment plants at Amman and Zarqa, and eventually flow into the King Talal Reservoir.

The balances of the individual subareas confirm that the water demand of the Amman-Zarqa region cannot be satisfied by the natural water resources there available. Government plans envisage an extension of the existing water production facilities in the very region, and the construction of a pipeline between the King Talal Reservoir and Amman. Considering these plans and the particular priority of adequate municipal water supply, it appears reasonable to think of an integrated central water supply system for the greater Amman-Zarqa region. The balance computations have been made accordingly. They incorporate the recycling of the treated sewage returnflows. This is to be taken into account in order to meet with the projected demand, and indicates also the urgent need of measures to be taken for sewage treatment and control of water pollution. Recycling operations are a common practice in areas with large demand and limited natural water resources. They are combined with treatment of sewage to acceptable standards, and with a subsequent additional water treatment complying with standards of potable water supply.

In addition to the recycling of some 25 MCM of annual surface returnflows, resources of about 40 MCM retained in the King Talal Reservoir have been envisaged for allocation to the Amman-Zarqa water supply. Their reliability as well as aspects related to the technical means for their potential exploitation are the dominant background of the proposed allocation programme. The remaining 33 MCM necessary to satisfy the water demand of Amman-Zarqa will be produced from the resources available in the very area. These include some 10 MCM of estimated uncontrolled returnflows entering

the groundwater aquifers in the urban and industrial districts of the region. According to the balance computations, certain quantities of surplus flow can be expected to leave the Amman-Zarqa region and eventually the Zarqa River Basin, most likely as groundwater flow or as baseflow in the lower Basin. It will be the subject of future surveys, after implementation of the recycling operations, to investigate the actual effects and to study the possibilities of a further use of such surplus flows. The surveys should also be seen in connection with environmental aspects, which may ask for the maintenance of a minimum flow with adequate water quality in the upper course of the Zarqa River. The expected returnflow of treated sewage (although less than 1 m^3/s, on the average) in 1985 will presumably contribute to acceptable conditions.

The balance established for the total Area V indicates that basically all the available resources are needed in the area itself. Accordingly, the allocations have been made to comply with the projected demand data. For the municipal water supply (1.4 MCM) of the Jarash region, the suggested incorporation into the "northern central supply system" was taken into account. In line with present and planned irrigation schemes about 15 MCM, partly (2 MCM) from groundwater resources, have been envisaged for transfer into some downstream and Jordan Valley (Area II) irrigation areas. Most of these transfers base on surface water resources which are assumed not to be controlled by the King Talal Reservoir, and which include an estimated volume of 5 MCM of flood flow originating from catchments downstream from the reservoir. These flood components do not appear to be exploitable in 1985. They will continue to discharge into the Jordan River. The groundwater stored throughout the Zarqa River Basin is not considered as a potential for major long-term development. The stored quantities should be seen only in terms of a supplement to the

groundwater resources which have been estimated as available for annual exploitation and which are used for various purposes.

It is to be noted that regarding the use of water retained in the King Talal Reservoir, the water allocation programme applied in the balance computations does not correspond fully to existing plans for the operation of the reservoir. The particular situation of the greater Amman-Zarqa region, however, seems to justify a reconsideration of these plans in line with the suggested projections. Some consequences with regard to present project layouts and necessary modifications may stand against a new concept; but all considerations should be guided by the aspect that adequate domestic and industrial water supply in the Amman-Zarqa area is a dominant condition for the projected socio-economic development of Jordan. The figures of the expected water demand may not necessarily be reached by 1985. They demonstrate, however, the order of magnitude; and it is obvious that reliable water resources need to be allocated urgently, in order to cope with the development of such water requirements. Present information and assessment do not indicate significant volumes of reliable annual water resources other than those which are going to be retained in the King Talal Reservoir. They form a source which is immediately available and exploitable with reasonable technical and economic means. Their utilization in the Amman-Zarqa area would not imply a reduction of the water resources required in the Jordan Valley (Area II) according to the development projections for 1985. But some specific project layouts may have to be reviewed and adapted. Nevertheless, an additional recycling of the water supplied into the Amman-Zarqa region seems to be indispensable. The technical details regarding the most economic recycling operations should be studied with some priority. The returnflow after sewage treatment may be recycled through the King Talal Reservoir and the pipeline system to Amman-Zarqa. It may also prove to be feasible to

use the returnflow for a controlled artificial recharge of the aquifers, (see also the present studies for the Abdoun Reservoir), from which groundwater is pumped for the water supply in Amman and Zarqa.

Summarizing the findings from the area balances of the northern regions in Jordan, it appears that the projected 1985 water demand can be satisfied through the suggested allocation of the resources. Apart from the modifications which are considered necessary with regard to the utilization of the water resources of the Zarqa River Basin, the water allocation programmes outlined in the area balances correspond largely to plans formulated earlier by various Government agencies.

The development projects envisaged in the central regions of Jordan suggested a joint interpretation of the projected area balances for the Dead Sea Riftside Wadis (Area VI), the Wadi Mujib Basin (Area VII), and the Wadi Hasa Basin (Area VIII). The projected demand data are primarily related to the plans of irrigation development in the Southern Ghors, and to the industrial water requirements expected from the operation of the Potash Project at the southern end of the Dead Sea. The projected figures of the domestic and municipal water demand indicate considerable improvements compared to the present conditions, but they remain small in relation to the other demand projections.

For the northern section of Area VI, the balance computations show a surplus of about 14 MCM of suitable surface water resources. They seem to justify detailed surveys regarding the possibilities and potentials of their future utilization. Specific attention has been paid to the increased municipal and domestic water requirements. Irrigation demand is not expected to rise significantly until 1985. The allocation of water for municipal and domestic supply anticipates the use of local groundwater and baseflow (springflow). Apart from

individual supply of scattered villages, it is thought reasonable to extent the present "South of Amman System" operated by the Water Supply Corporation, and to arrange for an integrated central water supply scheme which incorporates suitably located and major communities of the adjacent Wadi Wala area (Area VIIa). This corresponds to existing plans, and the present transfer of water from resources of the Amman area could be abandoned in near future. The local resources exceed the projected demand. It will, however, depend on the results of detailed surveys whenever the integrated central supply scheme may also be served by an exploitation of the available groundwater resources of the Wadi Wala area.

The projected annual water demand of almost 63 MCM in the southern section of Area VI (south of the Wadi Mujib gorge) requires to make use of the estimated resources (about 44 MCM) as far as it appears practicable. Only some 3.5 MCM of flood flow are considered not to be exploitable. The allocation of water for domestic purposes was given first priority, and extensions of existing water supply schemes and production facilities have been taken into account in the area balances. They include transfers of groundwater from the neighbouring Wadi Mujib Basin (Area VIIb). The projected irrigation and industrial water demands cannot be satisfied from the very area resources; the use of local resources in the existing, mainly private, irrigation areas should therefore continue with priority. For the other requirements, local resources have been allocated to a limited extent. According to the assumptions of the area balance and in line with the tentative plans for the diversion of Wadi Mujib baseflows into the area of the Southern Ghors, some 25 MCM need to be transferred from the Wadi Mujib in order to comply with the total projected demand. The final decision regarding the allocation and exploitation of the individual resources for the alternative demand sectors in the Southern Ghors (irrigation and Potash Project) will

have to be based on the related technical and economic considerations.

The corresponding area balances of the Wadi Mujib Basin (Area VII) and the Wadi Hasa Basin (Area VIII) indicate that the estimated annual resources, locally combined with an exploitation of stored groundwater, will allow to satisfy the projected demand in these two areas and to transfer the supplementary quantities which are required in the area of the Southern Ghors. Some 37 MCM of annual flood flows in the Mujib Basin and some 16 MCM of floods and baseflow from the Hasa Basin will remain unused according to the projected plans. These resources and the considerable volumes of stored groundwater should be seen as a subject of future detailed surveys in order to determine the potentials for a long-term development. Such surveys should also serve a review of the effects resulting from the local exploitation of stored groundwater in the area of the desert irrigation schemes and the phosphate mines. The projected abstractions are likely to affect the long-term availability of the baseflows at the lower reaches of the Wadi Mujib and the Wadi Hasa.

Basically, however, the area balances of the central regions of Jordan confirm that the existing medium-term development plans might be accomplished, as far as the water resources are concerned. The implementation of the various projects will therefore depend primarily on the findings of the detailed technical and economic studies. The extent of estimated surplus resources justifies further surveys regarding their long-term exploitation.

The southern and eastern regions of Jordan do not anticipate any large-scale water demand in 1985. In Area IX (Wadi Araba North), the use of the limited local water resources will hardly differ from the present situation. The projected

improvements of domestic water supply were given priority, but they result primarily from extensions of existing municipal water supply schemes which import resources from outside the area. The estimated local surplus water resources are no significant base for further development. The tentative plans for the implementation of a copper mining industry may have to be abandoned because of this constraint. It appears from the comparative review of available resources and projected industrial demand that the technical means necessary to provide the water may not be economically feasible.

In Area X (Wadi Araba South), the projected municipal and industrial water demand of Aqaba (about 9.4 MCM) stands in first priority. It cannot be satisfied from the heavily depleted local groundwater resources; the projected water allocation is therefore based on the existing plans of the Qa'Disi - Aqaba pipeline project. According to information, the layout of the pipe system is envisaged to have eventually a conveyance capacity of 17 MCM/year. A phased implementation of the project would enable to satisfy the water demand of the Aqaba area by 1985. Some water use for irrigation near Aqaba is expected to continue, supplemented by about 2-3 MCM of treated sewage returnflows, which are likely to result from the increased domestic and industrial water demand. Sewage collection and treatment are to be seen as very important components within the scope of the various development plans and projections which have been formulated for the Aqaba region.

In Area XI (Southern Desert:Qa'Disi), the projected exploitation of the available resources will be concentrated to the well fields of the Qa'Disi area. To a considerable extent, the water production is going to draw on stored groundwater. The demand projections (26 MCM) both for local irrigation and for the water transfer to Aqaba can presumably

be satisfied; however, considering also the projected investment for the implementation of the pipeline, the supply into Aqaba should have preference in case of limitations in the water production. This may apply particularly with regard to the long-term development of the water demand in Aqaba, provided reuse of treated sewage or desalination of seawater for domestic and industrial purposes would not be taken into account eventually. The balance computations for Area XI nevertheless indicate a significant surplus of stored groundwater which seems to be exploitable for local individual development works, most likely irrigation, and relevant surveys should be initiated for long-term plans. The available surface water resources do not justify any specific consideration.

The projected conditions in Area XII (Jafr Basin) are similar to those estimated for Area XI. The water demand will primarily have to be satisfied through the exploitation of stored groundwater. The annual water resources and their local availability cannot support the projected development of the demand for irrigation and industrial water supply. Present information does not allow a detailed analysis regarding the extent to which the projected water production in the individual subareas will base on annual and/or stored groundwater. The use of surface water is assumed to continue in line with the present situation, and no use of the very limited and scattered flood runoffs (about 10 MCM) which originate from the rainfall over the western basin, has been envisaged by 1985. The water allocation shown in the area balance placed first priority on the water supply for domestic and municipal purposes.

Further surveys and reviews appear to be necessary in due course, in order to make sure that the projected large-scale exploitation of groundwater for irrigation and phosphate mining works is not causing constraints to the production of groundwater for domestic supply schemes. Some problems

areas and well fields. Although small compared to the other water requirements, the domestic supply is to be given preference, particularly over irrigation. Nevertheless, according to the balance computation, the Jafr Basin seems to avail of surplus groundwater resources. They justify detailed surveys regarding suitable locations and the potentials of long-term local development.

The projected water balance of the Azraq Basin (Area XIV) does not differ significantly from the corresponding analysis of the present water use. There are no specific development projections and plans for the area. The estimated surplus of available annual resources (about 25 MCM) and some 1,700 MCM of groundwater stored in the area should become the subject of detailed surveys for long-term development. The quantities still exploitable in the very Azraq-depression may include some 13 MCM of baseflow (springflow), but any further estimates regarding the most suitable locations for extended future groundwater production cannot be supported adequately through the available information. Therefore, no use of the resources for water supply outside Area XIV has been envisaged in the projected area balance. Provided that the results of detailed surveys and studies do not justify the considerable investments for a large-scale annual export of the water into particular demand centres (e.g. Amman-Zarqa area), the available and exploitable resources should serve local development projects primarily. According to the review of socio-economic and landuse conditions, such local developments could aim at extended irrigation agriculture, and a number of small flood retention basins may prove to be feasible to make use of the surface resources in addition to the groundwater.

Projection 2000:
The area balances with regard to the expected situation in the Year 2000 take account primarily of the projected water demand for municipal and industrial purposes. As far

as irrigation is concerned, the projections related to the situation in 1985 were assumed to be valid basically also in 2000. For some areas, modifications have been applied, anticipating an improved utilization of the available water resources. Further, returnflows of treated sewage were considered as a significant supplement to the natural water resources, and they have been incorporated into the area balances accordingly.

The overall-picture of the regional distribution of water demands and water resources in the Year 2000 reflects the same tendencies and concentrations which were identified for the projections of 1985:

- The municipal and industrial water requirements to be satisfied in the greater Amman-Zarqa area are likely to increase to about 183 MCM per year;
- The supply of irrigation water into the Jordan Valley is not expected to exceed considerably the quantities of the 1985-projections;
- The other major demand centres remain in line with the 1985-projections; in the Aqaba area, an annual domestic and industrial water demand of about 14.5 MCM will have to be taken into account.

The considerations regarding the individual area balances and the suggested water allocation programmes correspond therefore to the outlines given in the medium-term projections. They adapt the allocation of the available resources to the increased demand data. As far as estimated resources are concerned which exceed defined water demands, no specific development projections have been made, but surveys have been suggested which may serve an improvement of the data base and final conclusions regarding an appropriate utilization of all the available resources. It is to be noted that the long-term projections can be seen only as a tentative information. They depend, more than the medium-term 1985 plans, on the policies and strategies eventually

determined by the Government, and on the results of future regular reviews of the real achievements and trends.

The projected area balances of the northern regions are governed by the allocation of the water resources for the "northern central water supply system" and the Jordan Valley. Following the suggested layout and the priority of an integrated municipal water supply scheme the demand projections would require to provide almost 33 MCM from the resources of the Yarmouk River (Maqarin Reservoir), while local groundwater production for the scheme in the Year 2000 is assumed to yield about 5 MCM. The diversion of Yarmouk resources into the Jordan Valley (Area II) will remain in the order of about 255 MCM, on the average. Thus, without consideration of the possible effects of "over-year" storage in the Maqarin Reservoir, some 19 MCM would be available in the reservoir to serve the rights of water users outside Jordan.

The exploitation of the water resources of the Riftside Wadis (Areas III and IV) assumes some improvements in local irrigation schemes. The area balances, nevertheless, indicate that diversions into the Jordan Valley (Area II) can be maintained in line with the 1985-projections. The expected returnflows of treated sewage are likely to increase the potential supply to about 95 MCM (compared to about 80 MCM according to the 1985-projections). A modification of the water resources allocation programmes seems to be reasonable for the Salt/Sweilih/Wadi-es-Sir region in Area IV. The rising demand of municipal and industrial water supply and the locations suggest to incorporate these communities into the integrated water supply system serving the greater Amman-Zarqa area. This suggestion was taken into account in the relevant area balances for the Year 2000.

The potential allocation of the available water resources indicates that the total water supply for irrigation purposes in the Jordan Valley (Area II) will presumably not exceed

some 365 MCM. The final studies on the Maqarin Reservoir as well as subsequent experiences from the operation of the reservoir may prove that larger quantities than assumed in the present balance computations can eventually be transferred into the Jordan Valley. Surplus flows because of the suggested recycling operations may also prove to become available for diversion from the Zarqa River Basin. Based on the present information, however, such extended projections cannot be supported adequately. Similar reservations apply to the possible utilization of the Wadi Raqqad/ Lower Yarmouk floodflows and of some 10 MCM of surplus flows in the northern section of the Dead Sea Riftside Wadis (Area VIa). Provided all these supplementary sources were effective in the Year 2000, the annual water supply for irrigation in the Jordan Valley may reach the order of 450 MCM. This supply could serve an extension of irrigated land beyond the scope of the 1985-projections, or cover increased water requirements which are likely to result from irrigation efficiencies lower than assumed in the project plans.

The projected area balance of the Zarqa River Basin (Area V) takes full account of the potential returnflows of treated sewage. It is thought reasonable to assume that by the Year 2000 the necessary sewerage systems and treatment plants have been completed particularly in the greater Amman-Zarqa area, and that they will allow a controlled recycling of the water used for domestic and industrial purposes. Thus, combined with the available natural water resources, a water supply in line with the projected demend could be provided from the very area resources. It is to be noted that the assumed full operation of sewerage systems will reduce considerably the extent of uncontrolled groundwater recharge in the urban and industrial districts. Unlike the assumptions applied for the 1985-area balance, a reuse of these uncontrolled returnflows for the water supply of Amman-Zarqa has not been taken into account. At present, an assessment of

the actual quantities is hardly possible. They will certainly contribute to the groundwater flow or surface baseflow in the lower basin. As outlined in the interpretation of the 1985-projections, the technical system finally adopted for the recycling operations, and further surveys regarding the effects on groundwater, surface flows, and environmental conditions will reveal the extent of surplus resources and indicate their potential utilization within the Zarqa River Basin or in the Jordan Valley. Surplus flows would also result from water imported into the Amman-Zarqa area from outside the basin. According to the area balance, such import of resources does not appear to be necessary, provided sewage returnflows are controlled and treated in line with the required standards. The present projections do not envisage the import of water. Available information as yet does not identify reasonable quantities of reliable resources, which could be transferred economically. Relevant surveys and studies, however, should continue. An economic import of water into the Amman-Zarqa area may facilitate the maintenance of the water quality during the recycling operations, and would eventually supplement the water supply into the Jordan Valley.

Also the area balances projected for the central regions of Jordan support the allocation of the water resources in accordance with the outlines of the medium-term plans. Area VIa (Dead Sea Riftside Wadis north of the Wadi Mujib gorge) indicates a surplus of some 10 MCM of suitable surface flows. Subject to the findings of the suggested detailed surveys they could be exploited for use in the Jordan Valley, the Southern Ghors, or the Amman-Zarqa area. They may also be considered for utilization in the very area for purposes other than irrigation. In the southern section of the Dead Sea Riftside Wadis (Area VIb), the projected water supply will continue to draw on the diversion of surface flows from the Wadi Mujib; additionally extensions have been envisaged for the domestic water supply schemes, which were programmed in the 1985-projections.

The area balance of the Wadi Mujib Basin (Area VII) assumes a reduced surface baseflow. This estimate takes account of long-term effects which are likely to arise from the extensive groundwater exploitation in the irrigation and industrial schemes located in the upper basin. An allocation of potential floodflows has not been made. Present information is too scarce for realistic projections. Future surveys will certainly verify the extent of exploitable floodflows and their potential utilization in the Southern Ghors, or for other specific purposes inside and outside the area. The same applies with regard to the stored groundwater resources.

Also for the Wadi Hasa Basin (Area VIII), a reduction of baseflow resources has been assumed as a consequence of the projected groundwater exploitation. The area balance shows that apart from floodflows which may require flood protection works but are not considered as a resource for potential development, practically all the surface flows will have to be diverted into the areas of the Southern Ghors. This is different from the 1985-projections. Although the water demand is not expected to rise significantly beyond the plans of 1985, the assumed reduced baseflow diversion from the Wadi Mujib will have to be compensated by a full utilization of the Wadi Hasa baseflows. Basically, however, the long-term development projections of the central regions seem to comply with the allocation programme of the water resources. Further surveys, after implementation of the various development projects, will help to review and modify the assumptions applied for the balance computations, and to confirm additional resources which at present have not been allocated for utilization.

As far as the southern and eastern regions of Jordan are concerned, compared to the expected 1985-situation the long-term projections do not anticipate signifcant changes. The available water resources of Area IX (Water Araba North) do not support additional development, and those estimated to

be exploitable in Area X (Wadi Araba South) will presumably be exhausted by the Year 2000. The projected municipal and industrial water demand of the Aqaba area (14.4 MCM/year) should be satisfied through groundwater pumped from Qa'Disi, while returnflows of treated sewage have been envisaged for allocation to irrigation areas near Aqaba.

The annual groundwater production at Qa'Disi (Area XI) would have to be raised to about 32 MCM in order to meet the demand projections of Aqaba in addition to the irrigation requirements which would result from the operation of the Qa'Disi irrigation scheme. Such production may prove to exceed the capacity of the Qa'Disi well fields, although considerable volumes of groundwater are estimated to be stored in Area XI. Additional well fields may have to be investigated. As outlined in the interpretation of the 1985-projections, however, the water supply into Aqaba should continue to have preference over water supply for irrigation in Qa'Disi. Some of the water requirements in Aqaba could eventually also turn out to be economically satisfied through recycling of used water or through desalination of seawater. Although plans for the implementation of the Qa'Disi-Aqaba pipeline have been formulated, surveys regarding such supplementary water supply facilities seem to be justified for long-term development.

The projected area balances of the Jafr Basin (Area XII) and of the Azraq Basin (Area XIV) show adaptations to increased local water demand. But no allocations for the utilization of estimated surplus resources have been envisaged at present. A verification of these resources appears to be among the primary objectives of further local surveys. Allocation policies should then be determined accordingly.

4. Conclusions for Strategies and Policies

4.1 Development Priorities

It is acknowledged that the development of water resources for domestic and municipal water supply stands in first priority. Adequate and reliable water resources need to be allocated. They should enable to provide the water at the lowest practicable cost through water supply schemes which are technically sound and flexible enough to cope with long-term trends and fluctuations of the water demand.

Municipal water demand, as far as quantities and localities are concerned, is concentrated particularly in the Amman-Zarqa area and throughout the population centres of the northern regions of Jordan. At present, the conditions of the water supply are inadequate. The water demand in Amman-Zarqa is intensified because of the significant water requirements of industries. According to the various development projections, this agglomeration of municipal and industrial water demand is not likely to change in future. The projected demand data may not necessarily be achieved, but they indicate the urgent need of decisions and arrangements regarding the allocation and development of reliable water resources for these demand centres. The situation is aggravated by the fact that although most of the natural water resources of Jordan are available in the northern regions, the very considerable irrigation water requirements in the Jordan Valley have to be satisfied simultaneously.

The comparative review of water resources and demand also indicates the urgent need of effective regulations and measures for conservation and protection of the water resources.

Control of water pollution is indispensable, and recycling of water after use will have to be initiated in near future in order to cope with the increasing water demand, particularly in the population and industrial centres. The improvement and extension of municipal and industrial water supply systems is to be combined with the corresponding implementation of sewage control and treatment works. Priority should further be given to such arrangements and operations which help to control excessive water consumption and make the best use of the scarce resources.

As regards the existing plans, programmes and development priorities, no significant modifications seem to be necessary. The area balances indicate that the projected water demand can be satisfied through a coordinated allocation of the water resources and through the relevant implementation and operation of the development projects. Water envisaged for irrigation purposes certainly has to comply with acceptable quality standards. In case of conflicting interests, however, preference should be given to the use of the water for municipal and industrial water supply.

4.2 Allocation of the Water Resources

The allocation of the water resources outlined in the projected medium-term (1985) and long-term (2000) area balances is to be regarded as a recommendation and background information for final decisions on policies and strategies. The present plan of water resources allocation may deviate in some parts from individual points of view of the Government agencies. It is therefore to be seen as a tentative programme, and subject to modifications which the Government may consider necessary in due course. After final approval and determination of the policies and strategies, however, the allocation plan and the pertaining action programmes should be regarded as the National Water Master Plan and be pursued accordingly by all concerned.

Summarizing the conclusions drawn from the projected area balances it appears appropriate to adopt the following major strategies for the allocation, management, and control of the available water resources:

- The existing municipal water supply schemes in the northern regions suggest their incorporation into an integrated "Northern Central Water Supply System", serving the population centres and communities throughout the northern regions. To satisfy the projected water demand (1985: 23.8 MCM; 2000: 37.8 MCM), an allocation of part of the very reliable and suitably located water resources of the Yarmouk River has been envisaged. According to the estimates, in 1985, about 21.8 MCM would have to be diverted from the Yarmouk. By the year 2000, the annual diversion requirements may be in the order of 32.8 MCM, assuming that through a gradual extension of the present well fields between Ramtha and Mafraq the exploitation of the available groundwater resources could be increased eventually to an annual production of 5 MCM. The suggested operation of the "Northern Central Water Supply System" would not necessarily depend on the implementation of the projected Magarin Reservoir. Considering the water demand projections, a continued transfer of water from the resources at Azraq and Dhuleil does not seem to be reasonable. There is a heavy groundwater depletion at Dhuleil, and the long-term potential of a water export from Azraq is as yet not confirmed with sufficient reliability.

- The expected development of the water demand in the Amman-Zarqa area indicates the necessity to make full use of the water resources which are reliably available in the Zarqa River Basin. In addition to the allocation of the local baseflows and groundwater resources to the various water users in the river basin, the surface flows which are going to

be retained in the King Talal Reservoir should be reserved in first priority for the water supply in Amman and Zarqa. An integrated central water supply system for the greater Amman-Zarqa area would be of advantage. As outlined in the projected area balances, such central system would enable to satisfy the projected water demand from the local resources and from those stored in the King Talal Reservoir, but necessarily combined with a recycling of used water. Adequate recycling operations and arrangements for water quality control are to be seen as very important components of the strategy which will have to be adopted for the use of the water resources in the Zarqa River Basin. For long-term plans, the incorporation of the Salt/Sweilih/Wadi-es-Sir water supply into the supply system of the greater Amman-Zarqa area seems to be appropriate. Any surplus flows should be released for use in the Jordan Valley.

- The allocation of water resources which cope with the water demand projections of the Jordan Valley depends entirely on the implementation of the Maqarin Reservoir and on a very effective exploitation and controlled utilization of the surface and underground flows of the riftside catchments. For irrigation purposes in the very valley region, the suggested allocation programme envisages average annual diversions of about 255 MCM from the Yarmouk River. 200 MCM of these diversions would be released from the water planned to be stored in the Maqarin Reservoir. In addition, some 80 MCM annually have been envisaged for 1985 as potential diversions from the riftside catchments; they are expected to yield some 95 MCM by the Year 2000. Thus, supplemented by the very limited resources of the valley region itself and by some surplus flows leaving the Zarqa River Basin, the projected medium-term (1985) water requirements

(about 350 MCM) of the Jordan Valley can be satisfied. It is to be noted, that any further irrigation development in the Jordan Valley, going significantly beyond the scope of the 1985-projections, cannot be supported at present by sound proposals for the allocation of supplementary water resources. Some 70 MCM, on the average, may be developed in long-term programmes through additional storage on the Wadi Raqqad or on the lower Yarmouk River, and some 10 MCM may finally prove to be feasible for annual diversion from the Dead Sea catchments north of the Wadi Mujib gorge. According to present assessment of resources and needs in the various areas and regions, however, it is unlikely that water resources exceeding 450 MCM can eventually be allocated for irrigation purposes in the Jordan Valley.

- The allocation of the water resources retained in the Maqarin Reservoir anticipates allowances of about 30 MCM in 1985 to serve rights of water users outside Jordan. The projections for the Year 2000 require a reduction of these allowances to about 20 MCM per year. Definite inter-governmental agreements will have to be taken into account finally; they are, however, not likely to affect the basic allocation programme.

- Integrated central systems for municipal water supply should serve the communities of

  - the Madaba-Dhiban-Northern Wadi Wala region;
  - the Karak-Western Wadi Mujib region;
  - the Tafila-Shaubak region.

  The allocation plan envisages the gradual extension of the existing pipelines and water production facilities. The projected long-term water demand within each of these three regions (about 3-4 MCM/year) can be satisfied through an exploitation of local resources.

- The municipal and industrial water supply of the Aqaba area is to be based on the groundwater resources of Qa'Disi, but recycling operations should be initiated early in combination with considerations regarding the reuse of treated sewage. Pollution control is of utmost importance, and water-saving practices in industries seem to need particular attention and efforts. The potentials of seawater desalination for part of the industrial water supply may be promoted in long-term plans, considering that a continued large-scale groundwater production at Qa'Disi might cause problems during the course of future years.

- For towns and communities outside the integrated central systems, the exploitation of local resources through an extension of existing or through new individual municipal supply schemes is envisaged in the water resources allocation plan. The utilization of specific springflows or groundwater is to be decided after local surveys and studies.

- The available baseflows of the Wadi Mujib and the Wadi Hasa Basins are allocated for diversions into the Southern Ghors in order to supplement the utilization of the available local resources for irrigation and industrial purposes. An allocation of the estimated average annual flood flows (25-30 MCM) of the Wadi Mujib Basin is not reasonable as yet. More detailed surveys regarding potential sites for adequate storage and exploitation of the sporadic floods are to be made.

- The planned implementation of irrigation and industrial projects in the desert/highland regions is to be based on the exploitation of locally available groundwater resources. Further schemes in the Jafr Basin and the Qa'Disi/Southern Desert area may become possible after relevant surveys, but potential long-term effects of groundwater abstractions and of consequences resulting to other water users are to be investigated and controlled.

- According to present assessment, the resources of the Azraq Basin should be allocated to a gradual extension of local development projects. Similarily, the groundwater resources of the Wadi Dhuleil area can be considered only as resources for a continued local utilization.

- Water pollution Control is to be initiated and maintained effectively in all the areas of concentrated municipal and industrial water use; additionally in the areas delineated for specific regulations regarding water protection.

4.3 Consequences regarding Existing Development Plans

The envisaged allocation of the water resources meets with the existing development plans to a large extent. Some details of present technical and operational project layouts, nevertheless, may have to be reviewed and adapted if the suggested allocation programme becomes effective. Such adaptations and modifications will primarily refer to project works which are related to the utilization of the water resources of the King Talal Reservoir. The existing development programmes of the Jordan Valley are not affected. The allocated water resources will comply with the demand data of the medium-term projections, provided the technical and organizational infrastructure for the development, exploitation, and control of the allocated resources is going to be implemented. The allocation to the Jordan Valley of supplementary water resources for substantial irrigation developments beyond the scope of the 1985-projections is unlikely to be possible. The projected irrigation efficiencies may not be achieved after completion of the schemes, and any surplus resources which may result from the neighbouring catchments, would then primarily have to compensate the effects of the lower efficiencies. This is also to be seen

infrastructure in the irrigation areas of the Jordan Valley.

The suggested modification of the existing programmes regarding the utilization of the water resources retained in the King Talal Reservoir stands against the point of view that surface water resources with acceptable quality should be reserved for irrigation purposes. The expected substantial increase of the water demand in the Amman-Zarqa area, however, requires early technical arrangements based on reliable water resources. Resources other than those of the King Talal Reservoir which meet the requirements in terms of quantity and accessibility, cannot be identified reliably at present or in near future. Accordingly, the King Talal Reservoir should serve the Amman-Zarqa area in first priority. Existing plans for extensions of present water supply facilities should be adapted to this allocation programme and eventually lead to the suggested integrated central supply system for the greater Amman-Zarqa region.

The present initial steps directed to control of water pollution and treatment of sewage effluents need to be pursued and extended with particular efforts. In the municipal and industrial districts, such measures have to become effective before long in order to facilitate the necessary recycling of the water and to protect the natural resources.

As regards the Southern Ghors irrigation development and the Potash Project, there appear to be no conflicts as far as the allocation of the water resources is concerned. Although the findings of the final project studies are not yet available it is unlikely that the projects will not be implemented and the resources thus become available for other purposes. Supplementary

water resources even may be developed from storage of flood flows in the Wadi Mujib Basin. Such surveys should be taken into account for long-term plans. The present development programmes for a copper mining industry in the Northern Wadi Araba area, however, may meet with problems. No water resources seem to be available which could reasonably cope with the projected water demand.

For the Aqabe area, the prospects and potentials of seawater desalination should continue to be studied. The development plans for Aqaba should not be based on water supply from Qa'Disi only.

4.4 Consequences regarding Regional Development

The main centres of water demand correspond to the centres of the dominant socio-economic and regional development in Jordan. This indicates that the tentative outlines of a potential regional development are not in conflict with the suggested allocation of the available water resources. Final considerations and detailed regional development plans may therefore be formulated and pursued accordingly after approval of the National Water Master Plan.

5. Action Programme

5.1 Determination of Water Resources Allocation Policies

Water resources development works realized at present or programmed for near-range implementation should fit into long-term plans. This requires urgently to establish the basic policies for the allocation and corresponding development of the water resources.

The policies and strategies to be adopted need to become the first objective of decisions which are to be made at high governmental level. They are anvisaged to take account of national and local points of view, to define the priorities in case of conflicting interests, and thus to provide some legal status to the National Water Master Plan, in order to exclude conflicting developments in the utilization of the water resources. Any withdrawel of water has consequences to other interests. The present analysis shows that regarding the distribution in time and locality the water requirements can be satisfied through the available natural water resources and through recycling operations.

5.2 Allocation of Water Resources and Water Rights

After determination of the policies and strategies to be adopted, the present tentative plan of water resources allocation may need some adjustments. It will then constitute the National Water Master Plan and open the way for the detailed planning, implementation, and operation of the necessary works by the agencies and water users to whom the resources were allocated.

The allocation of the water resources should preferably be combined with the allocation of corresponding water rights. Abstractions of water may have to be tied to detailed licenses which are based on present water uses and expected developments.

New laws and regulations may have to be adopted, in line with the decided policies and strategies, and existing laws, regulations, customs, and traditions will have to be reviewed accordingly by the Government.

5.3 Pollution Control and Recycling of Water

The scarcity of the natural water resources and the ever increasing danger of water pollution make it imperative to intensify the efforts which provide strict regulations and measures for effective protection and conservation of the water resources. These efforts are to be guided within the scope of the policies and strategies of the National Water Master Plan.

The available documentation outlines measures which enable to safeguard the water resources for direct or future utilization . They aim at pollution control of surface flows according to applicable standards, and they delineate areas where restrictions in land use seem to be necessary in order to protect ground-water resources from the hazards of pollution.

Pollution control is important with regard to environmental aspects, but indispensable in view of the need to augment the supply of water. The efficiencies of water use may be increased to some extent through adequate water management in the various projects. A repeated use of the available resources, however, will become more and more urgent in the centres of municipal and industrial water demand. This calls for immediate actions regarding water purification and approved policies for recycling operations.

5.4 Administration and Legislation

The implementation of the National Water Master Plan is to be based on a smoothly working administration which fits into the existing Government system. A multiplicity of competences regarding the management and control of the water resources should be avoided. Rearrangements in line with the current Five Year Plan for Social and Economic Development 1976-1980 were initiated recently and should be pursued in order to adapt the administration and legal structure to the needs. All activities related to the implementation of the National Water Master Plan are to be guided and controlled by a high-level Government body (Supreme Water Council).

Arrangements regarding legislation are equally important. They are to be made in line with the established policies and strategies. They are to define the responsibilities and competences within the administrative structure of the agencies engaged with water resources planning and development, and they are to cover the details of water rights, water metering and water rates, water quality and pollution control, and watersaving measures. All abstractions and returnflows need to be subject to licenses and controls which determine the quantities of off-takes and the quality of returns. They are the base to make sure that water resources planning and operation comply with the legal provisions and priorities established through the National Water Master Plan.

5.5 Data Acquisition and Information Management

The recently completed documentation quotes the deficiencies of the available data base and outlines a number of recommendations for the preparation of improved information during the course of the future years.
Acquisition and processing of data are to be supported through the administration and legal arrangements, and they are to be regarded as a basic component of the

National Water Master Plan. All surveys, studies, and operational programmes should be directed towards the goals to be achieved according to the established policies and strategies.

Particularly, the information on available and exploitable water resources in the various areas and regions should be improved through specific surveys and data processing. Such surveys should continue and aim at a data acquisition in view of problems which might arise during detailed project planning, and in view of the problem that the scarcety of the available water resources requires efficient water use and measures which augment the water supply whenever this is possible with reasonable means. Thus, through the surveys, also the aspects of watershed management, i.e. measures related to erosion control, flood control, and conservation of water, will have to become the subject of long-term development programmes. Near-range surveys and plans regarding watershed management for obvious reasons can refer only to limited flood control works (dikes, channel improvements) which accompany other water resources development projects and serve the protection of project infrastructure.

The administration and legal arrangements for the implementation of the National Water Master Plan should further provide obligatory guidelines and instructions for a regular flow of information between all concerned with the control and the use of water resources. The monitoring system is to cover all data on actual and expected water use and water management, achievements of water quality control, and the information regarding detailed studies on water resources and related development projects. Such information management is considered important for the maintenance of up-to-date information, and will facilitate adjustments and improvements of the Plan.

5.6 Near-range Measures

Apart from the present activities for the planning and implementation of specific water resources development projects which appear to be in line with the tentative plan for the water resources allocation, immediate attention should be directed to

- effective measures for the control of surface water quality in the vicinity of municipal and industrial areas;

- technical alternatives and details of adequate project layout for the recycling of treated sewage in the greater Amman-Zarqa area;

- potentials and technical requirements for an increased groundwater production in the Mafraq-Ramtha area considering the suggested layout of the "northern central water supply system";

- coordinated and complete data acquisition regarding the water resources and their present management in the eastern riftside catchments of the Jordan Valley.

All other surveys and data processing regarding basic information on water resources should continue and gradually be improved in accordance with the policies and guidelines established in the National Water Master Plan. As quoted in connection with the studies for the development of the Jordan Valley and the Yarmouk water resources, the expected substantial reduction of natural discharges into the Dead Sea is not likely to cause serious effects.

It should, however, become the subject of investigations in order to verify the tentative conclusions or to identify the potential effects and consequences in detail. Among the near-range measures, also specific surveys on the water resources of the Azraq area may be initiated in order to improve the information on the location and quantities of the exploitable resources, and to extend this information to the groundwater resources stored in the deep aquifers.

5.7 Review of Plans and Policies

The National Water Master Plan is to be regarded as the guideline for a coordinated implementation of water resources projects which are capable to cope with long-term development projections. Projections, however, seldom come true and available background data are not consistent in all cases. The Plan and the various conclusions should therefore be reviewed in intervals of about five years and extended accordingly. Such review will enable to reconsider and if necessary to revise parts of the Plan and the policies, taking account of more recent data and better information on water resources, their utilization, and the potential development of the country.

During the course of future years, certainly more sophisticated methodologies (e.g. through linear programming or dynamic simulation approach) may prove to be applicable in order to analyse how various sources of water could best be used to supply a number of users at different places and times. A recent ASCE-publication describes the consideration of seasonal and stochastic factors in water planning. They take account of the mostly non-linear cost functions of water supply and waste water treatment, the stochastic availabilities of water resources and supply, and the seasonal variations of the water requirements of different water users.

6. Outlook

Summarizing the findings, it appears that Jordan's water resources are sufficient to satisfy the water demand expected to result from the implementation of the present development plans.

A detailed interpretation has been made of the regional distribution of water resources and water demand. It indicates that appropriate water allocation strategies will have to be established to satisfy the projected demand. Water resources development projects will have to be implemented in line with these established strategies. Some modification of the existing water allocation programmes seems to be necessary, particularly as far as the water resources of the Zarqa River Basin are concerned. Urgent attention must also be paid to water conservation measures. The projected water demand in regions like the greater Amman-Zarqa area will necessitate strict regulations for pollution control and for the implementation of sanitary sewage treatment facilities to allow the recycling and reuse of the water resources for domestic and/or other purposes. The expected future development cannot be based on the potential natural water resources alone, also because of economic constraints.

The present documentation is to be seen as the first approach to the formulation of a coordinated water allocation policy for Jordan. It will help to fulfil the envisaged objectives. A great number of institutions, agencies, and individuals - both governmental and private - have provided their advice, assistance, and support during the preparation of the Plan. All these contributions deserve full acknowledgement and were gratefully appreciated by the team. They were a great encouragement in the undertaking of the work, and they

indicate that there is a sound base for the implementation of the Plan. Much, however, is still to be done and utmost efforts of all concerned will have to continue for a successfull completion of the water resources development in accordance with the targets set for the national development of Jordan.