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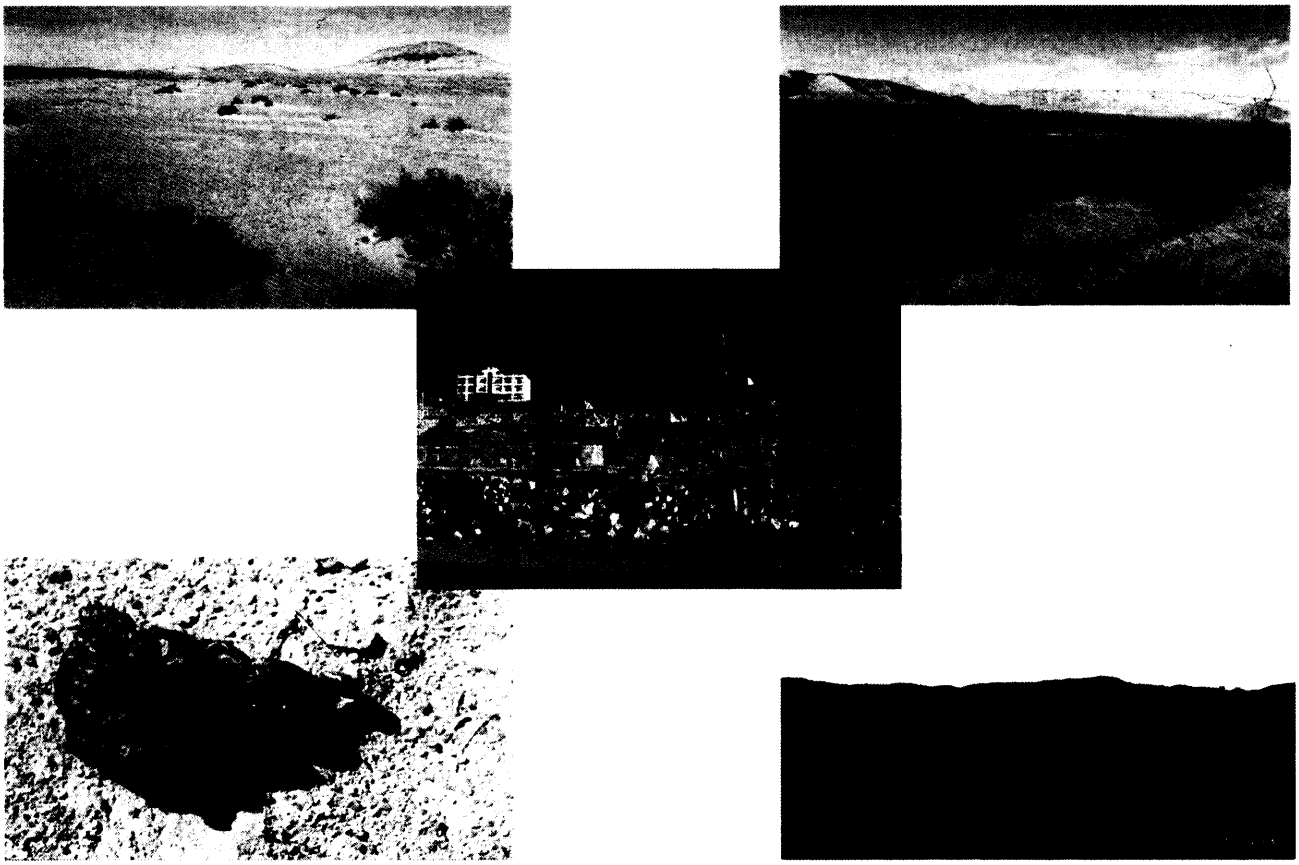
المملكة الاردنية الهاشمية

The Hashemite Kingdom of Jordan

MINISTRY OF WATER & IRRIGATION



Environmental and Social Assessment
Disi-Mudawarra to Amman Water Conveyance System

Main Report – Part B: Water Sector Assessment

June 2004

consolidated consultants
engineering & environment

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LIST OF ABBREVIATIONS

ARICAD	Arab International Company for Agricultural Development
ASEZ	Aqaba Special Economic Zone
ASEZA	Aqaba Special Economic Zone Authority
a.s.l	Above Sea Level
BOO	Build, Own, Operate
BOOT	Build, Own, Operate, Transfer
BOT	Build, Operate, Transfer
CC	Consolidated Consultants Engineering and Environment
CITES	Convention on International Trade in Endangered Species of Wild Fauna and Flora
CMS	Conservation of Migratory Species
CRM	Cultural Resources Management
CSCs	Common Services Councils
DADP	Disi Area Development Plan
DAI	Development Alternatives, Inc.
DEHC	Department of Environment and Health Control
DOA	Department of Antiquities
DOS	Department of Statistics
Dunum	A dunum represents 1,000 m^2 (1 Dunum = 0.1 hectare)
EA	Environmental Assessment
EC	Electrical Conductivity (expressed in µS/cm)
EIA	Environmental Impact Assessment
EIRR	Economic Internal Rate of Return
EPC	Executive Privatisation Commission
EPL	Environment Protection Law
ERC	Electricity Regulatory Commission
ESA	Environmental and Social Assessment
ESMP	Environmental and Social Management Plan
ESSD	Environmental and Socially Sustainable Development
EU	European Union

FAO	Food and Agriculture Organization
FOE	Friends of Environment
GCEP	Government Corporation for Environment Protection
GDP	Gross Domestic Product
GEF	Global Environment Facility
GOJ	Government of Jordan
GRAMECO	Grains, Fodders and Meat Production Company
GTZ	German Agency for Technical Cooperation
ha	Hectares (1 ha = 10 dunums)
IBAs	Important Bird Areas
IRR	Internal Rate of Return
IT	Information Technology
JACA	Jordan Aqua Conservation Association
JD	Jordanian Dinars (1 JD = 1.41 US Dollars; 1 JD = 1.16 Euros)
JES	Jordan Environment Society
JIB	Jordan Investment Board
JISM	Jordan Institute for Standards and Metrology
JREDS	Jordan Royal Ecological Diving Society
JUST	Jordan University of Science and Technology
JVA	Jordan Valley Authority
KAC	King Abdallah Canal
KTDR	King Talal Dam Reservoir
l/c/d	Litres per Capita per Day
LEMA	Lyonnaise des Eaux, Montgomery Watson Arabtech Jardaneh - a private operator
MCM	Million Cubic Meters
MEMR	Ministry of Energy and Mineral Resources
MMA	Ministry of Municipal Affairs
MOA	Ministry of Agriculture
MOE	Ministry of Environment
MOH	Ministry of Health

MOP	Ministry of Planning
MOT	Ministry of Tourism
MPWH	Ministry of Public Works and Housing
MSS	Marine Science Station
MWI	Ministry of Water and Irrigation
NES	National Environmental Strategy
NGO	Non-Governmental Organization
NPV	Net Present Value
NRA	National Resources Authority
O&M	Operation and Maintenance
OMS	Operation and Management Support project
PC	Project Company
PMU	Project Management Unit
ppm	Parts Per Million
QACU	Quality Assurance and Compliance Unit
RO	Reverse Osmosis
RSCN	Royal Society for Conservation of Nature
RSS	Royal Scientific Society
SCBA	Social Cost Benefit Analysis
SCS	US Soil Conservation Service
SOP	Standard Operating Procedures
sp./spp.	Specie(s)
SWWTP	As-Samra Wastewater Treatment Plant
TRC	Telecommunication Regulatory Commission
TOR	Terms of Reference
TSP	Total Suspended Solids
UFW	Unaccounted for Water
USAID	United States Agency for International Development
USD	US Dollars (1 USD = 0.709 JD; 1 USD = 0.83 Euros)

WADICO	Al Wafa for Agricultural and Animal Development
WAJ	Water Authority of Jordan
WERSC	Water and Environment Research and Study Centre
WHO	World Health Organization

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MAIN REPORT – PART B
WATER SECTOR ESA

ENVIRONMENTAL AND SOCIAL ASSESSMENT REPORT

MAIN REPORT – PART B: WATER SECTOR ESA

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MAIN REPORT – PART B: WATER SECTOR ESA

1 INTRODUCTION

The proposed Disi-Mudawarra to Amman Water Conveyance System is being undertaken by the Ministry of Water and Irrigation (MWI) of the Hashemite Kingdom of Jordan. The development and implementation of this project pose a range of significant environmental and social issues since it will be based on the use of a non-renewable fossil groundwater aquifer and require changes in the existing patterns of water use. While justified under the unique water resources management situation in Jordan, such a development was subjected to a detailed environmental and social impact study that allows decision makers and stakeholders to understand the potential impacts at the sectoral and project specific levels over the short-, medium-, and long-term.

1.1 Background

Jordan is known for its scarce water resources. Throughout history, the people in Jordan have suffered from water shortages due to the semi-arid climate that is associated with limited annual rainfall. Over the past few decades, the problem was enormous due to high natural population growth, rural to urban migration and major influxes of population in response to political and economic crises in the Middle East. These trends have resulted in increased demand from domestic and industrial users.

The main water resources in Jordan are groundwater sources, surface water resources and treated wastewater effluent. The variability in the surface water resources left no choice but the use of groundwater resources to cover part of the shortage.

The total renewable safe yield of the groundwater resources in the whole of Jordan is 277 MCM/year, which does not include the Disi aquifer as this is a non-renewable source. Although extraction from these sources exceeded this safe yield by more than 200 MCM/year in recent years, Water Authority of Jordan (WAJ) was unable to meet the substantially increasing demand. The declining per capita water availability in Jordan, the limited storage capacity and projected future water deficits are presented in **Section 3** of the Main Report - Par B.

Continuation of this overexploitation of groundwater sources at these high levels will lead to mining these sources as well as deteriorating the quality of abstracted water, which will lead at the end to an extensive damage of the aquifers. Therefore, the Ministry of Water and Irrigation (MWI) and WAJ laid out planning strategies for utilising water resources to ensure optimum use in conjunction with municipal demands. The water resources strategy included existing and potential sources. Investment programs were developed to implement new projects such as water harvesting, dams and rehabilitation and restructuring water systems to minimize the unaccounted for water (UFW). Concentration was made on demand management and public awareness programmes. New sources were identified to relief the existing groundwater source and allow the natural recharge of these sources and to restore their water quality which shall relief part of water shortage in Greater Amman area.

One of the major water demand centres is Greater Amman area. The water supply in the area has been outstripped by the demand and rationing program was implemented by WAJ during the summer months since 1988. This situation is deteriorating each year by the increase of demand and therefore, MWI had to consider the option of implementing the Disi Project by conveying water from the southern part of Jordan to Amman.

The contract for preparation of the feasibility study and preliminary design for the Water Conveyance System from Disi-Mudawarra to Amman was awarded by MWI to Harza Group. The feasibility study and preliminary design were submitted to the Ministry in 1996 and the detailed design and tender documents in 1997. An optimisation of the design was later awarded to Brown and Root North Africa who submitted their report in 2001.

The Disi Aquifer, also known as Rum aquifer system, is a transboundary aquifer that extends from south of Jordan into Saudi Arabia where it is known as Saq Aquifer System. However, both the Rum and the Saq actually form one aquifer system with the larger portion located within Saudi Arabia. Generally, the groundwater flows from the Saudi Arabia in the south towards north east Jordan and in Central Jordan it deviates to north west and lastly towards west where it discharges its water in the Dead Sea and in the deep wadis draining the eastern highlands towards the Rift Valley.

1.2 Project Objectives

The main objective of this project is to supply additional high quality water to Greater Amman region from the deep fossil Disi Aquifer by conveying the water a distance of approximately 325 km from Amman. For a number of years water has been outstripped by demand in the Greater Amman Region and MWI has no option but to implement a water rationing program during the summer months. This situation has been ongoing since 1988, and is becoming more complex each year as water demand in this area increases. The provision of this reliable additional water supply would provide an opportunity for Jordanian authorities to reduce groundwater abstractions in the Greater Amman Region and allow for partial restoration of renewable resources in this region.

The project has also a secondary objective and that is to provide five emergency turnouts from the conveyance pipeline that will run from the water well field in the south of Jordan due north to the south of Amman. These turnouts will be located at key locations to ensure reliable water supply to secondary urban areas along the pipeline under emergency conditions and for short durations.

1.3 Organization of the ESA Study

The ESA process has consisted of the following main preparation activities:

- Consultation and Communication Program
- Three Rapid Diagnostic Field Reports
- Annotated Outline of the ESA Study - Parts A, B, and C
- Preliminary Draft ESA Main Report - Parts A, B, and C
- Draft ESA Reports - Executive Summary and Parts A, B, and C
- Final ESA Reports - Executive Summary and Parts A, B, and C

The Consultation and Communication Program was prepared in the planning phase of the ESA study. This program provided the framework of principles and approaches for the communications of social and environmental concerns and information to diverse audiences. It is planned for the study team and the proponent to respond to public concerns about exposure to social and environmental impacts and risks. The overall advantage of this communication program is to ensure that the anticipated adverse impacts and risks can be effectively mitigated.

The purpose of this program is to ensure the involvement of the best available information, experience and knowledge within the local and national community in the assessment. Local communities' communication and active public participation is an important tool in the ESA and in the implementation of the project-specific environmental and social management. This tool ensures that the proposed project messages are constructively formulated, transmitted, and received and that they result in meaningful feed back by the recipient, this would result achieving the following:

- Better understanding and appreciation of target groups to the proposed project conditions and benefits.
- Project communications more credible by local communities and affected populations.
- Community participation in helping and making choices to develop suitable and acceptable avoidance/mitigation scenarios.

Also, early at the beginning of this study the Consultant conducted rapid diagnostic assessment for both biological and archaeological settings within the project corridor, this preliminary assessment served as the basis for the impacts assessment of the project-specific impacts on biological, archaeological and cultural heritage resources, and as a framework of requirements to be reviewed by the MWI and considered for the Build-Operate-Transfer (BOT) terms of reference and for other parties involved in the project. The three submitted Rapid Diagnostic Reports are as follows:

1- Social, Resettlement and Land Acquisition Issues in Abu Alanda to the airport highway water pipeline segment: This report investigated in a diagnostic manner four main tasks of the TOR in order to verify available data and to design and conduct relevant surveys and investigations that might lead to proper analysis of each task.
2- Ecological Issues in the areas close the Wadi Rum Protected Area: This revised the previous designs, updated information on previously conducted assessments and considered new areas, which were recently proved to be of great ecological values, and are important for the survival of threatened species or containing characteristic and unique communities. It addressed the current ecological status of the project alignment. It also indicated the hot spots identified along the proposed alignment.
3- Archaeological and Historic Issues in the northern and southern water pipeline segments: This diagnostic report provided a diagnosis of the main archaeological and cultural heritage sites and issues along the project locations of all facilities related to the pipeline.

The Annotated outline consisted of the full table of contents used for the ESA in each of Parts A, B and C.

The Final Report, it is submitted in accordance with the Terms of Reference for the project. This Report is the sixth and the final of the required technical reports and its purpose is to provide the complete details of all work performed, analyses made, and justification of options and recommendations proposed. This report builds upon the reports completed previously and the comments raised by MWI. The Final Report is submitted in five separate sections which comprise the executive summary and the three parts of the study. These sections are as follows:

- **Executive Summary** which is prepared in both Arabic and English languages.

- **Main Report- Part A** which presents an overview of the Disi-Mudwarra to Amman Water Conveyance System project. More specifically, this section of the study addresses the following issues:
    - Policy, Legal and Administrative Framework in Jordan
    - Applicable World Bank Policies
    - Description of the Proposed Project
- **Main Report- Part B** which is the Water Sector Environmental and Social Assessment. It provides a full picture of the water shortage problem in Jordan and the steps taken to reduce this shortage by development of local sources. More specifically, Part B addresses the following issues:
    - Water resources trends and water balance
    - Water policies and trends
    - Water sector management structure
    - Improvements in water use efficiency and conservations
    - Use of economic incentives
    - Environmental and social challenges in the water sector in Jordan
- **Main Report- Part C (Volumes 1, 2 and Maps)** which is the Project Specific Environmental and Social Assessment. Volume 1 of Part C is the main report and Volume 2 includes annexes referred to within Volume 1 except for **Annex C5** which is included in the document referred to as Maps. Main Report- Part C assesses the project-specific environmental and social concerns with regard to the following major subjects:
    - Physical Environment
    - Biological Environment
    - Agricultural Resources
    - Social Settings
    - Archaeological and Cultural Heritage Sites

Each of these sections stands alone so that it can be reviewed separately from the rest of the report's sections.

1.4 Description of Parts A, B and C of the ESA Study

Main Report: Part A - Overview addresses the policy, legal and administrative framework in Jordan. It focuses mainly on the institutional and legislative framework related to the institutions involved in the management and monitoring of the environment in Jordan, the institutions concerned with legislation and regulation of the sector, and the institutions tasked with enforcing these, with a view to determine the status of the legal and institutional context and to assess the environmental management capacity of the Kingdom, in particular those of relevance to the project. Also, this section highlight salient features of Jordan's environmental management capacity, in particular factors that affect the implementation of the project. It also addresses the set of policies and procedures that guide the operations of the World Bank and that are set out in the Bank's Operational Manual and indicates what safeguard policies are applicable to the proposed project.

Main Report: Part B - Water Sector Assessment of the Environmental and Social Assessment Study for the Disi project provides a full description of the background context against which the Disi project will be implemented. More specifically, this section:

1- Places the project and related activities in the context of the broader series of short-, medium- and long-term actions; and
2- Describes the evolving water policy framework in Jordan from 1997 – 2002, the analysis of alternative development scenarios for the water sector, the specific and cumulative impacts and measures to strengthen the water sector.

In achieving those objectives, Part B addresses the following:

- Water resources trends and water balance;
- Water policies and trends;
- Water sector management structure;
- Improvements in water use efficiency and conservations;
- Use of economic incentives; and
- Environmental and social challenges in the water sector in Jordan.

Main Report: Part C - The project specific ESA assesses the project-specific environmental and social concerns with regard to the following major subjects:

1- Physical Environment
2- Biological Environment
3- Agricultural Resources
4- Social Settings
5- Archaeological and Cultural Heritage Sites

The assessment process is based on the findings from site investigations, field surveys, consulting affected populations and groups, literature review, and pin pointing sensitive habitat and archaeological sites.

The ESA encompasses analysis and documentation of the existing baseline conditions with regard to the assessed subject areas within the project corridor. Also, the analysis includes evaluation of the alternatives to the proposed project including the “No action” alternative and alternatives to the development of the well field, alignment of the pipeline, and sitting of supporting facilities.

The direct and indirect zones of effect were identified and potential impacts were assessed and quantified whenever possible. The impacts were found to be either temporary or permanent in nature. Cumulative impacts were also evaluated and suitable mitigation and management programs were suggested.

To uphold the governmental environmental policy, a planning phase to identify the shape and framework of the Environmental and Social Management Plan (ESMP) has been completed during the environmental and social assessment phase. The ESMP is structured as follows:

1- Rational and Justification
2- Planning and Framework of the ESMP
3- Environment and Social Management Plan (ESMP)
4- ESMP Control
5- Implementation and Operation
6- Checking and Corrective Action
7- Management Review

1.5 Relationship between Parts A, B and C of the ESA Study

The relationships between Parts A, B and C of the ESA Study are recognized in order to understand their inter linkages.

As discussed in the TOR, the proposed project's development and implementation present a range of significant environmental and social issues since it will be based on use of a non-renewable fossil groundwater and require changes in the existing patterns of water use. This was discussed in "Part B-Water Sector Assessment" and the reflection was considered in "Part C-Project Specific Environmental and Social Assessment" with the help of "Part A-Overview" that presented the legal and institutional tools. Under the unique water resources management situation in Jordan, this development is subjected to detailed environmental and social impact studies to allow decision makers and stakeholders to understand the potential impacts at the sectoral and project specific levels. The Environmental and Social Management Plan (ESMP) in Part C provides the proposed framework for mitigation, monitoring, and institutional development actions, as investigated in Part A, to be integrated into the design and implementation of the project. It also provides a sense of the present and future implications on the water sector in Jordan. **Figure 1** presents a schematic diagram for the general links between the three parts of the ESA study.

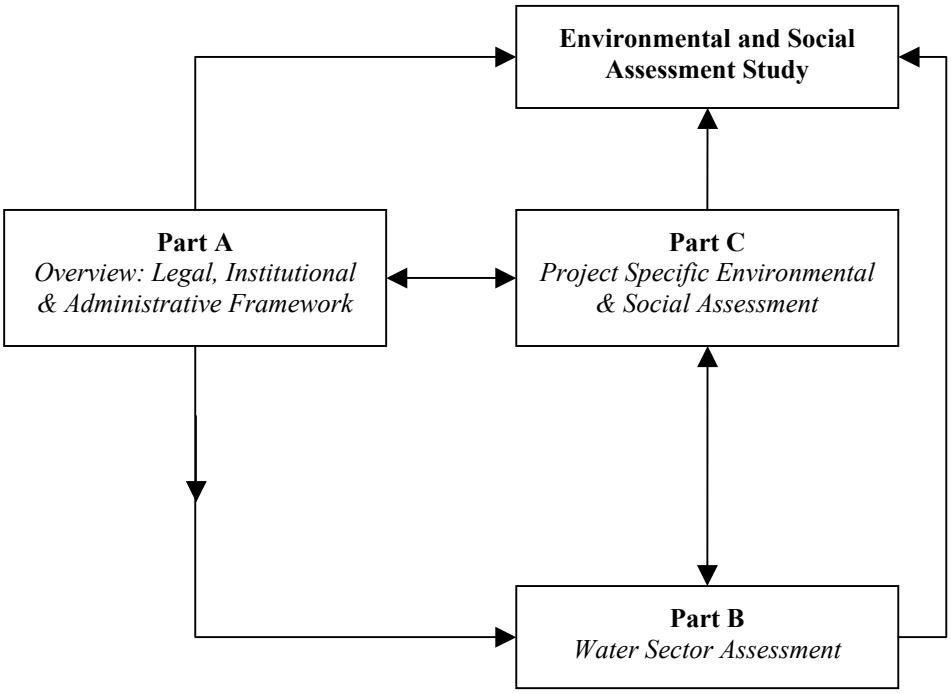


Figure 1: Schematic diagram linking the three parts of the ESA study

1.6 Consultations during the ESA Study

Public consultation is a powerful tool to ensure the involvement of potentially affected groups and national capacities in the decision-making process with regard to the environmental and social aspects of their concern. The consultations allow the participation of stakeholders so as to identify social and environmental concerns at the beginning of the ESA process. Also it is considered as an important tool for informing and educating the public in order to enhance their understanding and appreciation to the following:

- The need and nature of the proposed development;
- The need to protect and properly manage our environment;
- The potential impacts of the project on the environmental, socio-economical and archaeological settings; and
- The public role in protecting their local environment.

During the course of the ESA development a set of communication and consultation activities have been conducted in order to ensure that the stakeholders' views, issues of concern, foreseen impacts and worries are taken into consideration while assessing the project related impacts. It is anticipated that the construction of the Disi-Mudawwra to Amman Water Conveyance System will profoundly affect all the current and future social changes of the population in the project area and to a large extent the natural and the built-up environment as well as the status of water resources in Jordan. For elaborating on the social and environmental assessment study, it was decided that two-way discussions of substantive issues must be held with stakeholders from national and local governmental organizations and interested individual citizens. Hence, under the auspices of the Ministry of Water and Irrigation, two scoping sessions were held on March 27th and April 3rd 2003 in Amman and Aqaba, respectively. Both sessions have been attended by a wide spectrum of government, national and NGO's representatives during which background materials on the project have been distributed and discussed by all parties concerned. Scoping sessions identified substantive issues of specific concern and feedback comments and views were collected and classified. These discussions were very helpful in disseminating all necessary information to the public. The outcome of these sessions indicated unanimous support to the project.

In addition to the public consultation, the Consultant started the consultation process with direct interviews with the Governors and Mayors in the five Governorates of the south in addition to other stakeholders in the region. The objectives of the project as well as the conveyance system alignment and the direct and indirect benefits to the population in the area have been extensively presented. Comments and views of the Governors have been recorded and presented in the procedures to be taken to achieve the study purposes. All views were in fact very constructive and in favour of the project as a major indispensable water project.

A second phase of consultation sessions were held according to World Bank procedures. These sessions aimed at presenting to the project-affected groups the findings of the Draft Environmental and Social Assessment (ESA) Study and the relevant ESA material. Hence, under the auspices of the Ministry of Water and Irrigation, three second consultation sessions were held on November 13th, 18th and 20th in Abu Alanda, Amman and Aqaba, respectively. The sessions have been attended by a wide spectrum of government, national and NGO's representatives during which Arabic and English summaries of the Draft ESA study were distributed and discussed by all parties concerned. The outcome of these sessions was helpful in pinpointing several issues that needed to be highlighted in the final study. In addition, the second consultation sessions informed the participants that the Executive Summary in both Arabic and English would be made available at a number of locations in Jordan.

1.7 ESA Disclosure

A complete copy of the Environmental and Social Assessment Study will be disclosed at the following locations:

- Ministry of Water and Irrigation
- Ministry of Environment
- Aqaba Special Economic Zone

The Executive Summary in both Arabic and English would be made available at a number of locations in Jordan. These locations were selected in coordination with the Ministry of Water and Irrigation and are summarised below:

- Ministry of Public Works and Housing
- Ministry of Health
- Ministry of Municipal Affairs
- Ministry of Agriculture
- Royal Society for Conservation of Nature
- Department of Antiquities
- Governorates of Karak, Tafileh, Ma'an and Madaba

The complete Disclosure list is provided in **Annex C4**- Part C of the Main Report. The Government will also provide a copy of the Environmental and Social Assessment to the World Bank under a cover letter that authorizes the Bank to disclose these documents to its Board of Executive Directors and at the InfoShop in Washington, D.C. The World Bank will be provided with both printed and electronic copies of the document for this purpose.

1.8 Maps to Support Environmental and Social Management Plan

The developed Environmental and Social Management Plan (ESMP) is supported with maps produced at a scale of 1:25,000 to show the route of the conveyor and affected areas as well as proposed mitigation measures (see **Table 1**). These are included in Part C of the Main Report. The ESMP is also supported by GIS maps elaborated with a set of topographical maps and satellite imageries. This system is prepared to present the project-specific sensitive environmental, social and archaeological settings identified within the project direct and indirect zone of effect. The presented sensitive sites are linked to information sheets listing the anticipated impacts, proposed mitigation measures and monitoring programs.

It should be noted that only one biological hot spot is shown on the maps of scale 1:25000 as the remaining biological hot spots are outside the project corridor and the drawing boundary. However, all the biological hot spots are shown on the GIS maps.

The GIS base maps are reproducible and printable to facilitate maximum usability by users and adaptability to any change in the plans and/or environmental and social conditions. GIS maps are provided on three CD-ROMs included in **Annex C5**. The contents of these CDs are as follows:

- CD-1: GIS base maps and satellite images
- CD-2: Part 1-Topographical maps scale 1:25,000
- CD-3: Part 2-Topographical maps scale 1:25,000

A list of the available maps along with their respective locations is presented in **Table 1**. Copies of the base maps showing the conveyor route and hot spots are included in **Annex C5**.

Table 1: List of project related maps

Map Number	Map Description	Scale
Drawing No. (001)	From Station (0+000) to Station (6+000)	1/25,000
Drawing No. (002)	From Station (6+000) to Station (22+000)	
Drawing No. (003)	From Station (22+000) to Station (36+000)	
Drawing No. (004)	From Station (36+000) to Station (50+000)	
Drawing No. (005)	From Station (50+000) to Station (65+000)	
Drawing No. (006)	From Station (65+000) to Station (79+000)	
Drawing No. (007)	From Station (79+000) to Station (93+000)	
Drawing No. (008)	From Station (93+000) to Station (107+000)	
Drawing No. (009)	From Station (107+000) to Station (126+000)	
Drawing No. (010)	From Station (126+000) to Station (143+000)	
Drawing No. (011)	From Station (143+000) to Station (151+000)	
Drawing No. (012)	From Station (151+000) to Station (174+000)	
Drawing No. (013)	From Station (174+000) to Station (188+000)	
Drawing No. (014)	From Station (188+000) to Station (204+000)	
Drawing No. (015)	From Station (204+000) to Station (219+000)	
Drawing No. (016)	From Station (219+000) to Station (233+000)	
Drawing No. (017)	From Station (233+000) to Station (250+000)	
Drawing No. (018)	From Station (251+000) to Station (266+000)	
Drawing No. (019)	From Station (266+000) to Station (282+675.731)	
Map C1	The locations of archaeological sites within Segments B and C	Not to scale

2 BACKGROUND ON JORDAN'S WATER SECTOR

In order to recognize deeply the water problem in Jordan, a historical background about Jordan's water sector is presented below.

The shortage of water in Jordan is a chronic problem that dates back as the early as 1970s. The late King Hussein was always keen at emphasizing that the development of the country's water sector is vital for the development of all other sectors in the country. Also, King Abdullah the Second considers the water issue to be of top priority in the work of government on long-term basis. These considerations reflect the seriousness of the water problem in Jordan.

In Jordan, the development of the water institutions dates back to the 1951 when the Health Institution was developed to monitor water quality. Afterwards, the Western Ghor Canal Authority and the Central Water Authority were created in 1951 and 1960, respectively. However, after the Arab Summit of 1964, those two authorities were cancelled and replaced by the Natural Resources Authority of 1965. In the same year, the "Rawafed" Institution was developed with the responsibility of developing the water resources of the Jordan River and its tributaries. This institution adopted the Khaled Dam and Jordan Valley projects.

In 1975, the responsibility for drinking water was diverted from the Natural Resources Authority to a newly created authority named the Drinking Water Institution. This institution was responsible for all water projects in the Kingdom except for Amman city for which the Water and Wastewater Authority was formed.

In 1972, the responsibility for the areas below sea level on the Eastern Bank of the Jordan River was transferred from the Natural Resources Authority to a new institution named in 1977 the Jordan Valley Authority (JVA). In 1984, the Drinking Water Institution and the Water and Wastewater Authority were merged into one authority which is the Water Authority of Jordan (WAJ). On October 1st of 1988, the Ministry of Water and Irrigation (MWI) was created and the Water Authority and the Jordan Valley Authority were placed within this Ministry.

In the early 1990s the water shortage problem started to accelerate after the Gulf Crisis. The lack of water resources became more prominent with the increase in water demand in response to the natural and crises driven population growth, improvement of living standards, and the developments of the economic, industrial and touristic sectors.

In trying to meet the country's growing water demand, groundwater aquifers are being exploited at more than double their sustainable yield on average due to the abrupt surges in population levels through control relaxing on drilling operations and on licensed abstraction rate. This can be attributed to the low investment requirement for developing extra groundwater sources. Also, the situation has reached a level where the toxicity index (pollution load compared to renewable water resources) is high and the water costs compared to GDP do not allow the full cost recovery. This deterioration was inevitable due to the Gulf Crisis at that time. With limited and provisional solution, the water shortage cannot be fulfilled completely.

For a number of years supply has been outstripped by demand in the Greater Amman Area and the Water Authority of Jordan has had no option but to implement a water rationing program during the summer months to deal with the water shortage. The situation has been on-going since 1988 and is deteriorating each year as demand in this area increase which leads to a rationing program for the entire year with very low reliability at summer period. The Disi-Mudawarra to Amman Water Conveyance System will result in a reliable water supply to Amman especially during the summer. This project was proposed many years ago but due to lack of funding, the

project was always being postponed. However, due to the pressing need for additional sources of water, serious efforts have been made to secure funding for this project at great deal of efforts.

At present, the drinking water for Amman is supplied mainly from the upland aquifers and new developed aquifers from south such as Lajoun Aquifer. Therefore, another important aspect of the Disi project is that its implementation will secure additional source of drinking water to Amman and thus relieve the upland aquifers from over abstraction. Also, the Disi project will have an indirect effect on the quality of the wastewater which in turn would lead to a better effluent quality to be used for irrigation as a replacement for valuable freshwater.

Once the Disi pipeline is completed it will serve as a Southern National Carrier for Jordan. However, it should be noted that the Disi project would cover only part of the water shortage problem but would not close the country's growing water gap.

3 ENVIRONMENTAL AND SOCIAL BASELINE CONDITIONS: JORDAN'S SCARCE WATER RESOURCES

3.1 Demand Sectors

Water demand is presented in this section for both main uses:

- Municipal and Industrial.
- Irrigated Agriculture.

The full investigation of the water demand is analysed with costs, tariffs, and investments in order to show the importance of the water issue in Jordan. The ongoing measures for water loss reduction are addressed, which can be a big reduction in the Jordanian water demand in the near future. This could be addressed in both sections: demand and supply.

The gap between future demands and supply is discussed in different time scales and scenarios. This will highlight the importance of the Disi water even in the near future and optimistic scenario. **Table 2** and **Figure 3** show the historical supply for the period 1985-2001 to the different sectors with future demand forecasting up to the year 2020 according to the Ministry of Water Irrigation projections.

Demand forecasting is conditioned by water availability which is in turn sensitive to rainfall conditions. The sector most affected by water availability is irrigated agriculture during dry weather years. Since agriculture has the least priority in water allocation, the supply fills up the domestic demand before irrigation and consequently the deficit concentrates in the agricultural sector. This is evident by comparing the irrigation supply during the wet years of 1992 and 1993 to the irrigation supply of the dry year of 2001. In addition, **Figure 2** matches the behaviour of irrigation supply, domestic and industrial supply and rainfall. This matching reveals no change in the behaviour of domestic and industrial supply in response to changing rainfall conditions whereas the behaviour of the agricultural supply reveals a similar variation as that of rainfall. Water year 1991/1992 divided the rainfall record into two intervals: before and after. The rainfall trend for the period before 1991/1992 was increasing, which was reflected on irrigation water supply. For the period after 1991/1992, the decrease in both irrigation water supply and rainfall was detected. The projection for irrigation considers the average water year with growing demand and that the growing demand in irrigation cannot continue due to water shortages. This fact is considered in the 2015 and 2020 projections.

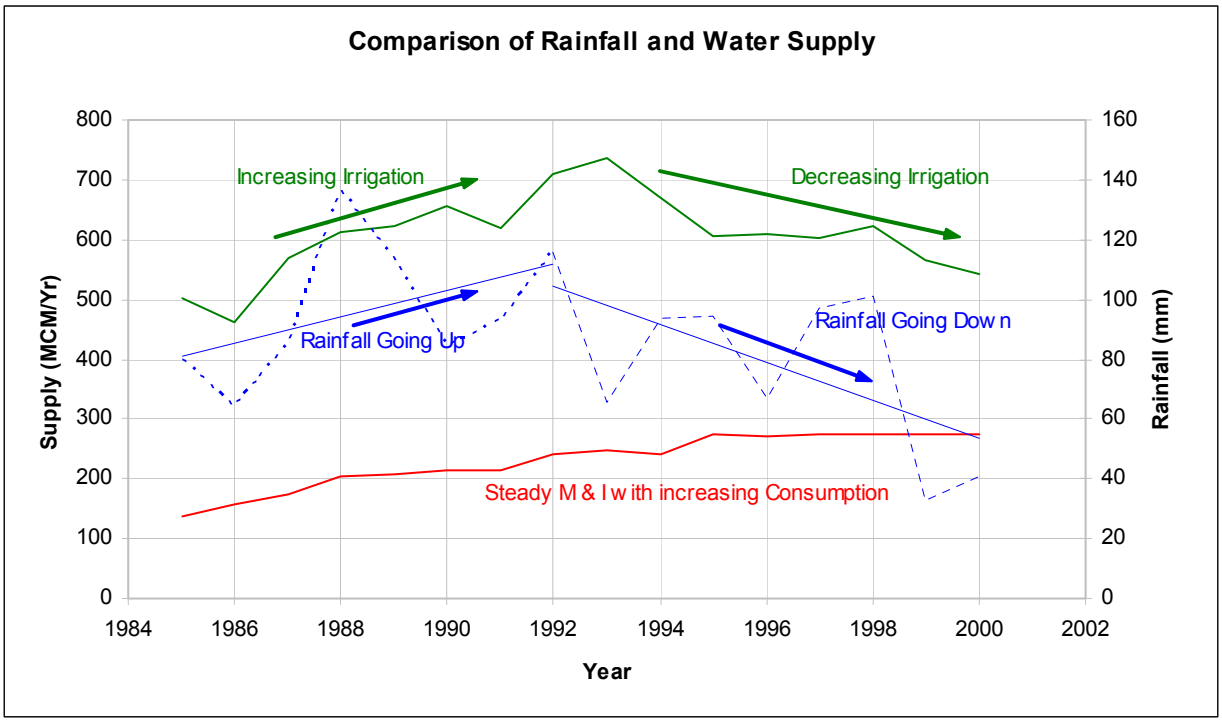


Figure 2: Irrigation and "Domestic and Industrial" Supply versus Jordan's average annual rainfall

Table 2: Jordan water supply (MCM) by sector according to the MWI

Year	Domestic	Industrial	Irrigation	Total	M&I
1985	116	22	501	639	138
1986	135	23	461	619	158
1987	150	24	570	744	174
1988	165	39	613	817	204
1989	170	36	624	830	206
1990	176	37	657	870	212
1991	173	42	618	833	215
1992	207	35	709	951	241
1993	214	33	737	984	247
1994	216	24	669	909	240
1995	240	33	606	878	272
1996	236	36	610	882	272
1997	236	37	603	876	273
1998	236	38	561	835	274
1999	232	38	532	801	207
2000	239	37	541	817	276
2001	246	33	495	774	279
2005	281	76	750	1107	357
2010	380	93	746	1219	473
2015	463	112	704	1279	575
2020	517	130	665	1312	647

Source: Ministry of Water and Irrigation (MWI)

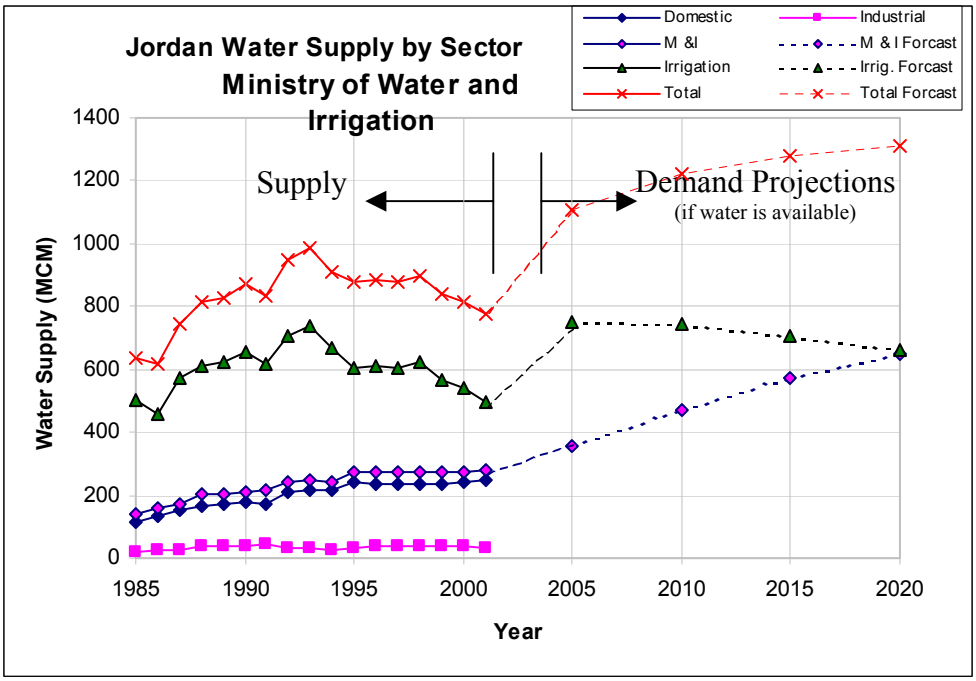


Figure 3: Jordan water supply by sector, historical and future forecasting according to MWI projection

Table 3 and **Figure 4** show the historical supply for the period 1986-2000 to the different sectors with future forecasting up to the year 2020 according to World Bank Report of 2001. The historical supply is the same as the data of **Table 2**. Even the projections are similar with differences of not more than 2-3%. The only difference is the irrigation demand projection for the years 2005 and 2020, which could be more realistic than the MWI projections. The irrigation demand of around 680 MCM per year could be a sensible amount in the light of dryness and global warming. The projection of the year 2020 can be attributed to Jordan water shortages but the unrealistic projection is for the year 2010.

Table 3: Jordan water supply (MCM) by sector according to WB Report of 2001

Year	Domestic	Industrial	Irrigation	Total	M&I
1986	134	23	461	618	157
1987	150	23	570	743	173
1988	165	39	614	818	204
1989	170	36	624	830	206
1990	178	42	658	878	220
1991	179	42	613	834	221
1992	206	35	709	950	241
1993	214	36	737	987	250
1994	233	28	668	929	261
1995	280	36	606	922	316
1996	243	40	609	892	283
1997	240	45	597	882	285
1998	242	51	554	847	293
1999	238	56	521	815	294
2000	246	57	534	837	303
2005	**World Bank 2001**		679	1042	363
2010			764	1250	486
2015			693	1282	589
2020			627	1287	660

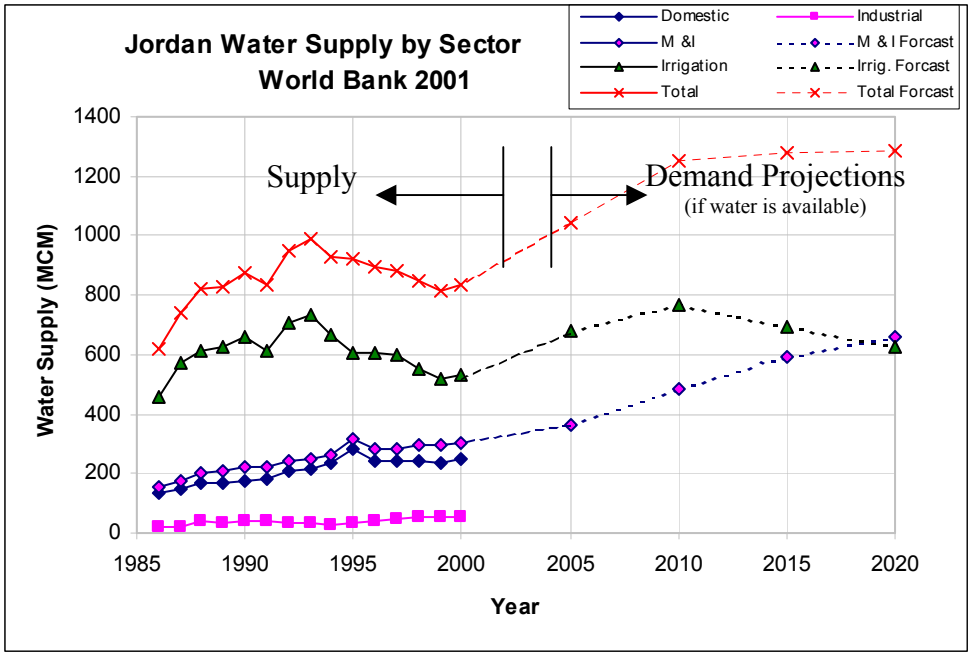


Figure 4: Jordan water supply by sector, historical and future forecasting according to WB-2001 projection

Municipal and industrial demand were increased from 21% at the year 1985 to 36% at the year 2001 out of the total demand according to MWI figures and as shown in **Figure 6**. **Figure 7** was developed according to World Bank projection with no considerable difference as compared to **Figure 6**.

Table 4 shows the irrigation water supply from 1996 to 2000 according to the source and the region. Surface and groundwater supplies show a decreasing trend as compared to the increasing trend of treated wastewater reuse for irrigation. This trend is reflected in **Figure 5**.

Table 4: Irrigation water supply according to source

Item	1996	1997	1998	1999	2000	2001	2000
Surface Water	254	272	294	239	216		39.93%
Groundwater							46.77%
Upland	237	222	209	198	195		36.04%
Midland	4	4	4	5	5		0.92%
JRV	56	44	46	53	53		9.80%
Subtotal	297	270	259	256	253		
Wastewater							13.31%
Upland	7	8	11	11	12		2.22%
JRV	52	53	60	59	60		11.09%
Subtotal	**59**	**61**	**71**	**70**	**72**		
Total	**610**	**603**	**624**	**565**	**541**		**100.00%**
Surface + Ground Water	**551**	**542**	**553**	**495**	**469**		

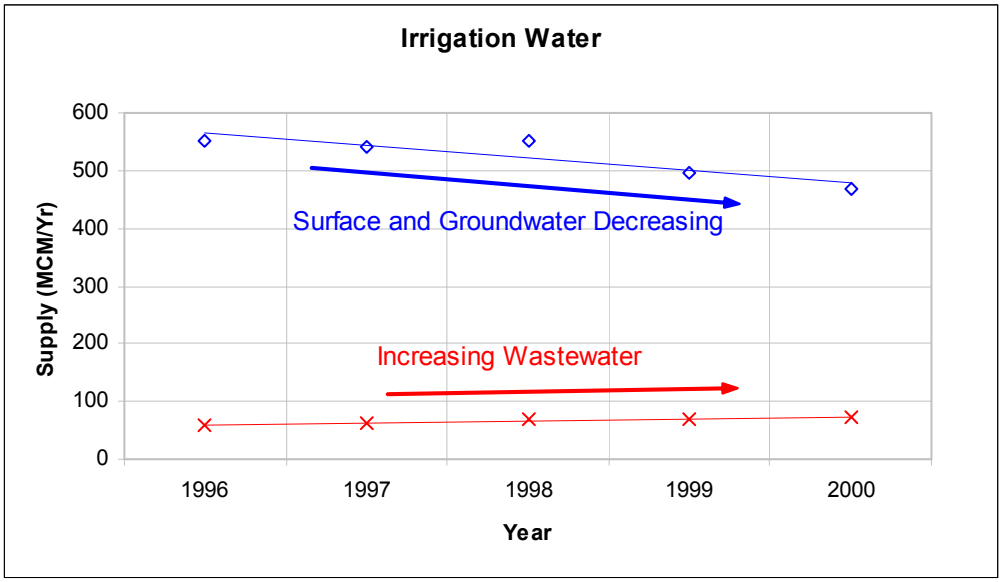


Figure 5: Irrigation Water Supply by source

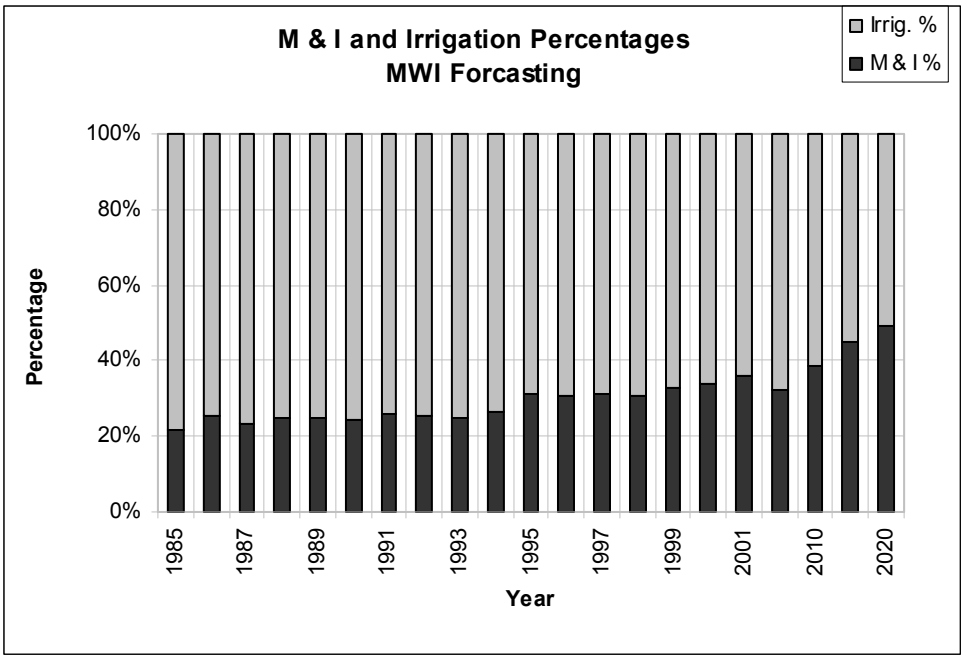


Figure 6: Municipal and industrial (M & I) percentage compared to irrigation consumption according MWI projection

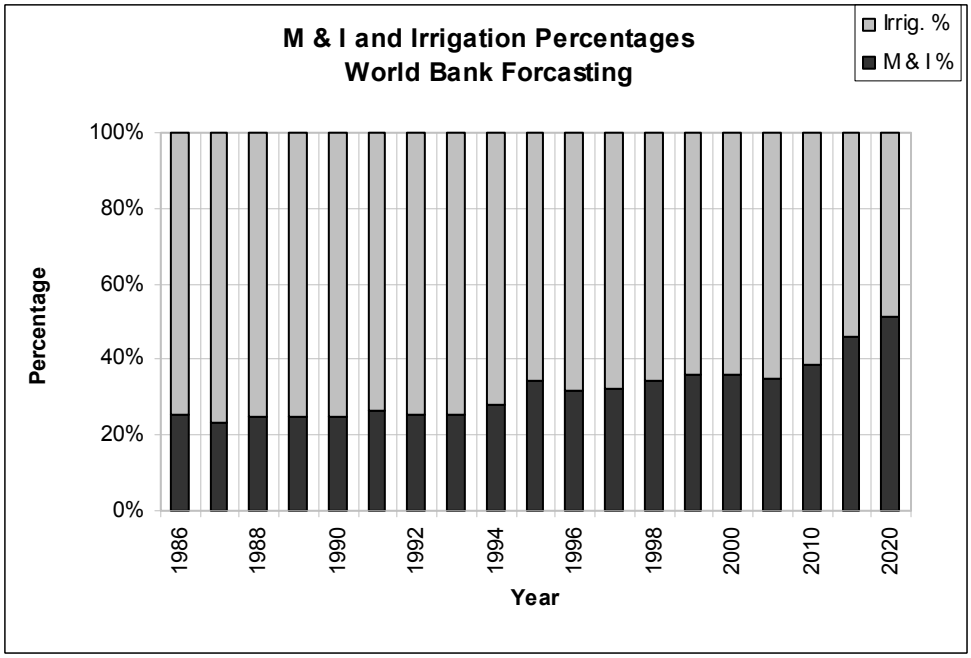


Figure 7: Municipal and industrial (M & I) percentage compared to irrigation consumption according WB-2001 projection

World Bank discussed the demand, supply, and deficit in the older reports of 1988 and 1997. A comparison between the two reports is discussed in **Table 5**. This comparison indicates some differences. These differences are due to the scarce water condition in Jordan and the unnatural growing demand due to sudden jumps in population such as refugees flowing after Gulf Crisis and others. **Table 5** compares domestic and industrial demand as outlined in the World Bank reports of 1988 and 1997. The main differences are in the future forecasting, which reflect the deteriorating water condition in Jordan between the year 1988 and the year 1997.

Table 5: Domestic and industrial demands, World Bank reports (1988 and 1997)

Year	Domestic Demand		Industrial Demand	
	WB 1988	WB 1997	WB 1988	WB 1997
1985	115.7		28.0	
1990	151.4		37.0	
1995	192.0	275.0	53.0	38.0
2000	231.0	388.0	74.0	78.0
2005	266.8	411.0	86.5	96.0
2010	324.0	438.0	111.0	119.0
2015	365.6	522.0	132.7	128.0
2020		616.0		142.0

3.2 Supply Sources

The supply section deals with Jordan's water resources using updated figures. The water resources are discussed at three different time scales:

- Present supply.
- Long term average with and without adjustment due to drought periods.
- Future forecasting in three time scale action:
    - Short-term.
    - Medium-term.
    - Long-term.

The forecasting discusses accordingly the GOJ framework taking into consideration the Action Plan and the Investment Program. The section integrates all water resources:

- Surface Water
- Groundwater
- Treated Wastewater
- Management
- Non-Conventional
- Regional

Jordan's water sector is complicated due to its chronic shortage problem. Therefore, the investigation needs an expert team with a wide knowledge about Jordan's water sector in order to discuss its touchy water issues. The water sector team and the project manager worked together in the GTZ Regional Study as well as other studies related to Jordan. They had communication with the key personnel in the MWI through a Steering Committee. The present Minister was a member in that steering committee. Therefore, the water sector team studied Jordan's water resources together with the key persons in the MWI through the scheduled meetings and complied with their valuable comments. Data were collected using the listed references in the TOR, other references, and the open files of the MWI.

3.2.1 Surface Water

The climate of Jordan ranges from Mediterranean to desert. The Rift Valley and the highlands belong to the semi-arid to arid climate zone, which is largely affected by moist westerly air masses in winter. In summer, dry easterly and north-easterly desert winds affect the Kingdom. Winds are generally westerly to south-westerly.

Mediterranean climate dominates most of the highlands on both sides of the Jordan River and in the mountain chains east of the Dead Sea and Wadi Araba extending as far south as Ras El Naqeb. Dry summers with an average maximum annual temperature of 39 °C occur between April and October. In winter months, from November till March, the average minimum annual temperature is 0-1 °C. In winter, the average mean daily temperatures recorded at Amman Airport and Deir Alla were 10 °C and 17 °C, respectively, for the period 1981-1998.

The average temperature in the wet season is generally higher in the Jordan Valley than along the seashore on the west and falls again over the highlands and within the eastern plateau. The average annual evaporation rate ranges from 2,042 mm in Zarqa to 5,038 mm in Ma'an and from 2,594 mm in the Jordan Valley to 3,516 mm in the eastern hills.

Seasonal, uneven and fluctuating rainfall affects the country between October and May. Eighty percent of the annual rainfall occurs between December and March. Average annual rainfall in Jordan ranges from < 50 mm in the eastern desert to approximately 600 mm over Ajloun heights, as shown in **Figure 8**. **Table 6** presents the categories into which Jordan may be classified based on the rainfall distribution:

Table 6: Classified categories according to rainfall distribution

Zone	Annual Rainfall (mm/year)	Area (km^2)	Area as a percentage of the total area of Jordan	Rainfall Volume Fifty Years Average (MCM)
Semi- humid	500-600	620	0.7 %	425
Semi- arid	300-500	2,950	3.3 %	1,170
Marginal	200-300	2,030	2.2 %	530
Arid	100-200	20,050	22.3%	2,950
Desert	< 100	64,350	71.5 %	3,425
Total		**90,000**	**100 %**	**8,500**

Source: MWI

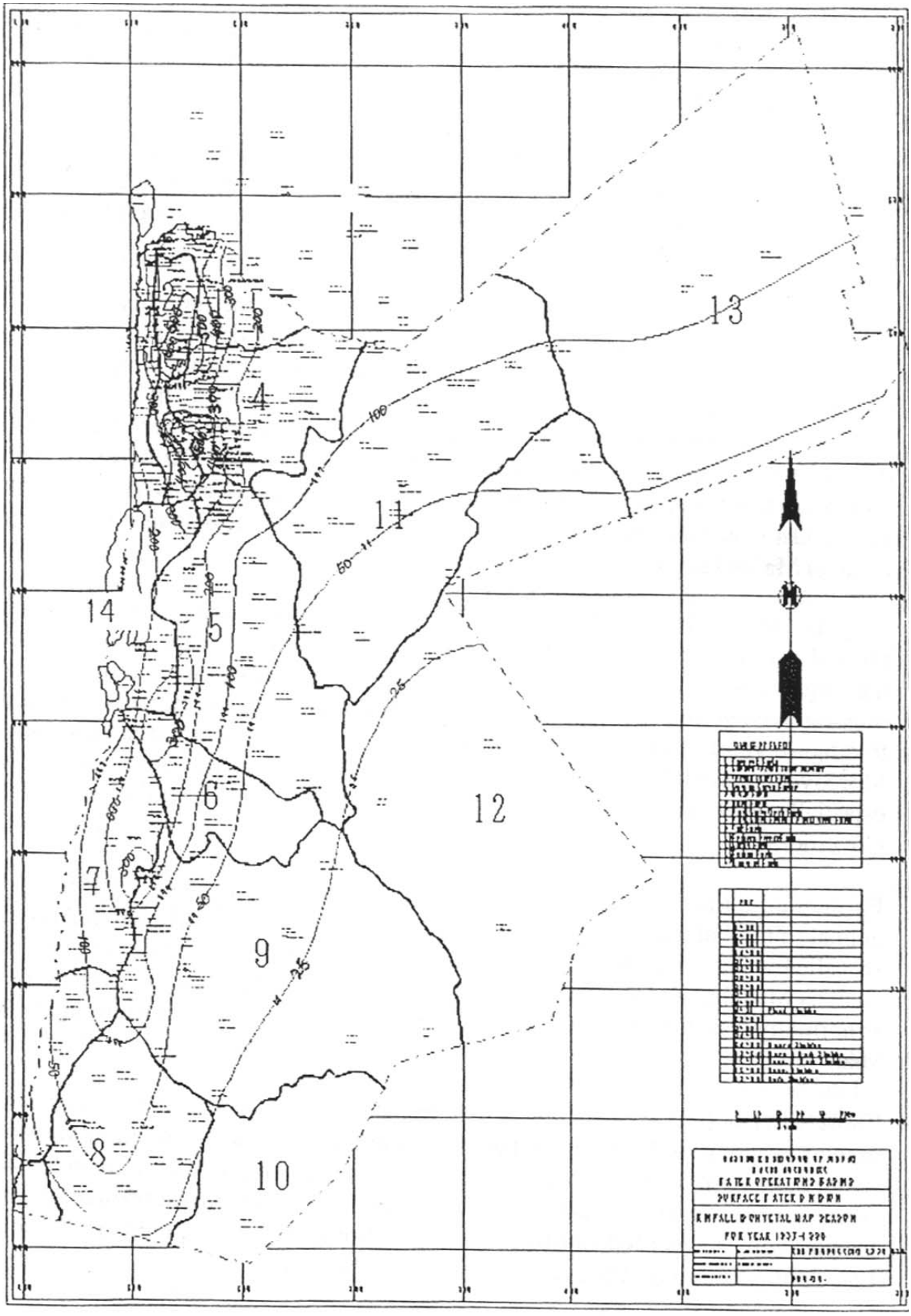


Figure 8: Rainfall distribution over Jordan (1937-1998) (Source: MWI)

About 93.8% of the total area of Jordan is arid or desert land with an average annual rainfall below 65 mm. This signifies the importance of the limited water resources as an instrumental factor in the overall socio-economic planning at the countrywide level, particularly to remedy the adverse effects that may result from force major situations, such as the involuntary immigration to North Jordan due to the Gulf Crisis.

Rainfall is the only source of water supply in Jordan to recharge the groundwater aquifers. It is scarce and unevenly distributed over the country. The mountainous highlands along the Jordan Valley-Dead Sea-Wadi Araba depression receive the majority of total rainfall volume. Estimates of long-term records (1937/1938-2000/2001) of rainfall distribution over Jordan indicate that the average annual rainfall volume over the country is around 8,360 MCM. **Figure 9** shows the average rainfall in mm per year over Jordan with the drought periods, which are below long term average.

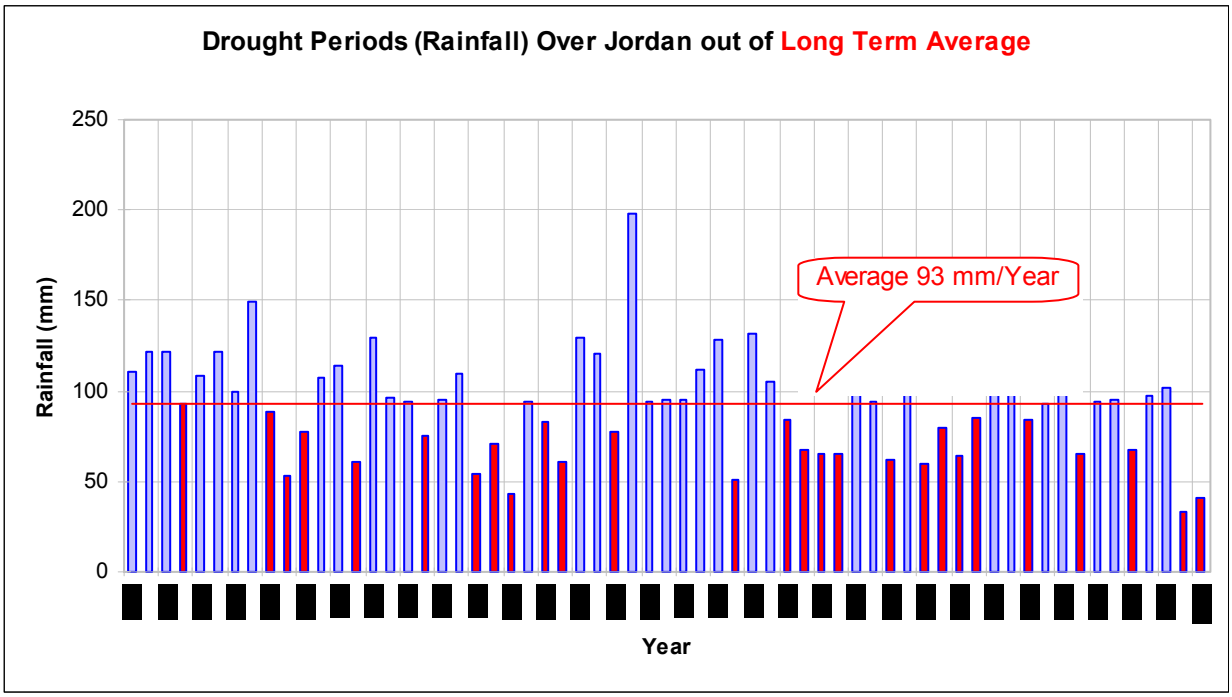


Figure 9: Average rainfall over Jordan in mm/year

The major topographic and geomorphologic features in Jordan control the drainage pattern. The overall drainage system in Jordan consists of two main flow patterns. The first one drains rainfall towards the Jordan Rift Valley, through deeply incised wadis and rivers dissecting the Jordan Valley-Dead Sea escarpments, to ultimately discharge into the Dead Sea. The second one drains rainfall through shallow streams and washes, which generally run eastwards from the western highlands towards the internal desert depressions and mudflats.

Based on the prevailing topographic terrain, there are fifteen surface water basins in the country as shown in **Figure 10** and **Table 7**.

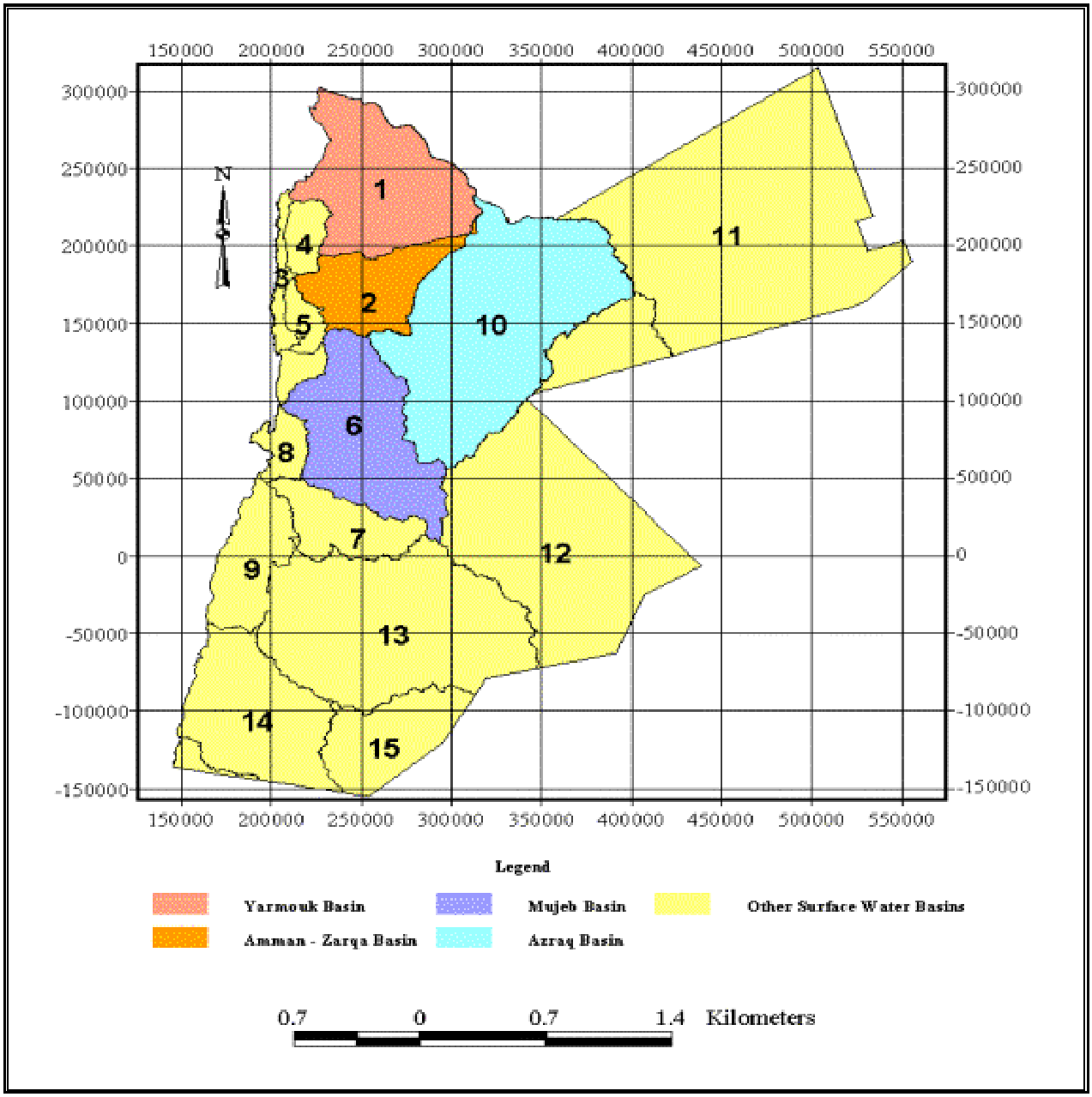


Figure 10: Major Surface Water Basins in Jordan
(Source: MWI with development by the Consultant)

Table 7: Surface water resources in Jordan[1]

No	Surface Water Basin					Sy	Population (1994)**	Area (Km²)	Average Annual Rainfall (mm)	Estimated Runoff Coeff. (%)	Long Term Rainfall Average 61 Years (MCM)	Surface Water Flows (MCM) Long-Term Av. (1937-1998)
	Region			Name								
1	DEAD SEA BASIN	JORDAN RIVER SUBBASIN	Northern Basins	Yarmouk*		AD	355,083	1,500	293	5.1	439	Base: 246 Flood: 109 Total: 355
2				Amman-Zarqa		AL	2,239,043	3,725	249	2.9	926	Base: 43.00 Flood: 25.30 Total: 68.30
3				Jordan Valley		AB	139,373	775	300	1.9	233	Base: 0.0 Flood: 2.73 Total: 2.73
4				J.V. Side Wadis	N	AE, AF, AG, AH, AJ, AK	500,024	975	599	2.9	584	Base: 37.37 Flood: 12.02 Total: 49.39
5					S	AM, AN, AP	137,906	725	404	3.4	293	Base: 25.18 Flood: 7.93 Total: 33.11
6		DEAD SEA SUBBASIN	Central Basins	Mujib		CD	260,244	6,675	132	4.0	884	Base: 31.38 Flood: 33.62 Total: 65.00
7				Hasa		CF	20,570	2,600	128	2.8	334	Base: 26.26 Flood: 5.47 Total: 31.73
8				D.S. Side Wadis		C	196,697	1,525	178	2.5	290	Base: 33.63 Flood: 6.06 Total: 39.71
9				N.Wadi Araba		D	79,128	2,975	135	0.7	403	Base: 8.58 Flood: 2.35 Total: 11.13
10	Eastern Desert Basins			Azraq*		F	26,031	12,200	71	2.7	866	Base: 0.0 Flood: 22.47 Total: 22.47
11				Hamad*		H	9,966	18,150	112	0.7	2,050	Base: 0.0 Flood: 9.58 Total: 9.58
12				Sirhan*		J	3,851	15,700	28	1.9	445	Base: 0.0 Flood: 7.49 Total: 7.5
13				Jafer		G	47,783	12,450	43	1.5	545	Base: 0.0 Flood: 8.0 Total: 8.0
14	Southern Basins			S. Wadi Araba		E	89,220	3,725	37	1.3	138	Base: 0.0 Flood: 2.09 Total: 2.09
15				Southern Desert*		K	958,	6,300	16	1.0	103	Base: 0.8 Flood: 1.18 Total: 1.18
T O T A L							**4,105,877**	**90,000**	**95**	**3.0**	**8,532**	**Base: 452 Flood: 255 Total: 706**

[1] Source of rainfall: JICA Study, 2001 & WIS/MWI * Basin area in Jordan ** DOS Population and Housing Census, 1994.

3.2.2 Groundwater Resources

The groundwater resources distributed all over the groundwater basins constituting Jordan are very scarce and actually vary in quantity and quality. Generally, the surface groundwater basins in Jordan are divided into renewable and non-renewable groundwater resources. The surface groundwater basins constituting Jordan are 12 basins, which are subdivided according to the upper most aquifer system, occurred in each of the basins. Groundwater divides indicated by different groundwater flow systems separate these basins from each other. **Figure 11** shows the different groundwater basins in Jordan and the general flow system in the upper aquifer. The safe yields of the upper aquifer systems of the different groundwater basins are shown in **Figure 12**. According to the geological succession and the different rock units occurring in the different areas of the groundwater basins, the rock formations in Jordan deposited above the basement complex which forms the base of the above sedimentary rocks of different ages. A generalized classification of the geological succession in Jordan is presented in **Table 8** and **Table 9**. Based on the lithological characteristics of the different rock units of the geological succession, these rocks are subdivided into aquifers and aquicludes.

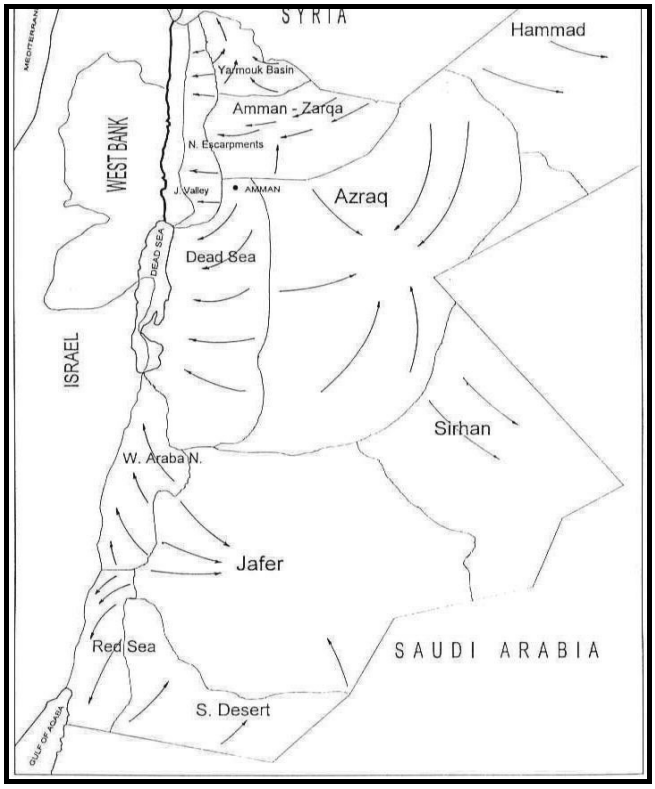
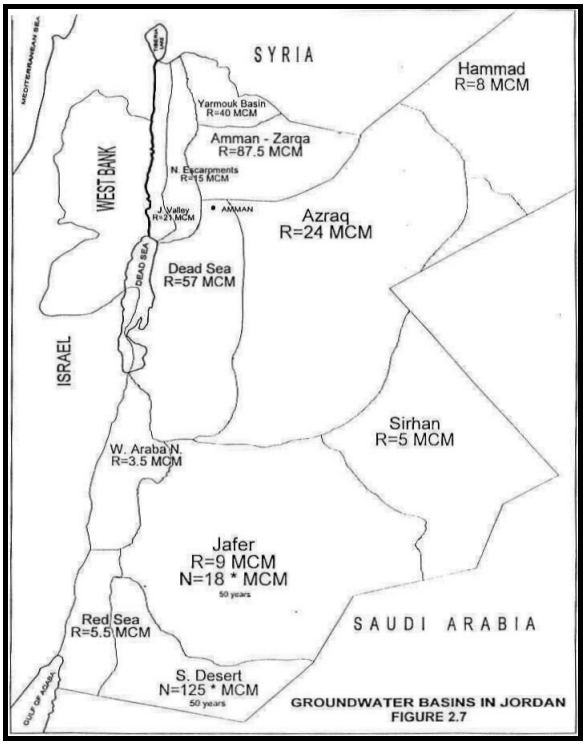


Figure 11: Groundwater basins and the general flow directions of the Upper Aquifer System in Jordan (Source: GTZ, 1996)



R: Renewable = 275 MCM/year

N: Non-Renewable = 143 MCM/year (50 years Abstraction)

Figure 12: Safe Yield of the different groundwater basins in Jordan (Source: GTZ, 1996)

Table 8: Generalized geological succession in Jordan

Period	Epoch	Group	Formation	Thickness (m)		
				Amman	Mujib	Jafer
QUATERNARY	Recent	Alluvial & Aeolian Rocks				
	Pleistocene	Plateau	Azraq			
TERTIARY	Pliocene		Sirhan			
	Miocene	Volcanic	Upper Basalts			
	Oligocene		Basalt Tuff			
			Middle Basalt			
			Lower Basalt			
	Eocene	Belqa Group	Wadi Shallala (B5)			
	Palaeocene		Rijam (B4)			40-50
UPPER CRETACEOUS	Maestrichtian		Muwaqqar (B3)		100-145	20-450
	Campanian		Amman (B2)	80-115	70-200	
	Santonian		W. Ghadran (B1)	20-40	Absent	
	Turonian	Ajloun Group	Wadi Sir (A7)	65-90	70-100	
	Cenomanian		Shu'eib (A5/6)	65-100	127	
			Hummar (A4)	40-65	Absent	
			Fuheis (A3)	80	70	
			Na'ur (A1/2)	200-230	Thin	
LOWER CRETACEOUS		Kurnub	Subeihi (K2)			
			Arda (K1)			
JURASSIC		Zarqa	Azab (Z2)			
TRIASSIC			Ma'an (Z1)			
PALAEOZOIC		Khreim	(K)			
		Disi	(D)			
PRECAMBRIAN		Sarmuj	(S)			
		Basement Complex (BC)				

The shaded area indicates the main water bearing formations in the carbonate aquifer system

Table 9: Geological succession of the Paleozoic sediments in South Jordan

Age	GP.	Form.	Max Thk (m)	Facies	Lithology	Hydrogeology
Mesozoic Sediments						
PALEOZOIC	KH	Khushsha	160	Inner shelf	Micaceous siltstones and fine micaceous sandstones	
		Mudawarra	250	Inner-mid shelf	Alternating beds of fine-medium micaceous sandstone and very fine micaceous sandstone or siltstone with basal shaley horizons	
		Dubaydib	150	Midshelf nearshore	Fine-medium sandstone with subordinate micaceous siltstone	
		Hiswa	70	Inshore	Fine micaceous sandstone and siltstones. Coarsening upwards	
		Umm Sahm	250	Shallow marine	Medium-coarse quartz arenite 3-4 laterally persistent siltstone bands 0.5-6m thick	
	RAM	Disi	350	Continental	Medium to coarse quartz arenite sandstone with occ. Pebble horizons. At top of formation, localised micaceous fine sandstone and siltstone beds (0.2-0.5m) Unconsolidated weakly cemented with oce. Well cemented horizons. Numerous horizontal-sub horiztal fractures.	CW2 results: K(1)=0.1-0.5 m/d Porosity=0.17-0.20 Sy(2)=0.1 T(3)=250-300 d/m^2 CW11 results: K=0.15-1.80 m/d Porosity=0.16-0.22 Sy=0.07-0.1 T=600-700 d/m^2
		Umm Ishrin	30	Continental	Medium-coarse quartz arenite sandstone with quartz overgrowth of calcite cement enclosing subrounded well sorted quartz grains. No conglomeratic horizons, generally fining upwards.	
		Burj	120	Shallow marine N of Petra, prograding shoreS of Petra	Dolomite-shale (carbonate lagoon) in N, fine-medium micaceous sandstone in S.	
		Salib	200	Continental	Medium-v. coarse cross bedded arkosix and subarkosic sandstone with con lomeratic beds.	

(1) K : Permeability
(2) Sy : Specific Yield
(3) T : Transmissivity

The hydrogeological map of Jordan (**Figure 13**) shows the upper aquifer distribution all over Jordan. All of the groundwater basins in Jordan are constituted from three main aquifer systems distributed vertically according to the geology of the basin. These aquifer systems are namely the upper aquifer system, intermediated aquifer system and deep aquifer system. According to the surface geology of each basin, the vertical distribution of each aquifer system in each basin mostly varies from one basin to another.

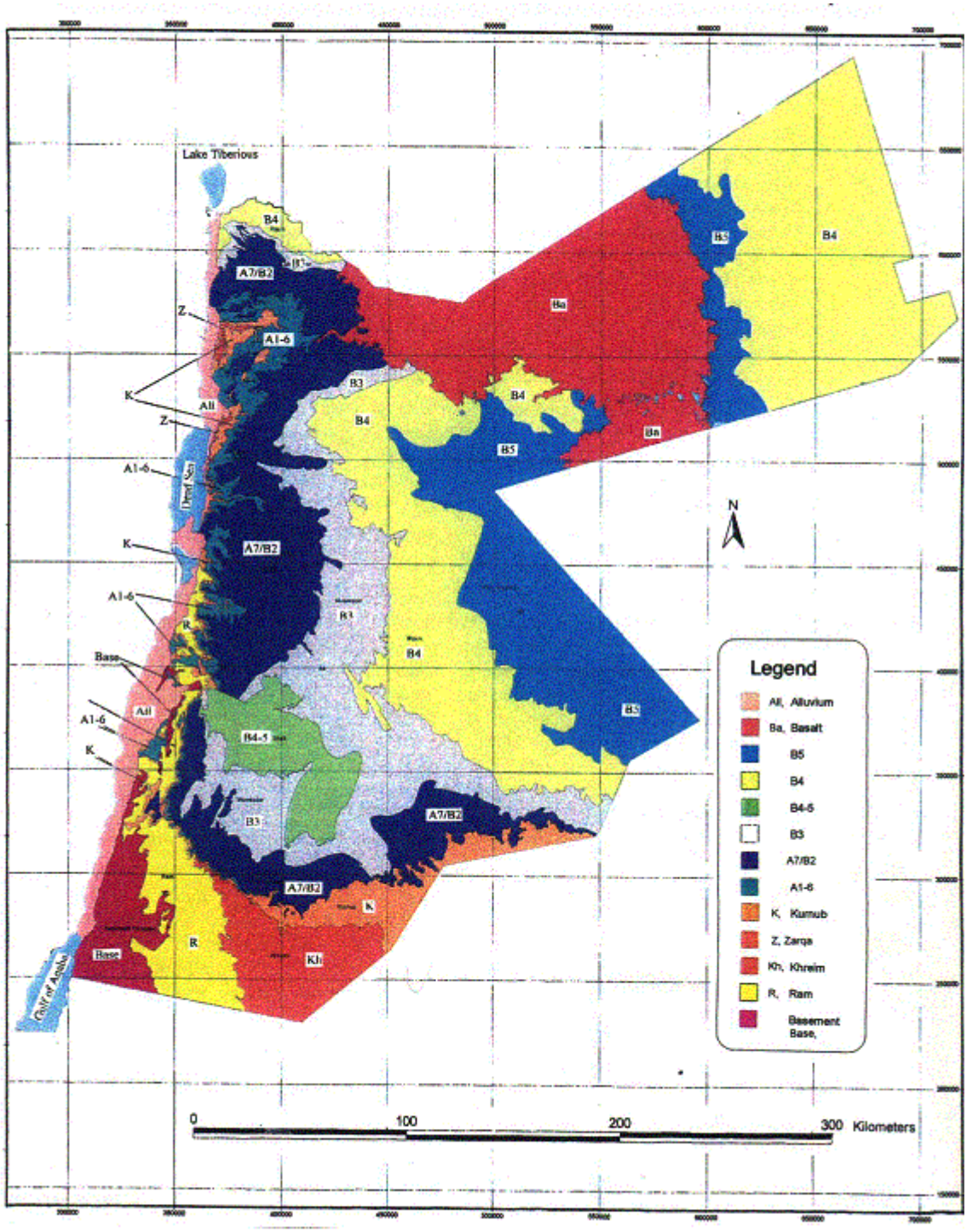


Figure 13: A generalized hydrogeological map of Jordan (Source: JICA, 2001)

The distributions of the upper, intermediate and deep aquifer systems in the different groundwater basins are presented in **Table 10**.

Table 10: Aquifers distribution in the different groundwater basins in Jordan

	Groundwater Basin	Upper Aquifer System	Intermediate Aquifer System	Deep Aquifer System
1	Yarmouk	Basalt Basalt + B_2/A_7 [1] B4[2]	A_{1-2} [3] + A_4 [4]	Kurnub (K) [5] K + Rum Triassic-Jurassic (T-J) [6]
2	Azraq	Basalt Basalt + B_4 + B_5	B_2/A_7 B_2/A_7 + A_{1-2} + A_4	K K + T-J + Rum
3	Zarqa	Alluvial Alluvial + B_2/A_7 Alluvial + A_4	A_{1-2} + A_4	K + Rum + T-J K + Rum
4	Dead Sea	Alluvial B_2/A_7	A_{1-2} + A_4	K + Rum + T-J K + T-J T-J + Rum
5	Jafer	B_4 B_4 + Alluvial	B_2/A_7 A_{1-2} + A_4	K K + Rum
6	Mudawarra-Southern Desert	Rum (Disi) + Khreim		
7	Sirhan	B_4	B_2/A_7 A_{1-2} + A_4	K K+ T-J + Rum
8	Hammad	Basalt Basalt + B_4	B_2/A_7 A_{1-2} + A_4	K K+ T-J + Rum
9	Northern Wadi Araba	Alluvial	B_2/A_7 A_{1-2} + A_4	Rum K
10	Red Sea	Alluvial	B_2/A_7	Rum
11	Jordan River Side Wadis	Alluvial Alluvial + B_2/A_7	A_{1-2} + A_4	K K + T-J K+ T-J + Rum
12	Jordan River Valley	Alluvial	B_2/A_7 A_{1-2} + A_4	K K + T-J K+ T-J + Rum

[1] B_2/A_7= Amman-Wadi Sir Formation Deposits of Late Cretaceous Age (Mesozoic Rocks)
[2] B_4 = Rijam Formation Deposits of Late Cretaceous – Early Tertiary Rocks (Mesozoic-Cenozoic Rocks)
[3] A_{1-2}= Fuhais Formation Deposits of Ajlun Group of Late Cretaceous Age (Mesozoic Rocks)
[4] A_4= Hummar Formation Deposits of Ajlun Group of Late Cretaceous Age (Mesozoic Rocks)
[5] K= Kurnub Group Deposits of Early Cretaceous Age (Mesozoic Rocks)
[6] T-J= Triassic and Jurassic Rocks Deposits (Mesozoic Rocks)

Table 10 shows clearly that the Mudawarra – Southern Desert contains only one aquifer system, which corresponds to the deep aquifer system in most of the other groundwater basins in Jordan. This aquifer system is presented as deep aquifer system even it is the only aquifer complex in the basin.

The prevailing conditions of the different groundwater basins of Jordan according to the utilized aquifer system for the different purposes are as presented in **Table 11**. This table shows that most of the groundwater basins are over abstracted and, due to this, salinization had occurred for the water of the upper aquifer system. The only two-groundwater basins, which contain non-renewable groundwater resources, are the Disi-Mudawarra basin and Jafer basin. The estimated abstracted groundwater amounts from the Mudawarra and Jafer are 125 and 18 MCM/year/50 years, respectively. The non-renewable aquifer system in Mudawarra underlies the intermediate and upper aquifer systems in all groundwater basins. **Figure 14** shows the generalized flows direction of the deep aquifer system all over Jordan.

Table 11: Water budget, safe yield and abstraction from the groundwater basins for the year 2000

No.	Basin	Aquifer	Safe Yield (MCM/a)	Domestic (MCM/a)	Industrial (MCM/a)	Agriculture (MCM/a)	Sum	Sy.-Abst.	Water Quality
1	Yarmouk	B4, B2/A7, A2	40.0	22.755	0.184	32.922	56.267	-16.267	Fresh but getting partly salinized
2	Side Wadis	A+K	15.0	4.913	0.000	5.120	10.033	4.967	Fresh
3	Jordan Valley	ALL	21.0	8.369	0.160	28.206	36.735	-15.735	Salinization
4	Amman/ Zarqa	Ba, B2/A7, A4, A2, K	87.5	67.141	6.121	62.516	137.812	-50.312	Salinization
5	Dead sea	B2/A7, A4, A2	57.0	33.855	15.098	32.117	83.204	-26.204	Salinization
6	Disi - Mudawarah	D	125.0	9.720	4.483	50.920	66.259	58.741	Fresh
7	Wadi Araba - North	ALL, B2/A7, K, D	3.5	0.000	2.784	0.563	3.514	-0.014	Salinization
8	Red Sea	ALL, D	5.5	1.061	0.157	3.695	5.016	0.484	Salinization
9	Jafer	Ba, B4, ALL, B2/A7, A1, K	18.0	7.183	6.282	9.931	23.450	-14.450	Salinization
10	Azraq	Ba, B4, B2/A7, AB, K	24.0	27.202	0.208	28.694	56.657	-32.657	Salinization
11	Sarhan	B5/4, AB	5.0	0.000	0.000	1.618	1.821	3.179	Fresh-brackish
12	Hammad	B4	8.0	0.562	0.000	0.097	1.148	6.852	Fresh-brackish
		Total		**182.761**	**35.477**	**256.399**	**473.000**	**-81.416**	
		Renewable	275.5						
		Renewable & Non-Renewable	418.5						

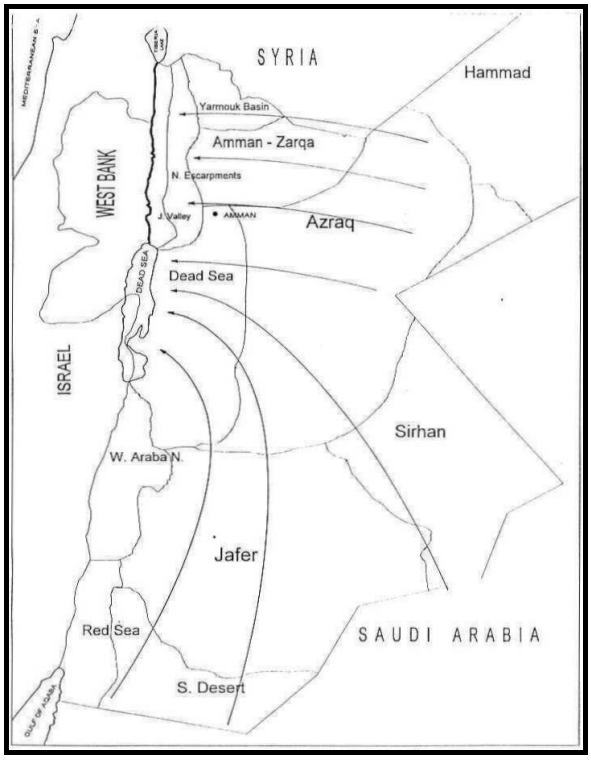


Figure 14: Generalized groundwater flow direction of the Deep Aquifer System in Jordan (Source: GTZ, 1996)

The flow direction of groundwater intermediate aquifer systems in groundwater basins in Jordan is shown in **Figure 15**. The intermediate aquifer systems in most of the groundwater basins in Jordan are considered to be renewable and as part of the upper aquifer systems where they are mostly over exploited.

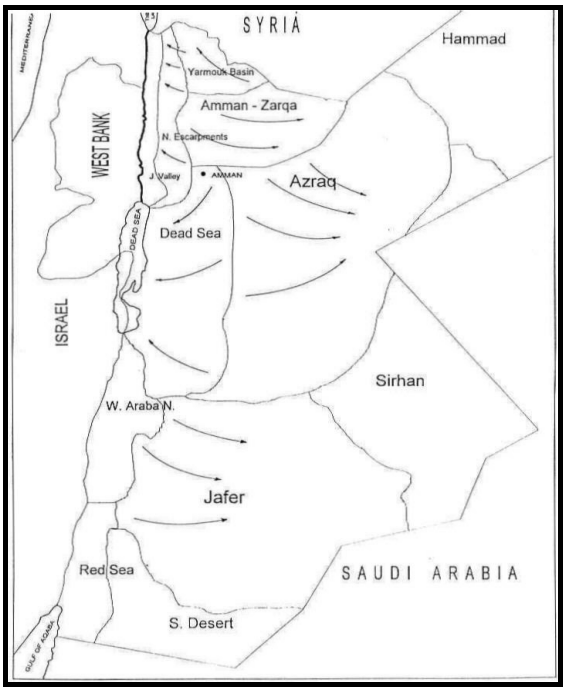


Figure 15: Generalized groundwater flow of the Intermediate Aquifer System in the different basins in Jordan (Source: GTZ, 1996)

Amman is actually supplied with domestic and industrial water from the three main groundwater basins occurring in the highland aquifer systems (upper and intermediate aquifer systems) and partly from Zai Water Treatment Plant, which utilizes the Yarmouk River water through King Abdullah Canal. The three main groundwater basins are the Azraq Basin, Amman-Zarqa Basin and the Mujib (Dead Sea) Basin. Since these basins are highly over exploited where the abstracted percentage in respect to the safe yields of these basins are 157.5% for Amman-Zarqa basin, 236% for Azraq Basin and 146% for the Dead Sea (Mujib) Basin. The water quality in these basins is highly deteriorated. This study has been designed to examine the environmental and social impacts of utilizing the Disi (Mudawarra) non-renewable groundwater for the domestic purposes in Amman. This utilization will relieve the highland aquifers of the Azraq, Amman-Zarqa and Mujib from over pumping and, thus, protect the groundwater of those basins from further deterioration and overdraft.

The total renewable safe yield of the groundwater sources in the whole of Jordan is 275 MCM per year. **Table 12** presents the safe yield of the renewable groundwater basins by Governorate. Extraction from these basins in the year 1998 was estimated at 416 MCM of which 173 MCM was for municipal use. The total municipal consumption in the year 1998 was 236 MCM of which 85 MCM was consumed in Amman Governorate. Groundwater sources supplied Amman with 53 MCM and 32 MCM was transferred from outside of the Governorate through the KAC (King Abdallah Canal)-Deir Alla-Zai line. **Table 13** shows the renewable groundwater potential and the actual abstraction from each groundwater basin.

Table 12: Safe yield (MCM/year) of renewable groundwater basins by Governorate

		Groundwater Basin												Total
		Yarmouk	Amman-Zarqa	Azraq	Jordan Valley	Rift Side Wadis	Dead Sea	Wadi Araba North	Wadi Araba South	Jafer	Southern Deserts	Sirhan	Hammad	
Governorate	Amman		12	6		2	14							34
	Zarqa		17	24		6								47
	Mafraq	20	48									1	8	77
	Irbid	18			8	3								29
	Ajloun					2								2
	Jerash	2	6											8
	Balqa		4		13	2								19
	Madaba						9							9
	Karak						16							16
	Ma'an						3	1		6	<1	4		14
	Tafileh						11	1						12
	Aqaba							2	6					8
	Total	40	87	30	21	15	53	4	6	6	<1	5	8	275

Source: JICA Study, 2001

Table 13: Groundwater potential and 1998 abstraction (MCM/year)

Basin	Yarmouk	Amman-Zarqa	Azraq	Jordan Valley	Rift Side Wadis	Dead Sea	Wadi Araba North	Wadi Araba South	Jafer	Southern Deserts	Sirhan	Hammad	Total
Yield	40	87	29 to 31	21	15	50 to 62	4	6	6 to 7	<1	5	8	271 to 286
1998	39	150	52	36	31	82	4	1	20	<1	<1	1	416
Balance	1	-63	-21 to -23	-15	-16	-20 to -32	0	5	-13 to -14	0	5	7	-130 to -145

Source: JICA Study, 2001

Table 13 shows that Amman-Zarqa basin is suffering from 172% over extraction percentage. Continuing over extraction of groundwater sources at this unacceptable high level will result in mining these sources. WAJ started phasing out Azraq well field as a result of long term over extraction and will consider other basins once Disi water reaches Amman.

The total annual municipal water supply across the country maintains more or less the same level of around 240 MCM for the period between the year 1996 and the year 2001 as shown in **Table 14**. The Governorate of Amman occupied 37.5% of the total water supply as an average for the entire period, followed by the Governorate of Zarqa and Irbid with 13.2% and 12.8%, respectively.

Table 14: Municipal Water by Governorate 1996 to 2001

Governorate	Municipal Water Supply											
	1996		1997		1998		1999		2000		2001	
	MCM	lcd	MCM	lcd	MCM	lcd	MCM	lcd	MCM	lcd	MCM	lcd
Amman	89.6	145.2	88.8	139.6	85.7	131.4	88.2	131.7	91.3	133.1	93.6	133.2
Zarqa	31.7	126.9	31.5	122.4	32.0	121.2	30.1	111.1	31.8	114.5	32.7	115.2
Irbid	31.7	107.5	29.6	97.6	29.1	93.3	31.8	99.5	30.3	92.4	30.9	92.0
Mafraq	17.4	250.3	18.4	256.7	18.5	251.6	19.0	251.8	18.5	239.1	18.9	238.4
Balqa	19.2	176.7	18.9	168.8	19.1	166.4	17.9	152.2	16.3	135.4	15.2	123.3
Karak	8.5	127.6	8.7	127.6	9.4	134.0	9.2	127.3	9.2	124.8	9.4	124.4
Tafileh	2.0	83.7	2.3	92.0	2.3	89.8	2.2	83.8	2.4	89.3	2.6	94.5
Ma`an	6.8	219.5	6.8	213.5	7.3	224.7	7.2	214.3	7.5	220.6	7.7	220.5
Madaba	12.9	305.8	12.0	276.1	11.7	263.5	8.8	191.6	5.6	119.2	5.9	123.9
Aqaba	15.3	498.2	15.1	475.5	15.0	462.0	16.5	493.9	15.2	443.1	15.0	426.5
Ajloun	3.5	93.4	3.7	96.5	3.9	99.3	3.0	75.0	3.2	76.3	3.1	71.9
Jarash	3.9	79.2	4.1	82.8	5.2	100.4	3.6	67.5	4.2	78.5	3.9	71.2
Total	**242.5**	**149.6**	**239.9**	**143.7**	**239.2**	**139.7**	**237.3**	**135.1**	**235.6**	**130.8**	**239.0**	**129.6**

Source: WAJ
Notes: 1) The figures include touristic water and the water for small and medium industry.
2) The figures include physical losses.

The population grew at the average annual rate of 2.7% (for the period 1996 to 2001) and the per capita per day municipal water supply over the whole country decreased from 150 litres in 1996 to 130 litres in 2001 as shown in **Figure 16**. Amman l/c/d is kept constant for the last four years (1998-2001).

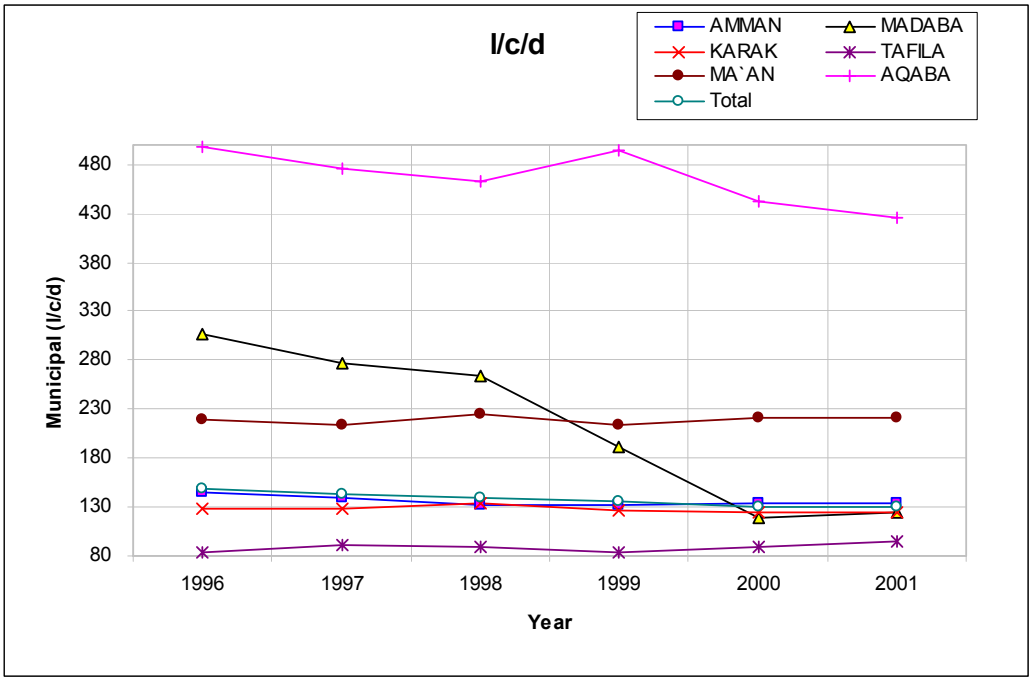


Figure 16: The per capita per day (l/c/d) municipal water supply for the study area

It is noted that the per capita per day water supply is over 200 litres in the two Governorates of Aqaba, and Ma'an. According to PMU, the unaccounted for water (UFW) is estimated to be around 50% of the water supplied, of which leakages or physical losses are around 25%.

It should be noted that demands in Greater Amman during the summer period increase dramatically due to a large influx of Jordanians returning from abroad for their holidays in addition to tourists from the region. **Figure 17** presents the monthly water supply to Amman for the period between the year 1996 and 2001. July consumption in the year 2001 is more than 9.5% of the total consumption, while February consumption is 6.8% of the total annual water supply.

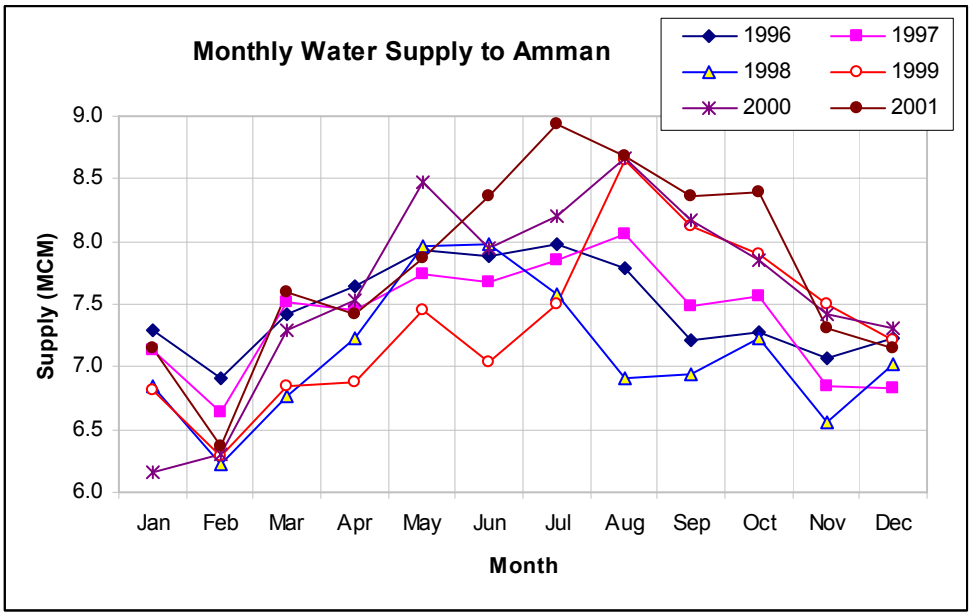


Figure 17: Monthly Water Supply to Amman 1996-2001 (Source: MWI)

Regarding water for big industries, whose sources are mostly groundwater, around 35 MCM have been annually supplied for the above years, and its demand is on the whole constant as shown in **Table 15**. The industrial demand is very modest and could be increased in the future.

Table 15: Industrial water supply 1996 to 2001

Item	1996	1997	1998	1999	2000	2001
Industrial Water Supply	36	37	38	38	37	33
UFW	About 10% Constant					
Actual Supply*	32	33	34	34	33	30

Source: MWI
Note: * Actual use from wells for major industries including the industrial water for Aqaba.

The sources of irrigation water are surface water, groundwater, and treated wastewater. The total water supply for irrigation was 540 MCM in the year 2000, of which surface water 40%, groundwater 47%, and treated wastewater 13% as shown in **Table 16**. It is noticed that both surface water and groundwater supply is on the whole on decrease, while treated wastewater supply is on the whole on the increase. Summing up, the general trend is that the total water supply is decreasing year by year as shown in **Figure 18**.

Table 16: Irrigation water supply by source 1996 to 2000

Item	1996	1997	1998	1999	2000
Surface Water	254	272	294	239	216
Groundwater	297	270	259	256	253
Upland	237	222	209	198	195
Midland	4	4	4	5	5
Jordan Valley	56	44	46	53	53
Treated Wastewater	59	61	71	70	72
Upland	7	8	11	11	12
Jordan Valley	52	53	60	59	60
Total	**610**	**603**	**624**	**565**	**541**

Source: MWI

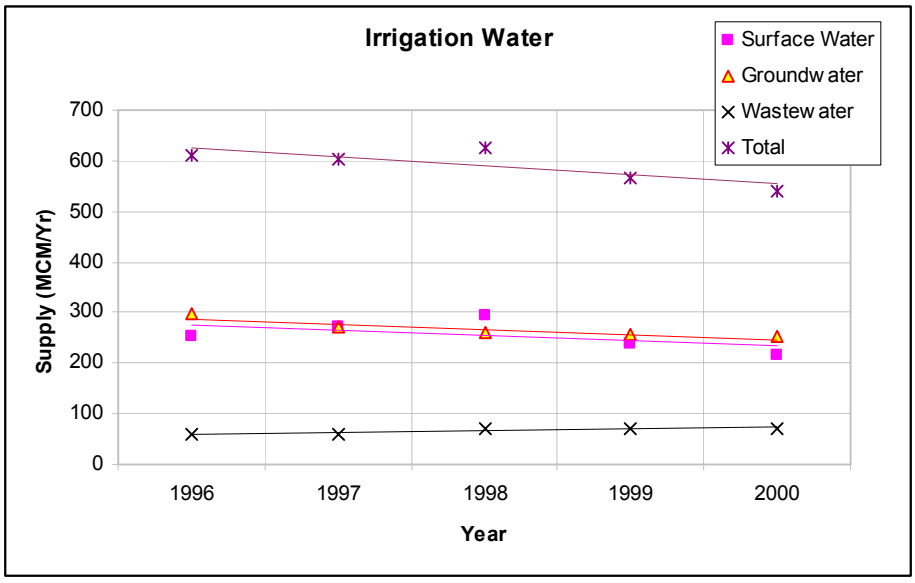


Figure 18: Irrigation water supply by source

3.3 Net Water Situation or Water Deficits

Throughout Jordan's history (as presented above), its people have suffered from water shortages due to its semi-arid climate and associated limited annual rainfall. Over the past few decades, the problem has been compounded by a simultaneous increase in size of population and demand for domestic and industrial users. The later is modest if compared with the domestic supply. However, even with the availability of the additional water from Disi, there would still be an excessive shortfall for the current planning horizon of the year 2020, particularly in the Greater Amman area, as discussed later in this subsection (**Subsection 3.3**). For a number of years now, supply has been outstripped by demand in the Greater Amman Area, and WAJ has had no option but to implement a water-rationing programme during the summer months. This situation has been ongoing since 1988, one which is deteriorating each year as demand increases.

This shortfall has led in recent years, to the over commitment beyond the safe yield, of most, if not all, of the existing groundwater sources in Jordan. Should this scenario persist, then the ultimate result would be the mining of each and every groundwater source. This is an option that is not acceptable, unless an alternative source is not available. Fortunately, this alternative is available now in Disi, which if combined with other measures being taken over time such as desalinization of water at Aqaba and the proposed Red Sea - Dead Sea Water Conveyance Project, will relief the over exploited aquifers. Therefore, the main objective of the Disi water is to supply additional domestic water to the Greater Amman Area.

After the commission of the Disi source it is planned to phase out the Azraq source and to reallocate elsewhere some of the water from other sources. It is assumed that the total contribution from existing sources would be reduced to 60 MCM per year with Disi source making up the remainder. On this basis, the output from Disi would be fully absorbed by Greater Amman in few years.

A review for three recent World Bank reports is presented in this section in order to highlight the importance of Disi water in addressing the water deficit. The Disi water could meet the growing domestic demand directly and could indirectly reduce the irrigation demand for fresh water. This indirect reduction is covered by reuse of the high quality treated wastewater in As-Samra Treatment Plant after Disi water is conveyed to Amman. The Disi water will help to enhance the quantity and quality of Amman wastewater.

Table 17 presents the Municipal and Industrial (M & I) demand, supply, and deficit as presented in the three World Bank reports at 1988, 1997, and 2001. Clear agreement can be noticed between 1997 and 2001 reports in future demand. But some differences in forecasting supply are there due to the advance development in water sector in the Kingdom at the last few years.

Table 17: Municipal and industrial demand, supply and deficit, World Bank reports (1988, 1997, and 2001)

Year	M&I Demand			M&I Supply		M&I Deficit	
	WB 1988	WB 1997	WB 2001	WB 1997	WB 2001	WB 1997	WB 2001
1985	143.8						
1990	188.3						
1995	245.0	313.0		277.0		-36.0	
1998			342.0		275.0		-67.0
2000	305.0	466.0		343.0		-123.0	
2005	353.3	507.0	463.0		363.0		-100.0
2010	435.0	557.0	533.0	525.0	486.0	-32.0	-47.0
2015	498.3	650.0	639.0		589.0		-50.0
2020		758.0	757.0	587.0	660.0	-171.0	-97.0

The agricultural demand, supply, and deficit are presented in **Table 18** as discussed by the World Bank reports 1997 and 2001. The two reports meet in the forecasting year 2005 and almost agree about the agricultural demand and supply with a slight difference. The deficit in the agricultural sector is great as forecasted by the 2001 report, which could be filled by using the growing treated wastewater after using Disi water in Amman.

Table 18: Agricultural demand, supply and deficit, World Bank reports 1997 and 2001

Year	WB 1977			WB 2001		
	Supply	Demand	Deficit	Supply	Demand	Deficit
1995	605.0	791.0	-186.0			
1998				623.0	863.0	-240.0
2000	617.0	791.0	-174.0			
2005	714.0	900.0	-186.0	679.0	858.0	-179.0
2010				764.0	904.0	-140.0
2015				693.0	897.0	-204.0
2020				627.0	890.0	-263.0

Table 19 (GTZ Study, 1997) presents the future with the present water demand, supply and deficit in Jordan up to the year 2040. **Table 20** (Al-Salihi, 1999) presents the future water supply to Jordan adjusted for rainfall decline in response to climate change.

Table 19 and **Table 20** address three aspects of water resources: demand, supply and deficit. The demand and deficit portions are divided to consumption sectors and the supply portion was divided according to source. Water quality was accounted for and three types were considered:

- Fresh for domestic use;
- Fresh to brackish for industrial and agricultural use; and
- Treated wastewater for industrial and agricultural use.

The irrigation demand was frozen due to lack of water supply for the agricultural sector. No fresh water was considered for irrigation after the year 2010 and a considerable reduction in fresh to brackish water. Treated wastewater could be the only source available for irrigation in the future.

Disi water was considered as water supply for domestic and the deficit could be high. However, fresh water deficit for domestic will start after the year 2010 even with Disi water.

Table 19: Present and future water demand, supply and deficit in Jordan up to the Year 2040 (MCM/yr)**

Item	*Pres. 1993*	*Year 2000*	*Year 2010*	*Year 2020*	*Year 2030*	*Year 2040*
WATER DEMAND TOTAL	**1001.5**	**1244**	**1518**	**1772**	**2025**	**2279**
Surface Water	414.4	400	472	592	592	592
Ground water	535.1	355	387	418	451	482
Demand Management Savings	0	20	20	20	20	20
Treated Wastewater	52	99	162	230	376	522
Desalination Water	0	2	20	37	53	70
Domestic	***218.5***	***367***	***489***	***729***	***969***	***1209***
Surface Water (Fresh)	51.3	172	249	446	497	497
Ground water (Fresh)	167.2	173	200	226	254	280
Demand Management Savings	0	20	20	20	20	20
Desalination Water	0	2	20	37	53	70
Industrial	***43***	***86***	***129***	***143***	***156***	***170***
Surface Water (Fresh to Brackish)	16.7	33.4	50.1	55.5	60.6	66
Ground water (Fresh to Brackish)	26.3	52.6	78.9	87.5	95.4	104
Irrigation	***740***	***791***	***900***	***900***	***900***	***900***
Surface Water	*346.4*	*194.6*	*172.9*	*90.5*	*34.4*	*29*
Fresh Water	268.1	133	128	51	0	0
Fresh to Brackish Water	78.3	61.6	44.9	39.5	34.4	29
Ground water	*341.6*	*129.4*	*108.1*	*104.5*	*101.6*	*98*
Fresh Water	55.3	0	0	0	0	0
Fresh to Brackish Water	286.3	129.4	108.1	104.5	101.6	98
Treated Wastewater	52	99	162	230	376	522
WATER SUPPLY TOTAL	**1001.5**	**876**	**1061**	**1297**	**1492**	**1686**
Fresh Water Total	541.9	478	577	723	751	777
Fresh to Brackish Water Total	407.6	277	282	287	292	297
Treated Wastewater	52	99	162	230	376	522
Brackish Water Desalination	0	2	20	37	53	70
Water Demand Management Savings	0	20	20	20	20	20
Surface Water Total	***414.4***	***400***	***472***	***592***	***592***	***592***
Fresh Water	319.4	305	377	497	497	497
Fresh to Brackish water	95	95	95	95	95	95
Ground Water Total	***535.1***	***355***	***387***	***418***	***451***	***482***
Renewable Total	442.1	262	281	300	320	339
Non-Renewable Total	93	93	106	118	131	143
Fresh Water Total	*222.5*	*173*	*200*	*226*	*254*	*280*
Renewable Water	147.5	98	112	126	141	155
Non-Renewable Water	75	75	88	100	113	125
Fresh to Brackish Total	*312.6*	*182*	*187*	*192*	*197*	*202*
Renewable Water	294.6	164	169	174	179	184
Non-Renewable Water	18	18	18	18	18	18
WATER DEFICIT TOTAL	*	**-368**	**-457**	**-475**	**-533**	**-593**
Fresh Deficit Total	*	**14.35**	**-7**	**-84**	**-280**	**-477**
Treated & Fresh to Brackish Deficit Total	*	**-382.4**	**-450.0**	**-391.0**	**-253.0**	**-116.0**
Domestic (Fresh)	*	**-**	**-**	**-**	***-145***	***-342***
Industrial (Treated & Fresh to Brackish)	*	**-**	**-**	**-**	**-**	**-**
Irrigation Total	*	***-368***	***-457***	***-475***	***-388***	***-251***
Fresh Water	*	14.35	-7	-84	-135	-135
Treated & Fresh to Brackish Water	*	-382.4	-450.0	-391.0	-253.0	-116.0

** Ground water abstractions exceed the safe yield by 25 % in order to fill the Gap.*
** The source considered 1993 as present year and it is kept for reference.

Table 20: Adjusted future water supply (resources) and deficit in Jordan up to the Year 2040 (MCM/yr)

Item	*Year 2000*	*Year 2010*	*Year 2020*	*Year 2030*	*Year 2040*
WATER DEMAND TOTAL	**1244**	**1518**	**1772**	**2025**	**2279**
Surface Water	316.0	372.9	467.7	467.7	467.7
Ground water	280.5	305.7	330.2	356.3	380.8
Demand Management Savings	20	20	20	20	20
Treated Wastewater	99	162	230	376	522
Desalination Water	2	20	37	53	70
Domestic	***367***	***489***	***729***	***969***	***1209***
Surface Water (Fresh)	208.3	291.0	392.6	392.6	392.6
Ground water (Fresh)	136.7	158.0	178.5	200.7	221.2
Demand Management Savings	20	20	20	20	20
Desalination Water	2	20	37	53	70
Industrial	***86***	***129***	***143***	***156***	***170***
Surface Water (Fresh to Brackish)	33.4	50.1	55.5	60.6	66
Ground water (Fresh to Brackish)	52.6	78.9	87.5	95.4	104
Irrigation	***791***	***900***	***900***	***900***	***900***
Surface Water	*74.3*	*31.8*	*19.5*	*14.5*	*9*
Fresh Water	33	7	0	0	0
Fresh to Brackish Water	41.7	25.0	19.5	14.5	9
Ground water	*91.2*	*68.8*	*64.2*	*60.2*	*56*
Fresh Water	0	0	0	0	0
Fresh to Brackish Water	91.2	68.8	64.2	60.2	56
Treated Wastewater	99	162	230	376	522
WATER SUPPLY TOTAL	**717.5**	**880.6**	**1084.9**	**1273.0**	**1460.5**
Fresh Water Total	377.6	455.8	571.2	593.3	613.8
Fresh to Brackish Water Total	218.8	222.8	226.7	230.7	234.6
Treated Wastewater	99	162	230	376	522
Brackish Water Desalination	2	20	37	53	70
Water Demand Management Savings	20	20	20	20	20
Surface Water Total	***316.0***	***372.9***	***467.7***	***467.7***	***467.7***
Fresh Water	241.0	297.8	392.6	392.6	392.6
Fresh to Brackish water	75.1	75.1	75.1	75.1	75.1
Ground Water Total	***280.5***	***305.7***	***330.2***	***356.3***	***380.8***
Renewable Total	207.0	222.0	237.0	252.8	267.8
Non-Renewable Total	73.5	83.7	93.2	103.5	113.0
Fresh Water Total	*136.7*	*158.0*	*178.5*	*200.7*	*221.2*
Renewable Water	77.4	88.5	99.5	111.4	122.5
Non-Renewable Water	59.3	69.5	79.0	89.3	98.8
Fresh to Brackish Total	*143.8*	*147.7*	*151.7*	*155.6*	*159.6*
Renewable Water	129.6	133.5	137.5	141.4	145.4
Non-Renewable Water	14.2	14.2	14.2	14.2	14.2
WATER DEFICIT TOTAL	**-526.6**	**-637.4**	**-687.1**	**-752.0**	**-818.5**
Fresh Deficit Total	**-86.0**	**-128.2**	**-135.0**	**-437.7**	**-640.2**
Treated & Fresh to Brackish Deficit Total	**-440.5**	**-509.2**	**-451.3**	**-314.3**	**-178.4**
Domestic (Fresh)	***-***	***-***	***-100.83***	***-302.71***	***-505.17***
Industrial (Treated & Fresh to Brackish)	***-***	***-***	***-***	***-***	***-***
Irrigation Total	***-527***	***-637***	***-586***	***-449***	***-313***
Fresh Water	-86.0	-128.2	-135.0	-135.0	-135.0
Treated & Fresh to Brackish Water	-440.5	-509.2	-451.3	-314.3	-178.4

3.4 Key Assumptions Supporting the Projections/Objectives

Review of Jordan's water situation in **Section 3.3** and the discussion of alternatives in **Section 5** reveal important facts about the water deficit. These facts can be summarized as follows:

- Total potential of Jordan's national water resources is not enough to fulfil the growing demand in all sectors.
- Demand sectors could be categorized into two different priorities:
  - Domestic and Industrial Demand Sectors
  - Irrigation Water Demand Sector
- Groundwater resources have been abused for the last decade in order to fulfil the gap. This is harming the resources seriously in terms of both quantity and quality.
- Freshwater became limited and as from now cannot fulfil the domestic demand starting.
- Treated wastewater could be the potential source for the irrigation sector.
- Jordan has to look for non-conventional sources to meet the growing demand in the domestic sector.

According to above, management measures adopted by the Kingdom and the actions required to manage the water scarcity in Jordan could be presented in **Figure 19**, which gives a clear picture of the tremendous efforts undertaken by the GOJ to reduce the gap between demand and available water resources.

	Present	Year 2020
• **Demand**		
• Municipal	----------►	Increasing
• Industrial and Touristic use	----------►	Increasing
• Irrigation use	----------►X	Needs to be decreased
• **Supply**		
• Conventional Surface Water	----------►	To be developed
• Conventional Groundwater	----------►X	To be stabilised at current level or reduced to enhance quality and storage
• Fossil Groundwater	----------►	To be extracted
• Treated Wastewater Effluent	----------►	To be reused
• Brackish Groundwater	----------►	To be extracted
• Seawater Desalination	----------►	Future option
• Regional Water	----------►	Future option

Figure 19: Actions required for management of water scarcity

3.4.1 Water Resources, Demand and Flexibility Management

Water projections can be affected greatly by water resources availability, growing demand and management enhancement. Regarding growing demand, the World Bank discussed it and the following can be quoted: "Water requirements will continue to increase due to increasing population, including the impact of past refugee inflows into the country, raising the living

standards, unexpected strong increase in industrial water use, and an increase towards the targeted cropping intensity and area in the Jordan Valley (Water Sector Review, World Bank, 2001)".

The report forecasted the increase in total supplies from 898 MCM in the year 1998 to a sum of 1,287 MCM in the year 2020. This forecasting was based on the implementation without delays of all projects planned in the Investment Program 2000-2010. The increase was assumed to be concentrated in total water supply for municipal and industrial use, which was expected to increase from 275 MCM in the year 1998 to 660 MCM in the year 2020. This makes the share percentage increase from 30% to 52% of total water consumption from the year 1998 to the year 2020, respectively.

The above summarizes the important elements which controlled the assumptions for Jordan's future water sector projections.

3.4.2 Strategic Approach

As outlined in the Water Strategy for Jordan of 1997, priority will be given for provision of water for basic human needs of a modest 100 litres/per capita/per day with priority then given to use by tourism and industry. The continued population growth in Jordan has forced the allocation of water for domestic purposes at the expense of allocations for irrigated agriculture. These changes in allocations are subject to economic and social constraints given the number of people involved in irrigated agriculture. The general trend is towards limiting irrigation demand by use of new technologies and changes in crops that consume less water and by shifting workers over time from, agricultural to industrial jobs where possible.

3.4.3 Policies and Institutional Reform

The following summarize the main issues which are tackled by different policies:

- Policies estimate renewable freshwater available in year 2000 by 160 m^3/year/capita (Water Utility Policy, 1997).
- The country is of very limited surface water with very high rate of evaporation and the storage under ground surface could be the best approach (Groundwater Policy, 1998).
- Due to the tight water situation, wastewater is considered a resource (Irrigation Water Policy, 1998).
- Jordan's per capita share is projected to fall from 180 m^3 per year in 1997 to 90 m^3 per year by the year 2025 (Wastewater Management Policy, 1998).
- Renewable fresh water resource is estimated to be about 850 MCM per year including peace treaty water. It is expected that 125 MCM per year to be available from fossil aquifers and through desalination by the year 2005. The summation could reach 975 MCM per year (Wastewater Management Policy, 1998).
- Reorientation of the role of the government and the encouragement of private sector participation (Water Sector Action Plan, 2002-2006).
- No expansion of irrigated areas (irrigated areas in Jordan Valley limited to 427,000 dunums) (Water Sector Action Plan, 2002-2006).

In order to conduct such policies, MWI concentrates on institutional strengthening and training. **Table 21** presents the number of trainees for the period between 1994 and 2001 with the

percentage to the total number of employees in the Ministry. The percentage is depending on the financial situation and the international aids. The percentage could be around 10 % in average for the eight years, which reflects the importance of human resources in the water sector. The importance could be resulted from the challenge of water problem in Jordan.

Table 21: Training of Ministry of Water and Irrigation Employee

Year	1994	1995	1996	1997	1998	1999	2000	2001
Outside Jordan	54	79	87	62	45	30	39	41
Inside Jordan	295	822	756	997	499	269	399	664
Total	349	901	843	1059	544	299	438	705
Total Employee	6872	7300	7431	7414	7460	7762	7869	7709
% to Employee	5.1 %	12.3 %	11.3 %	14.3 %	7.3 %	3.9 %	5.6 %	9.1 %

3.4.4 Conjunctive Use and Development of Water Resources

The three projection scenarios discussed by the new Master Plan could be limited to water resources. Shows the possible limitation in the future demands. **Figure 20** shows the possible limitation in the future demands:

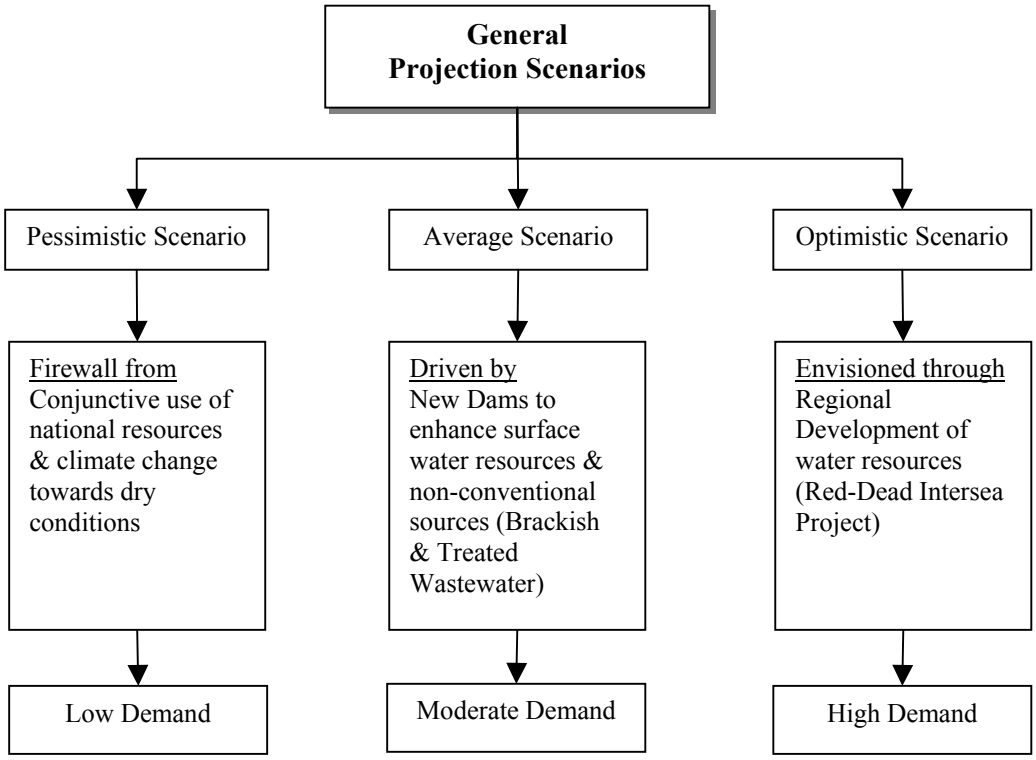


Figure 20: Projections versus conjunctive use and development of water resources

Water increase could be facilitated by the following projects:

- Tapping the Disi aquifer for Amman demand centre
- Exchanges of consumption between Highland cities and agriculture to replace Yarmouk River freshwater by treated wastewater
- Wehdeh Dam and Wadi Mujib system
- Hisban/Zara Main brackish water desalination
- Peace Treaty waters
- Loss reduction in Greater Amman and other cities networks
- Intersea Project (Red-Dead Sea)

Brackish water has the highest potential as a non-conventional means of augmenting Jordan's water resources (Water Utility Policy, 1997).

Other economically, politically, socially and environmentally viable non-conventional water augmentation option is seawater desalination at Aqaba (GTZ, 1997).

3.4.5 Demand Management - Water Conservation, Pricing and Public Awareness

The "Water Sector Action Plan of 2002-2006" indicated that great attention would be given to cost recovery issue. This was achieved through:

- Restructuring the water tariffs to encourage the public to save water and consume less. Consideration was taken to the poor community where a constant amount was applied to a certain consumption after which an increase in tariff is applied to each consumed cubic metre of water.
- As an additional measure towards water conservation, the Government has an ongoing rehabilitation program of the water supply systems to reduce losses through the networks. This program covers all parts of Jordan, for example construction is an ongoing process in Amman and the hydraulic analysis is being conducted for Karak, Ma'an and Tafeileh Governorates, as well as the water loss reduction program in Irbid.
- Public awareness campaigns were conducted as it is considered one of the main components for enhancing water conservation in Jordan. The following is the campaigns carried out in 2002: 350 including workshops in universities and schools; 70 targeting women through women associations; 12 meetings in different mosques; and coordination with hospitals, military, hotels and different ministries.

4 EVOLVING POLICY FRAMEWORK (1997 – 2002)

The Ministry of Water and Irrigation, in cooperation with the US Agency for International Development (USAID) and with a contribution of the German Agency for Technical Cooperation (GTZ), initiated a water policy development program for Jordan in early 1995. The program was supported by the USAID Water Quality Improvement and Conservation Project, implemented by Development Alternatives, Inc. (DAI).

The first phase of the program included establishing a water policy committee, chaired by the Undersecretary of the Ministry of Water and Irrigation, and composed of experts who represented the full range of perspectives and interests in the water sector in Jordan. The core of the water policy committee numbered roughly 25 and was drawn from the MWI, WAJ, and JVA staff; the Ministry of Planning; and the Jordanian and international consultant community.

Program participants identified and reviewed relevant literature, including water policies adopted by other countries, and studied in detail current and anticipated water problems in the country. The committee also reviewed existing laws and regulations related to water and identified policy gaps. Committee members with additional officers of the Ministry of Water and Irrigation formed 24 policy issue task forces which examined the issues closely, prepared policy profiles, and drafted policy statements, strategies, and action plans. The task forces then presented these products to the policy committee at regularly scheduled meetings. The policy committee reviewed and revised the policy statements, strategies, and action plans in open session. These policies and strategy developed in the year 1997 provide a framework within which all activities are implemented. These policies and strategy are reviewed in the following section.

4.1 Strategy and Policies

Jordan's water strategy in 1997 and policies in 1997 and 1998 are presented in this section in order to highlight the importance of the Disi project. The importance is extracted from the fact that such a resource is essential to fill the freshwater gap in the supply-demand balancing. In addition to the Jordan's Water Strategy (April 1997), the following policies are addressed:

- Water Utility Policy (July 1997)
- Groundwater Management Policy (February 1998)
- Irrigation Water Policy (February 1998)
- Wastewater Management Policy (June 1998)

In addition to those policies, other studies on Jordan's water resources are addressed.

4.1.1 Jordan Water Strategy of April 1997

The ***Jordan Water Strategy of April 1997*** discussed the following main issues regarding Jordan's water sector:

- Share of indigenous renewable water resources is 175 m^3 per annum in the year 1996, plus an average share of 0.1 hectare per capita of rain fed agricultural land.
- Annual quantity of municipal water was estimated by 57 m^3/capita or 156 litres per capita per day in the year 1996.
- Year 2005 is the target year for fully utilized freshwater resources.

- Toxicity index (pollution load compared to renewable water resources) is high.
- Groundwater aquifers are exploited at more than double their sustainable yield in average due to the abrupt surges in population levels through control relaxing on drilling operations and on licensed abstraction rate.
- Protection against desertification requires sustainability of agriculture.
- Water costs compared to GDP does not allow full cost recovery. The GDP in Jordan is very low GDP per capita (2001) 1,208 JD/capita and, according to JICA Study (December, 2001), payment for water as percentage of household income could reach 4.6%.

The strategy discussed very important subjects with advanced technical analysis using up to date methods and terminology. The share of indigenous renewable water resources was estimated in two main parts:

- The annual water supply per capita.
- The rain fed agricultural land.

The above sum of available water cannot fulfil more than 20% of the annual need per capita. The 80% deficit was filled partly with groundwater over abstraction and the major part with imported dry water. The dry water is represented mainly by the imported wheat. The strategy fixed the year 2005 as the fully utilization year regarding the freshwater resources, which Disi water is part of them according to Ministry of Water and Irrigation (MWI) Investment Program. The MWI investment program and the action plan are discussed in this report in the following sections.

Toxicity index was used by the strategy to define the harsh situation of the water resources scarcity in Jordan. Disi water could decrease the index considerably due to two facts:

- Increase the share of per capita for domestic demand.
- Change the disposed water quality due to its high quality.

The consumption of Disi water could relieve the over exploited aquifers and reduce the damage in both conditions:

- Quality of groundwater in the relief aquifers.
- Elevated water table level.

Elevated water table could reduce the abstraction energy and the salinity of the aquifers. High water table will lower the hydraulic gradient between the fresh water and the lower quality water of high salinity. This needs considerable difference in water level due to the water density differences. The Azraq aquifer could be a good example for execution of such strategy.

Jordan's Water Strategy of 1997 indicates on ***Resource Development*** the following:

- Water is a national resource, which can lead to a comprehensive national water data bank with a decision support unit of:
    - Monitoring
    - Data collection, entry, updating, and processing
    - Dissemination of information
    - Terminal in a regional data bank set-up

- Full potential of surface and groundwater shall be tapped:
    - To the extent permissible by economic feasibility, and by social and environmental impacts
    - Deep aquifers shall be investigated to support development planning
    - Interactive use with different qualities
    - Assessment of the available resources

- Wastewater shall be collected and treated to standards due to economy consideration and quality assurance that allow:
    - Its reuse in unrestricted agriculture and non-domestic purposes
    - Recharge groundwater aquifers
    - Blending with freshwater

- Marginal quality, brackish, and seawater sources shall be enlisted for desalination with consideration of advanced research in genetic engineering to support:
    - Irrigated agriculture; and
    - Additional water for municipal, industrial, and commercial consumption.

- A long future plan shall be formulated for development of water resources with extraction of five years plan, which is subjected to updating as necessary and compatible with other sectors.

- Priority criterion for projects implementation shall be based on:
    - Economic, social, and environmental considerations
    - Critical Path
    - Sustainability in the light of:
        - National water balance
        - Economic, social, and environmental opportunity cost of forgone alternative uses of water

- Priority will be given to allocation of:
    - Basic human needs of a modest share of 100 litres per capita per day
    - Followed by tourism and industrial purposes

The Water Strategy indicated on ***Resource Management*** the following:

- Priority is given to:
    - Sustainability of use of previously developed resources
    - Resources mobilized for Jordan Valley irrigated agriculture
    - Protection against:
        - Pollution
        - Quality degradation
        - Depletion

- Mining of:
    - Renewable groundwater aquifers, which shall be:
        - Checked

        - Controlled
        - Reduced to sustainable extraction rates
    - Fossil aquifers, which shall be carefully:
        - Planned
        - Implemented

- Tools of advanced technology shall be adopted and a dual approach of demand and supply management can be used in order to achieve the highest possible efficiency in:
    - Conveyance
    - Distribution
    - Application
    - Use

- Dynamic regime of demand and supply shall be instated and updated for targeting:
    - Minimum cost of operation and maintenance.
    - Cost of production of future requirements of units of water flow for industrial, commercial, tourism, and agricultural projects.

- Interactive use of multiple resources shall be targeted to maximize:
    - Usable flows
    - Net benefit of unit flow

- High priority shall be given to human resources development, which includes:
    - Continuous education
    - On-the-job and overseas training programs
    - Over-employment shall be trimmed for efficient management

- Wastewater management shall be developed to protect:
    - Public health according to standards
    - Quality degradation due to industrial wastewater

The Water Strategy indicated on ***Shared Water Resources*** the following:

- Rightful shares of the Kingdom shall be defended and protected through:
    - Bilateral and multilateral contacts
    - Negotiations
    - Agreements

- Due respect will be given to the provisions of international law as applicable to water sharing, protection and conservation.

- Bilateral, multi-lateral, and regional co-operation shall be pursued.

The issues addressed in Jordan's water strategy of 1997 are distributed across three levels: resource development, resource management, and shared water resources. These issues are summarized in **Figure 21**.

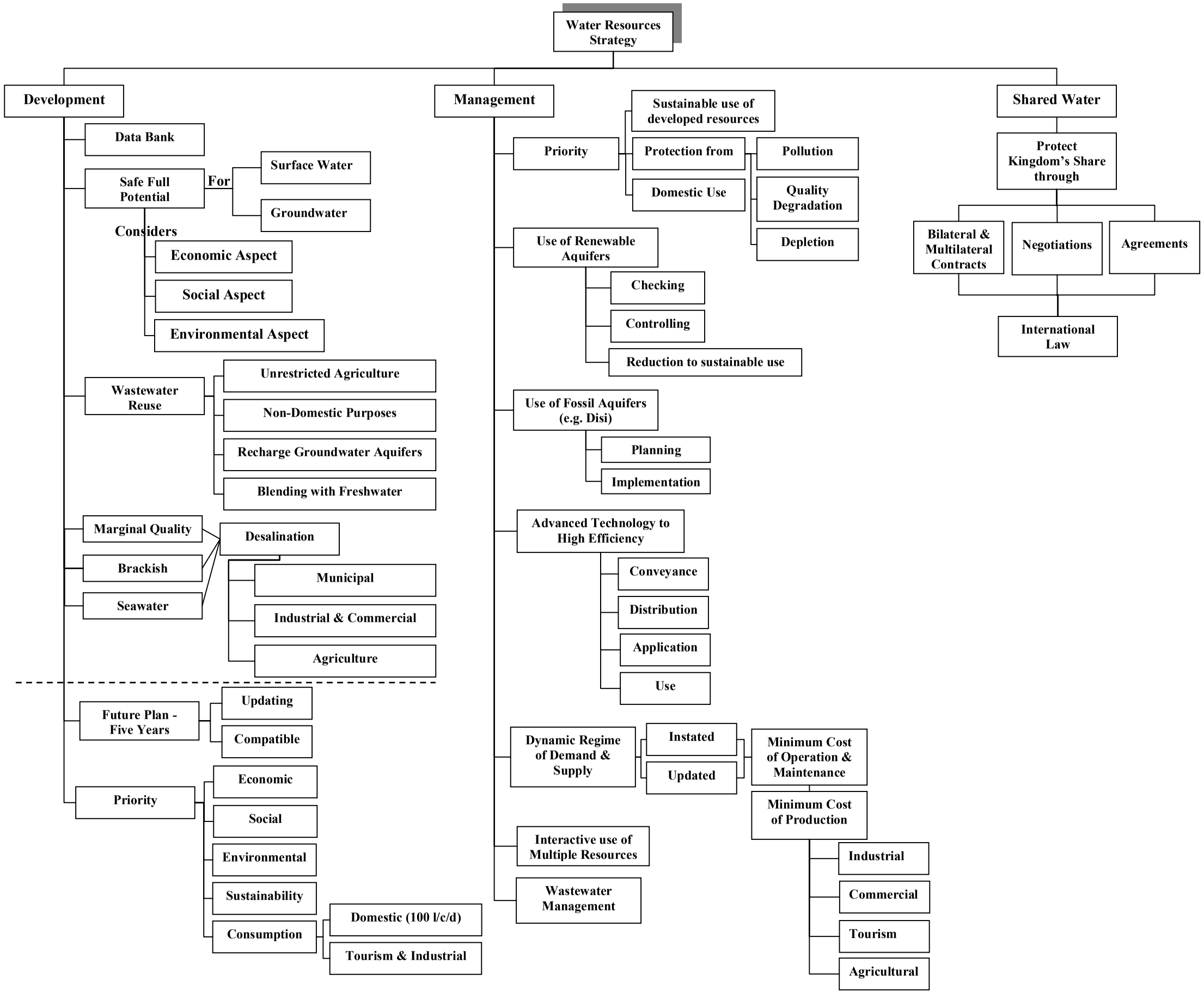


Figure 21: Jordan's Water Strategy

4.1.2 Water Utility Policy of July 1997

The ***Water Utility Policy in July 1997*** presents the first policy to be formulated under the Water Strategy. The policy discussed water resources in Jordan. It estimated the renewable freshwater available in year 2000 by 160 m^3 per capita per annum and compared it with the "water poverty line" of 500 m^3 per capita per year.

The policy estimated surface water potential by 692 MCM (Million Cubic Meters) per year, which assumed only about 475 MCM applicable for development. This was attributed to economic and geographic constraints. It states that enhancement of surface water can be managed through:

- Comprehensive monitoring and assessment program for quality, quantity, and uses.
- Establishing an integrated development and conservation program.

Groundwater was discussed by the policy as well and the unsustainable abstraction was highlighted. The depletion of groundwater aquifers was assigned by the policy as the major problem facing Jordan's water sector. This will put the sustainability of irrigation in the highlands and the Badia in great danger. Therefore, the Ministry is implementing a program that sets out legal and financial measures aimed at controlling and gradually reducing groundwater withdrawals with final objective of maintaining the safe yield of aquifers.

In conjunction with the above, the Ministry is pursuing planned and controlled groundwater mining from promising, extensive fossil aquifers as an option to secure incremental supplies for municipal and industrial uses. The groundwater use will take place conjunctively with surface water in places where such joint use has the potential for increasing the available supply.

The policy reviewed the availability of wastewater and shifted from a view that this was "waste" recognizing it as a strategic water resource that could be used in an optimal manner through effective collection, treatment and use in an environmentally sound manner. These figures can be summarized by the following, which related to the year 1996:

- Wastewater collection and treatment services were provided to fourteen major populated areas.
- Two million people (about 50% of the population) were served by sewerage systems.
- The effluent quantity was estimated at about 60 MCM per year.

The policy estimated that by the year 2020 the volume of wastewater reuse will be 200 MCM per year and stated more wastewater projects are planned. Therefore, the Ministry is developing a wastewater master plan to serve all areas throughout the Kingdom. In parallel, industries will be encouraged to recycle part of their wastewater and to treat the rest to acceptable standards before it is discharged into the sewer or elsewhere, as stated by the policy.

Brackish water was offered the highest potential non-conventional means of augmenting the country's water resources. It can be used directly or after desalination as outlined by the policy. The policy planned the development of brackish water option by the Ministry according to the following:

- Assess the potential of the resource
- Conduct technical, economic, and environmental feasibility

- Run research and studies on desalination and on optimisation of brackish water use in agriculture and industry

The municipal networks were discussed by the policy, which indicates inadequate investments. Distribution systems were defined by low efficiency comparing to the high level of services in the water supply sector. The most important parameters developed for service level assessment include:

- Maintaining water quality in the networks to within the standards.
- Frequency of summer water supply.
- Frequency of winter water supply.
- Response time for repair of network leakages, pressure loss, and sewer blockage.
- Reduction in waiting times for water and wastewater connections.
- Reduction in waiting times for the resolution of customer complaints.

The policy reflects perfectly the willingness of the water strategy for enhancing the water scarce resources of Jordan. Section two discussed this policy and the relief strategy of the exhausted aquifers due to over exploitation. The over exploitation was unavoidable due to high rate of demand. High rate of demand was the result of two situations:

- Economic impacts of large scale importation of food.
- Abrupt increase of population due to waves of refugees and returnees for last decades.

This policy concluded that water sector requires:

- Well management and efficient use
- Proficient management of water demand
- Development of all available sources
- Mitigation against adverse impacts and environmental protection

4.1.3 Groundwater Management Policy of February 1998

Groundwater Management Policy in February 1998 shows the condition of the groundwater resources up to the year 1997 and gives some history and future forecasting. The policy stated that the 12 water basins have wells sunk in and pumps installed capable of abstracting more water than the safe yield. Abstraction in the year 1997 exceeded the renewable average of recharge by 59%. The combined abstraction rate of all renewable basins approached 437 MCM per year against 275 MCM per year as sustainable yield. The over pumping ration ranges between 146% in minor aquifers to 235% in major ones.

This policy statements set out the Government's policy and intentions concerning groundwater management aiming at development of the resource, its protection, management and measures needed to bring the annual abstractions from the various renewable aquifers to the sustainable rate of each.

The policy stated as an action for over abstraction that "this situation could not be tolerated, and decisions were taken to treat the situation". As discussed earlier, the over abstraction issue is very important in countries such as Jordan. The country is of very limited surface water with very high

rate of evaporation and the storage under ground surface could be the best. MWI invested lately in reservoirs to harvest rainfall, which recharged the groundwater.

The policy referred to in the Water Strategy indicates that a gradual reduction of pumping from the groundwater aquifers has to be reduced so that the abstraction rate will be close to the annual recharge by the year 2005. The policy recognized the importance of the Disi water for domestic use rather than the present agricultural consumption. The policy discussed the lease in 1984 to lands in the southeast for agricultural production companies using Disi water.

On Resource Protection, Sustainability, and Quality Control, the policy focused on the need to withdraw water from non-renewable fossil aquifers, such as Disi, only after careful investigations of the technical, economic, environmental and social implications of such activities. An assessment would be made of the lifetime for each of these aquifers and an abstraction rate specified to allow for their responsible use until longer water supply solutions can be developed. The policy stated "New non-renewable groundwater sources shall be allocated to municipal and industrial uses as a first priority".

4.1.4 Irrigation Water Policy of February 1998

Irrigation Water Policy in February 1998 found that wastewater is considered a resource due to the tight water situation. Although, the policy stated that in remote sparsely populated areas, and after satisfying the local municipal and industrial needs from unallocated water resources, water resources shall be allocated to agricultural production including livestock.

Jordan is planning to produce high-income products to increase the productivity of the meter cube of water and to pay the full cost of water with no subsidy. This plan can relieve the pressure on the food importing and can partially address the social issues in the agriculture sector related to both income and employment.

This policy stated that maximum use shall be made of rainfall for crop production, and supplementary irrigation shall be employed to maximize production including increasing cropping intensities. No diversion of irrigation's waters to other uses shall be allowed without providing a replacement source of water suitable from a public health and environmental perspective for use in agriculture.

Changes in access to water resources for agriculture should only be made when cultivation endangers the sustainability of groundwater resources. This includes the potential depletion of groundwater from over pumping and/or the pollution of aquifers from agricultural chemicals and salts. The policy offers the farmers free leaching water out of surplus surface water during the wet season; especially to those using treated wastewater for irrigation in dry season.

4.1.5 Wastewater Management Policy of June 1998

Wastewater Management Policy in June 1998 presents the characteristics of wastewater in Jordan as different from other countries due to the fact that quality and quantity of the municipal water are low. The average salinity of municipal water is estimated by the policy at about 580 ppm, and average domestic consumption is around 70 litres per capita per day. This results in a very high organic load and a higher salinity than the normal salinity in wastewater as outlined by the policy. This becomes dominant in waste stabilization ponds, which treat 85% of the total

generated wastewater. Waste stabilization ponds lost considerable amount of water through evaporation, which leads to increase in the salinity levels in the effluents.

The policy warns about the increased supply of water for domestic use at the expense of spring flows into streams. The flow of freshwater in many of these streams have dried up as a result of increased pumping from the aquifers, and the flow was replaced with the effluent of treatment plants. Specifications and minimum standards are needed for the use of septic tanks in rural areas in order to protect the underlying aquifers. The policy considered the isolation of treated wastewater from surface and ground waters used for drinking, and the blending of treated effluent with relatively fresher water for suitable reuse.

The policy shows that Jordan's per capita share is projected to fall from 180 m^3 per year in the year 1997 to 90 m^3 per year by the year 2025. The policy estimated renewable 'fresh' water resources at about 850 MCM per year including Peace Treaty water. It is expected that 125 MCM per year to be available from fossil aquifers and through desalination by the year 2005. The summation could reach 975 MCM per year.

Disi water is the important part of the extra water that is planned to replace partially the low quality groundwater consumed domestically. This issue is of high importance in upgrading the quality of the treated wastewater, which fills to some extent the irrigation water urgent needs. The urgency is discussed above regarding the low income and social conditions of the agricultural sector. Accordingly, wastewater reuse will be multiplied four times in 20 years interval. The Wastewater Management Policy in June 1998 was estimated wastewater reuse as follows:

- About 60 MCM per year in the year 1997
- About 240 MCM per year in the year 2020

4.1.6 Jordan Water Resources Sector Study

Jordan Water Resources Sector Study (World Bank, 1988), Report # 7099-JO alerted the water sector about the tragedy of the water scarcity in Jordan even before the impact of refugee inflows into the country after the Gulf Crisis. The report expected the municipal water requirements to treble over the next 30 years, increasing from 125 MCM in the year 1986 to 366 MCM in the year 2015. Industrial water demand was expected also to grow rapidly from 28 MCM in the year 1986 to 133 MCM in the year 2015. Municipal and industrial water use as a percentage of total demand was expected to increase from 24% in the year 1985 to 30% in the year 2005 (this was accelerated and occurred in the year 1998 due to Gulf Crisis) and 45% in the year 2015.

The report estimated the long-term safe yield of groundwater resources excluding fossil aquifers at about 356 MCM per year and compared to that date consumption of 333 MCM per year. Surface water resources were estimated at about 540 MCM per year as base flow and 338 MCM per year of runoff. The wastewater reuse was expected to increase from 9 MCM in the year 1986 to 105 MCM in the year 2015, which is expected to go far beyond this figure in the year 2015.

4.1.7 Jordan Water Sector Review

Jordan Water Sector Review (World Bank, 1997), Report # 17095-JO reflects the findings of a Bank mission to Jordan in March 1995 with actions that were being taken by the Government, and recommendations for further action. The report provides an overview of the "critical situation" (as called by the report) of the water sector in the Kingdom and the sincerity of the challenge facing

the Jordanians. It shows a great deal of shortages in urban supplies without significant relief. In the same time, the agriculture share reached 70% of total consumption, which partially depends on groundwater over abstraction.

The report discussed the gap between supply and demand for municipal and industrial water services, which:

- Became widespread throughout Jordan
- Extended to most of the year
- Is affecting the great majority of the population
- Is undermining consumer confidence and willingness to pay for services

The report concluded that relief could not be immediate as both possible major supply augmentations, Disi/Amman Conveyance System and transfers from Yarmouk and Jordan Rivers will take years to implement.

The report estimated total renewable water resources available in Jordan by:

- 277 MCM per annum as groundwater
- 662 MCM per annum as surface water

939 MCM per annum in total

In addition to the estimated total renewable water, there are 143 MCM per year estimated to be available from fossil aquifers (125 MCM from Disi over a 50-year period and 18 MCM from Jafer over a 40-year period) and 50 MCM from brackish aquifers, which were not fully explored before 1997. The report shows that about 71 MCM in year 1995 was abstracted from Disi, 59 MCM for agricultural use and 12 MCM for municipal and industrial use in Aqaba. It is worth mentioning that above figures are referenced to reports from different sectors at the Ministry of Water and Irrigation.

4.1.8 The Hashemite Kingdom of Jordan Water Sector Review Update Main Report

The Hashemite Kingdom of Jordan Water Sector Review Update Main Report (World Bank, 2001), Report # 21946-JO presents the summary findings of the Update work carried out in 2000. The report outlined that a joint effort with MWI resulted in development of "Water Requirements" model with projecting future water requirements and water supply until the year 2020. The model indicated that water requirements will continue to increase due to increasing population, including the impact of past refugee inflows into the country, raising the living standards, unexpected strong increase in industrial water use, and an increase towards the targeted cropping intensity and area in the Jordan Valley.

The future water supply figures in the model were linked to the investment timing projected in the Investment Program for the period 2000-2010 as well as to estimates about further investments thereafter. The report forecasted the increase in total supplies from 898 MCM in the year 1998 to a sum of 1,287 MCM in the year 2020. This forecasting was based on the implementation without delays of all projects planned in the Investment Program 2000-2010. The increase was assumed to be concentrated in total water supply for municipal and industrial use, which was expected to increase from 275 MCM in the year 1998 to 660 MCM in the year 2020. This makes the share

percentage increase from 30% to 52% of total water consumption from the year 1998 to the year 2020, respectively.

The above increase can be divided into two intervals:

- Up to the year 2010 with increase of 193 MCM
- Up to the year 2020 with increase of 380 MCM

This could be facilitated by the following projects as assumed by the report:

- Tapping the Disi aquifer for Amman demand centre
- Exchanges of consumption between Highland cities and agriculture to replace Yarmouk River freshwater by treated wastewater
- Wehdeh Dam and Wadi Mujib system
- Hisban/Zara Main brackish water desalination
- Peace Treaty waters
- Loss reduction in Greater Amman and other cities networks

The above projects could reduce the groundwater abstraction for municipal and industrial use by 36 MCM for the period 1998 to 2010 and by 25 MCM for longer period 1998 to 2020, as outlined by the World Bank report. In the same time, the wastewater reuse could be increased from 67 MCM in the year 1998 to 232 MCM in the year 2020. Therefore, the reduction in the renewable groundwater abstraction for all uses can reach 122 MCM per year by the year 2020. This will ease the pressure on the Highland aquifers in order to reduce the overdraft and to protect them from salinisation.

The report separated between supply and requirements and estimated the total requirement for all uses by 1,205 MCM in the year 1998 and 1,647 MCM in the year 2020 against total supply of 898 MCM and 1,287 MCM, respectively. This will leave the Kingdom suffering from a "nagging" deficit, as called by the report, of 307 MCM in the year 1998 and 360 MCM in the year 2020.

MWI investigated the water condition in Jordan with great deal regarding the demand and supply figures in different time scale. These figures are of special importance for planning and management of water sector in near, intermediate, and a far future. The figures presented in **Table 22** are extracted from Ministry files for the years 1999 and 2000 with five years future forecasting intervals. The deficit in the above two years was satisfied by irrigation share cut, which is called as deficit irrigation and over abstraction of groundwater.

Table 22: Water demand and supply in Jordan for the years 1998 to 2020

Year	Water Demand			Water Supply			Deficit
	Municipal	Industrial	Agriculture	Municipal	Industrial	Agriculture	
1998	297	45	922	236	38	561	429
2000	321	54	922	239	37	541	480
2005	382	80	981	281	76	729	357
2010	435	102	1,002	380	93	742	324
2015	520	134	992	463	112	700	371
2020	615	168	963	517	130	662	437

Source: Ministry of Water and Irrigation, 2003

The deficit was planned to decrease dramatically according to the Ministry's new agricultural strategy. This agricultural strategy resulted from the reduction in the Wehdeh Dam reservoir

capacity. The deficit for the year 2000 will decrease to less than two third in five years. But the deficit increases again logically according to the population growth rate.

4.1.9 Water Sector Planning and Associated Investment Program 2002-2011

Water Sector Planning and Associated Investment Program 2002-2011 (MWI, 2002), the program compiled the water sector planning and investment projects over the period 2002-2011 as response to the importance of water for all aspects of economic and social development. The program outlined that no single action can remedy the country's water shortages; rather many actions are necessary to increase overall water availability.

The program used phrases like "the lowest in the world on a per capita basis" and "absolute water shortage" to show the scarcity of water in Jordan. All uses per capita share are declining from more than 160 m^3 per year at present (the year 2000) to only 91 m^3 per year by the year 2025 due to population growth. The year 2000 was 84% in water budget compared to the peak of the year 1993. Approximately 534 MCM or 65% of water was used for agriculture, 239 MCM or 29% was used for municipal use, 37 MCM or 5% was used for industrial purposes, and 7.4 MCM or 1% was used for livestock. This in total was 817 MCM Jordan's water budget in the year 2000. The water budget in the period 1995 to 1997 was constant at 880 MCM and was reduced to that figure in the year 2000 due to the limitation of the water supply against the actual demand.

The main goals of the investment program can be summarized in the following:

- Creation of uniform project baseline
- Schedule projects based on multiple scenarios
- Identify a role for private sector participation
- Identify least-cost solutions for development projects

The program conducted economic analyses of water resources and wastewater development projects considering: cost functions; economies of scale; average cost; and economic internal rate of return (EIRR). A financial analysis has been conducted to assist in ranking and prioritizing the development projects. The financial analysis included consideration of: social cost benefit analysis (SCBA); return versus costs; net present value (NPV); internal rate of return (IRR); and water intensity ratio.

Based on the economic analyses, the program consists of 53 projects (5 Technical Assistance, 10 Private Sector, 18 Water Supply and 20 Wastewater Projects) with a value of approximately US $ 2.50 billion. These planned projects, extending until the year 2011, will yield an additional 400 MCM/year of water. The investment program will proceed in stages and attempts to address the most urgent water needs will proceed first. Among the projects requiring immediate attention are water storage and dams, wastewater treatment and reuse, the reduction in unaccounted for water (UFW) in major urban areas, and the augmentation of urban water supplies. The program gave priority to the development of water management infrastructure to increase the production and supply of freshwater. Therefore, the program focused on the following major areas:

- The strengthening of water institutions
- Reduction of UFW through network rehabilitation
- Increasing the efficiency of water use
- The expansions of water supply
- Improvement of the quality and the quantity of wastewater services

- Public Awareness

4.1.10 Ministry of Water and Irrigation Water Sector Action Plan 2002-2006

Ministry of Water and Irrigation Water Sector Action Plan 2002-2006 (MWI, 2002), the plan listed all issues related to water sector and the time schedule for the interval between 2002 and 2006 (the detailed Action Plan outlined at **Annex B1**). These issues are distributed among the following:

- Institutional and Legal Issues
- Agricultural Water Use
- Cost Recovery
- Private Sector Participation
- Information Systems
- Adoption of International Conventions

The Ministry of Water and Irrigation plan for the five years starting at the year 2002 and ending at the year 2006 includes very important actions in order to use the available water resources efficiently. The plan lists the actions as in above starting with Institutional and Legal Issues in order to rehabilitate the institutional structure and to enhance the laws and by-laws. This can enforce the laws in very efficient manners to optimise the work done by MWI, WAJ, and JVA. The Institutional and Legal Issues actions are listed in the following:

- Institutional Reform- Establishment of regulatory body to:
    - Identify an appropriate structure for the water sector in Jordan.
    - Encompass greater private sector participation in service provision.
    - Reorientation of the role of the government.

- Development of an appropriate structural framework.

- Legal Issues
    - MWI: Modifying Ministry establishment's By-Laws.
    - WAJ:
        - Amendment to WAJ law- to enhance the enforcement measures.
        - New by-law for:
            - Groundwater monitoring and new agricultural use tariff-to reduce and control over drafting and illegal wells.
            - Wastewater regulations and connection fees: To allow for the smooth implementation networks through private lands and plots and to enhance financial viability.
    - JVA:
        - Amendment to JVA law: To allow for the commercial basis operations.
        - Restructuring of laws: To allow agricultural farm units to be consolidated up to 250 dunums in order to assure enhanced economic viability.
        - Farmers' participation in retail water management.

The important issue in the plan is the agricultural water use. The Ministry plans the following two important issues:

- Irrigated Areas
    - No expansion of irrigated areas- to limit the irrigated areas in the Jordan Valley by 427,000 dunums.
    - Reduction of groundwater abstractions
        - Ban summer crops in drought years to save 15 MCM per year.
        - Rent lands from farmers to save 15 MCM per year.

- Use of Marginal Water such as brackish and treated waste waters in agriculture
    - Substitute fresh water with marginal water.
    - Treated wastewater reuse up to the year 2005 can be available to amount more than 112 MCM per year out of 25 treatment plants. The amount is distributed among the following:
        - 30 MCM for Upland/Mid land.
        - 15 MCM for Industrial.
        - 59 MCM for Jordan Valley.
        - 4 MCM for Aqaba.
        - 4 MCM Locally.
    - Jordan River floods to be stored at Karama Dam and be used as brackish water.
    - Construction of desalination plant at King Talal Dam to reduce the salinity of stored water in the reservoir.

The Ministry gives a great attention to the cost recovery issue due to its economic importance. Three sub-issues plan the issue:

- Water Tariffs: To encourage public to save water and consume less.
- Rehabilitation of the water supply systems: To reduce losses through the networks.
- Increase efficiency through the following:
    - Number of employees to be reduced by 1 percent annually.
    - Training measures.
    - Public awareness program.
    - Increase water tariff by 8 percent in the year 2005 and another 8 percent by the year 2006.
    - Increase operation and maintenance cost recovery from less than 50 percent to more than 100 percent.

4.1.11 Other Water Studies

Middle East Regional Study on Water Supply and Demand Development (GTZ, 1997), (Deutsche Gesellschaft für Technische Zusammenarbeit GmbH), discusses the main options to bridge the long-term water gap and future pursuit specific projects are identified. Development of national water resources will contribute to bridging the water gap but still insufficient to cover the growing water deficit in the region. Therefore, additional new water has to be provided to cover the gap, which continues to exist even after this development. This includes water imports from outside the region either by sea or land and desalination of seawater, which are the two basic

options for supplementing the available conventional water in Jordan and the region. The options for supplementing the available conventional water in Jordan and the region include:

- Import of water from neighbouring countries by constructing pipelines/canal systems;
- Import of water by sea using tankers or medusa bags; and
- Seawater desalination.

Water imports from areas outside the region by land and/or sea and desalination of seawater using single seashore plants or the intersea project are the main options for supplementing the available conventional water in Jordan and the region. The assessment of the different potential options to meet the future demand considered the technical and economic/financial aspects, environmental impacts, and socio-economic and political implications. Seawater desalination seems to be the most suitable development option according to the prevailing conditions and available data.

Final Study for Water Sector Master Plan (JICA, 2001), (Japan International Cooperation Agency). The study includes the advice and suggestions of the concerned authorities of the Government of Japan. Also, included are comments made by the Jordanian Ministry of Water and Irrigation. The study's objectives are to:

- Formulate Water Resources Management Plan in Jordan using the tools that have been developed by the GTZ funded Water Sector Planning Support Project.
- Conduct Pre-Feasibility Study of priority project based on the findings and results of the Master Plan.
- Transfer technologies to counterpart personnel in the course of the study.

The study deals with the present conditions of water resources management in the Kingdom and presents the master plan for water resources management with the target year of 2020 to aim at:

- Unified, comprehensive, and sustainable management of the water resources.
- Strategic development of remaining scarce water resources.
- Shift to water recycling society.

The study considered special aspects in the Kingdom, which are:

- Global climatic change and characteristic of climatic change of the arid region.
- Cooperation for regional peace water development.

The relationship among these parameters was presented schematically in the study, which is reproduced in **Figure 22** with some development.

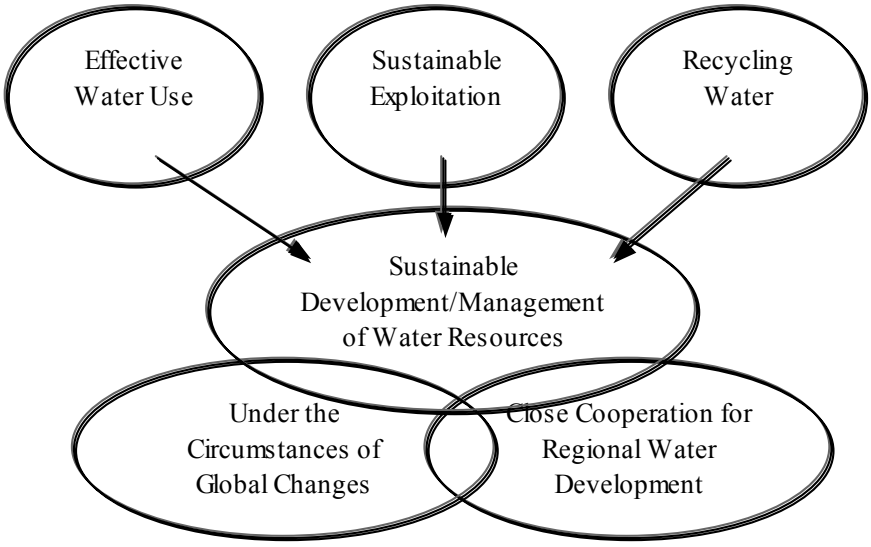


Figure 22: Relationship among the different parameters of the Water Resources Management Master Plan

The study used three different horizons:

- Short Term 2000 to 2005
- Mid Term 2006 to 2010
- Long Term 2011 to 2020

A water balance between the three main water uses (i.e., Municipal sector, Industrial and Touristic sectors, and Irrigation water use) and water resources development was set up for the planning years of 2005, 2010, 2015, and 2020. The basic considerations of each sector were:

- The increase in ***Municipal*** water corresponding to the population growth, from 4.7 million in the year 1998 to 9.2 million in the year 2020- Scenario 1 (Scenario 1 was based on the results of the balancing model that was jointly developed by MWI and World Bank)- was secured as first priority.
- ***Industrial*** and ***Touristic*** needs were satisfied with a certain priority. This is due to the fact that their importance in the national economy is expected to increase steadily. The shares in GNP are about 13% and 10% respectively, compared to agriculture of about 3%.
- ***Irrigation use*** sustainability shall be constrained according to the re-assessment of the renewable volume of groundwater resources. This means shifting:
    - Irrigation area in the Up/Mid land to Jordan Valley.
    - Fresh groundwater to treated wastewater.
    - Disi fossil groundwater to municipal use with socially acceptable measures.

4.2 Key Challenges/Objectives for Improvement

In a very direct statement, Minister of Water and Irrigation, Dr. Hazim El-Naser, described the function of water in the region by “gloomy”. His statement was quoted from the Forward of the Investment Program 2002-2011:

> "Economic and social development in the Arab countries depends, to a large degree, on the availability of good quality water and Jordan is no exception. Jordan lies in the arid to semi-arid zone. Rainfall is low and unpredictable in the majority of the Kingdom. Jordan has a per capita water supply well below the water poverty line of one thousand cubic meters per capita per annum. Having hosted several waves of refugees and displaced persons, the population of Jordan is growing at a very high rate. This, could with increased urbanization, has led to an increase in the demand for water. The water supply-demand imbalance is aggravated further by the increase in water pollution both in scale and intensity. Inefficiency in water use has compounded this critical situation. The water resources prospects for Jordan and the Arab region beyond the year 2020 seem at best gloomy. Water shortages will become a major constraint on development in many parts of the Arab world including Jordan."

In view of the above, the Government of Jordan has been actively working to mitigate the situation. No single action can remedy the country's water shortages; rather many actions are necessary to increase overall water availability. Jordan's water strategy stresses the need for improved resource management with particular emphasis being placed on the sustainability of present and future uses. Special care is advocated for protection against pollution, quality degradation, and depletion of water resources. Furthermore, Jordan aims to continually achieve the highest practical efficiency in the conveyance, distribution, application and use of water resources with the goal of adopting a dual approach of demand and supply management.

Table 23 presents the water resources management measures adopted in Jordan as extracted from the Water Action Plan and the following policies:

- Water Utility Policy (July 1997).
- Groundwater Management Policy (February 1998).
- Irrigation Water Policy (February 1998).
- Wastewater Management Policy (June 1998).

Table 23: Main water resources management measures adopted in Jordan

	Domestic and Industrial Sectors	Agricultural Sector
Supply Management	- Rehabilitate the institutional structure and enhancement of the laws and by-laws; for example: ▪ New by-law for Groundwater monitoring. ▪ New by-law for wastewater regulations and connection fees to allow for the smooth implementation networks through private lands and plots and to enhance financial viability.	- Rehabilitate the institutional structure and enhancement of the laws and by-laws; for example: ▪ New by-law for Groundwater monitoring. ▪ New by-law for wastewater regulations and connection fees to allow for the smooth implementation networks through private lands and plots and to enhance financial viability.
	- Invest in reservoirs to harvest rainfall	- Use marginal water such as brackish and treated wastewaters in agriculture.
	- Make available an expected 125 MCM per year from fossil aquifers (mainly Disi Aquifer) and through desalination by the year 2005	- Make maximum of rainfall for crop production, and supplementary irrigation shall be employed to maximize production including increasing cropping intensities
	- Implement a program that sets out legal and financial measures aimed at controlling and gradually reducing groundwater withdrawals with final objective of maintaining the safe yield of aquifers - Bring the annual abstractions from the various renewable aquifers to the sustainable rate. Pumping from the groundwater aquifers has to be effected so that the abstraction rate will be close to the annual recharge by the year 2005	- Substitute fresh water with marginal water; Treated wastewater in first place and then fresh to brackish water
	- Develop a wastewater master plan to serve all areas throughout the Kingdom. In parallel, industries will be encouraged to recycle part of their wastewater and to treat the rest to acceptable standards before it is discharged into the sewer or elsewhere, as stated by the policy	- Do not allow diversion of irrigation's waters to other uses without providing a replacement source fit for agricultural use unrestricted by health and public mainly through treated wastewater
	- Pursue a planned and controlled groundwater mining from promising, extensive fossil aquifers as an option to secure incremental supplies for municipal and industrial uses. The groundwater use will take place conjunctively with surface water in places where such joint use has the potential for increasing the available supply	- Bring the annual abstractions from the various renewable aquifers to the sustainable rate. Pumping from the groundwater aquifers has to be effected so that the abstraction rate will be close to the annual recharge by the year 2005
	- Offer brackish water as the highest potential non-conventional means of augmenting the country's water resources. It can be used directly or after desalination	- Isolate treated wastewater from surface and ground waters used for drinking, and the blend treated effluent with relatively fresher (fresh to brackish) water for suitable reuse
	- Store the Jordan River floods at Karama Dam and construction of desalination plant at King Talal Dam to reduce the salinity of stored water in the reservoir	
Demand Management	- Rehabilitate the institutional structure and enhance the laws and by-laws	- Rehabilitate the institutional structure and enhance the laws and by-laws
	- Adjust water tariffs to encourage public to save water and consume less. Increase water tariff by 8 percent in the year 2005 and another 8 percent by the year 2006, and increase operation and maintenance cost recovery from less than 50 percent to more than 100 percent	- Adopt a new by-law for new agricultural use tariff to reduce and control over drafting and illegal wells.
	- Rehabilitate the water supply systems to reduce losses through the networks	- Wastewater is considered a resource
	- Increase efficiency through the training measures, public awareness program.	- After satisfying the local municipal and industrial needs from unallocated water resources, water resources shall be allocated to agricultural production including livestock.
	- "New non-renewable groundwater sources shall be allocated to municipal and industrial uses as a first priority". The policy recognized the importance of the Disi water for domestic use rather than the present agricultural consumption	- Produce high-income products to increase the productivity of the meter cube of water and to pay the full cost of water with no subsidy
		- Recognize the importance of the Disi water for domestic use rather than the present agricultural consumption

4.3 Progress to Date

The MWI has proposed an intensive capital investment program to meet future water resources demands. However, it is important to note that in terms of costs and economic issues facing Jordan, development of even limited quantities of new water resources is very expensive. Estimates indicate that it will cost Jordan approximately JD 3.5 billion (US$ 5 billion) over a 13 year period to realize an increase in annual water supply of only 400 MCM. The increase in water supply will come mainly from Whedeh Dam, Adassiya diversion dam, dams in south (Wala, Mujib, Tannour), Disi project, rehabilitation of municipal networks, treated wastewater, desalination, and other surface and ground water projects.

Implementation of the groundwater management policy is exercised primarily by MWI and WAJ. As a result of institutional restructuring effective 1 January 1999, water resources planning, studies, and monitoring functions as well as the Water Information System are now under the authority of the MWI. The MWI now is in the process of developing the programs for these functions and integrating their operations. The issuance of licenses for drilling of new wells and groundwater abstraction as well as the enforcement and modification of these regulations and permits remains with WAJ. However, MWI will conduct the technical evaluation for each license and approve any abstraction amounts to be specified in the permit.

Expansion of the Zai water treatment plant and conveyor system from the King Abdullah Canal at Deir Alla is in progress and will double (to 80 MCM/year) the amount of water delivered to Greater Amman from the Jordan River Valley. The planned reservoirs and development project involving Wadi Mujib, Wadi Wala, and Wadi Hasa along the Dead Sea in Central Jordan have been financed and construction contracts were awarded in late 1998. Once completed, these reservoirs will deliver approximately 55 MCM/year to development projects in the southern Dead Sea region.

Automation of the King Abdullah Canal (KAC) has been in progress for several years. The objective of this project is to develop and adopt automated and monitored, and the project has been expanded to automate monitoring of surface water discharges to the KAC from the major side wadis. In addition, software has been developed and is being used for daily water management within the Jordan River Valley and for seasonal planning and forecasting. The KAC system will be connected to the new system for the Zai water treatment plant in order to monitor better the chemical and bacterial content of the water as well as any other related measurements. This will help maintain the effectiveness of the water treatment process.

The water sector agencies have begun the institutional restructuring process. In 1997, WAJ was restructured to separate water and wastewater services as independent operations as well as to separate bulk and retail water supply functions. In addition, a Project Management Unit (PMU) was established to monitor the capital investment program for Greater Amman, the anticipated management contract for Greater Amman, and the transfer of Operation and Management Support (OMS) project related expertise to other Governorates. JVA also has been undergoing restructuring; however, the future mission of JVA continues to evolve.

Further restructuring of both WAJ and JVA was initiated in early 1999. In addition, with the transfer of WAJ's water resources studies and monitoring functions and staff to MWI, water resources planning and management functions are now formally consolidated with the MWI.

In addition to securing its bilateral rights with Israel in the 1994 Peace Treaty, Jordan is actively involved in promoting regional cooperation through the Water Resources Working Group of the Multilateral Peace Talks. Likewise, Jordan was involved in discussions with Syria pertaining to

issues on the upper catchments of the Yarmouk River to reach an understanding over water sharing and flood storage between the two countries. This discussion led to an agreement for construction of Al-Wehdeh Dam. Jordan has long been a strong advocate of transforming the zero-sum game in water sharing, where there are winners and losers, into a positive-sum game where all concerned parties will be winners. Hopefully, in the context of future peace, there will be real cooperation among the countries of the region toward achieving the provision of safe and abundant water for future generations.

Private sector participation in providing services for infrastructure development would be one way to make the water more dynamic and would assist in realizing these water projects without constraining Jordan's borrowing capacity. Some components that could be directly provided by the private sector would include BOT (Build-Operate-Transfer)/BOO (Build-Own-Operate) water and wastewater projects and wastewater treatment package plants. In this context, the GOJ tried its best to get the donors involved in this issue, and the Government of Germany is strongly supporting Jordan to prepare and implement the introduction of such private management for water supply and sanitation in the Northern Governorate of Jordan. WAJ is working on an action plan with steps identified to proceed with BOO/BOT/BOOT (Build-Own-Operate-Transfer) agreements in the water sector. The GOJ actually have started. As-Samra Wastewater Treatment Plant, financed under USAID grant, is launched in the market as a BOT contract of 25 years, and it is expected that this project would be in operation in a year time. Regarding Amman Management Contract, depending on the evaluation of the performance of the LEMA (Lyonnaise des Eaux, Montgomery Watson Arabtech Jardaneh – a private operator) in Amman, if the results are encouraging, the GOJ will go for a step further. The GOJ has received from the World Bank a grant to study the possibility of extending the Management Contract area for Amman to include the Middle Governorates.

Although significant headways have been made in tackling and improving the water situation of the Kingdom, the problem will never be completely eradicated due to natural constraints such as the lack of adequate resources and the increasing numbers of the population, to name a few.

The road ahead will undoubtedly be hard and without continued assistance from the donor community and funding agencies will be impossible to traverse. The plan ahead highlights and presents Ministry's plan for achieving its objectives through various projects and studies as stipulated in the investment program.

4.4 Key (Complementary) Investments

The "Water Sector Planning and Associated Investment Program 2002-2011" (MWI, 2002) compiled the water sector planning and investment projects over the period 2002-2011 as a response to the importance of water for all aspects of economic and social development. The program outlined that no single action can remedy the country's water shortages; rather many actions are necessary to increase overall water availability.

Priority criterion for projects implementation shall be based on:

- Economic, social, and environmental considerations
- Critical Path
- Sustainability in the light of:
    - National water balance
    - Economic, social, and environmental opportunity cost of forgone alternative uses of water

This could be facilitated by the following projects as assumed by the report:

- Tapping the Disi aquifer for Amman demand centre
- Exchanges of consumption between Highland cities and agriculture to replace Yarmouk River freshwater by treated wastewater
- Wehdeh Dam and Wadi Mujib system
- Hisban/Zara Main brackish water desalination
- Peace Treaty waters
- Losses reduction in Greater Amman and other cities networks

According to Ministry of Water and Irrigation (MWI) Investment Program 2002-2006, Disi water is part of the year 2005, the year of full utilisation regarding the freshwater resources, and the project is needed to lessen the impacts of groundwater over-abstraction.

The above projects will reduce the groundwater abstraction for municipal and industrial use by 36 MCM for the period 1998 to 2010 and by 25 MCM for longer period 1998 to 2020, as outlined by the World Bank report (2001). In the same time, the wastewater reuse can be increased from 67 MCM in the year 1998 to 232 MCM in the year 2020. Therefore, the reduction in the renewable groundwater abstraction for all uses can reach 122 MCM per year by the year 2020. This will ease the pressure on the Highland aquifers in order to reduce the overdraft and to protect them from salinisation or any irreversible damages.

According to the Middle East Regional Study on Water Supply and Demand Development (GTZ, 1997), indicates that the development of national water resources will contribute to bridging the water gap but still it is insufficient to cover the growing water deficit in the region. Therefore, additional new water has to be provided. Water imports from areas outside the region by land and/or sea and desalination of seawater using single seashore plants or the intersea project (Red Sea - Dead Sea Water Conveyance Project) are the main options for supplementing the available conventional water in Jordan and the region. The assessment of the different potential options to meet the future demand considered the technical and economic/financial aspects, environmental impacts, and socio-economic and political implications. Seawater desalination seems to be the most suitable development option according to the prevailing conditions and available data.

5 ANALYSIS OF DEVELOPMENT ALTERNATIVES FOR THE WATER SECTOR

Jordan's water condition was discussed in many projects and was the subject of many literatures for many years. This is due to the real scarcity of water in Jordan. **Figure 23** presents the estimated year 2000 per capita withdrawal for Jordan compared with countries inside and outside the region. **Figure 23** shows that USA withdrawal is more than 10 folds that of Jordan. Even Israel is about 2 folds of that of Jordan. Jordan could be one of the poorest countries in water resources in the world.

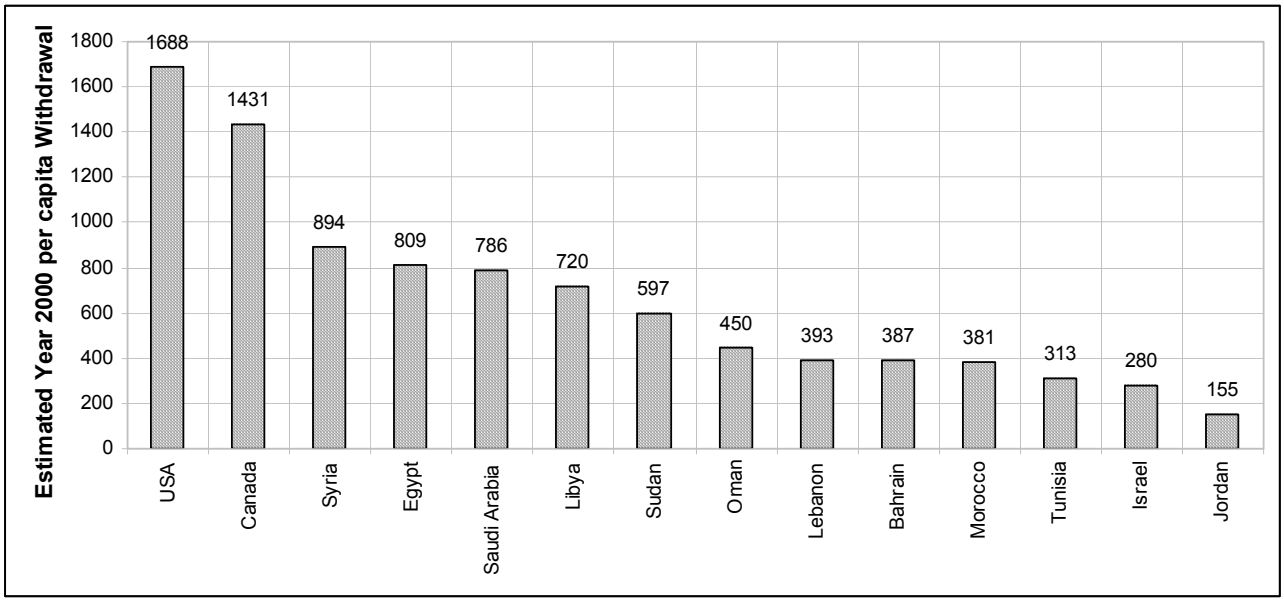


Figure 23: Estimated year 2000 per capita withdrawal for Jordan and other countries (Source: www.worldwater.org/table2)

Disi water could be the present and near future relief key to water problem in Jordan. The former statement is important but at the same time can give a wrong impression about the crucial water situation. The following text will explain in details what kind of options and alternatives Jordan can adopt. The global picture, sometimes is more important than the fine details, therefore, **Table 24** is developed to give sharp and direct picture with respect to:

- Implications of no action plan, which reflect the main impacts of Jordan's water scarcity.
- Current and Proposed Actions without Disi Project, which explain Jordan's efforts to relief the water problem.
- Cost Effectiveness to check the action against cost affordability now and near future.
- Satisfying Future Demand to check the action supplying water.
- Sufficiency to check the action for fulfilling the future water deficit.

Table 24: Implications of "No Action Alternative" and the current an proposed actions without Disi project

Implications of No Action Plan[1]	Current and Proposed Actions without Disi Project[2]	Cost Effectiveness[3]	Satisfying Future Demand[4]	Sufficiency[5]
▪ Increasing groundwater drawdown and deterioration of water quality due to overexploitation ▪ Low quality domestic water at water supply networks especially in terms of salinity level ▪ Low quality treated wastewater reaching the Jordan Valley due to low water quality consumed in domestic sector ▪ High deficit in fresh water for domestic water demand ▪ Unreliable rationing programmes of municipal water supplies in summer seasons ▪ Increasing the pumping rates or even continuing pumping at the present rates from affected basins (e.g. Azraq and Amman-Zarqa Basins) to meet the future domestic water demand will adversely affect the basins environmentally (e.g. Azraq oasis)	▪ Freezing irrigated land	✓	✓	×
	▪ Treated wastewater could be the potential source for the irrigation sector. Fast development to replace fresh surface and groundwater with treated wastewater for irrigation.	×	✓	✓
	▪ Institutional reform	✓	×	×
	▪ Further development of surface water to reach the yield	×	×	×
	▪ Management and further development of groundwater to reach the safe yield and financial measures aimed at controlling and gradually reducing groundwater withdrawals from overexploited with final objective of maintaining the safe yield of aquifers	✓	×	×
	▪ Brackish groundwater:			
	• Blended to be used for irrigation	✓	×	×
	• Desalinated to be used for irrigation	×	✓	×
	• Desalinated to be used for domestic	✓	✓	×
	▪ Seawater Desalination at Aqaba	×	✓	✓
	▪ Regional Water and promotion of regional cooperation through the Water Resources Working Groups	✓	✓	✓
	▪ Intersea Project (Red Sea - Dead Sea Water Conveyance Project)	×	✓	✓
	▪ Continuous review of the water tariffs for efficient use of water	✓	×	×
	▪ Ongoing rehabilitation program of the water supply systems to reduce losses through the networks and -reduce response time for repair of network leakages, pressure loss, and sewer blockage	✓	✓	×
	▪ Public awareness campaigns were conducted for enhancing water conservation	✓	×	×
	▪ In agriculture, Jordan is planning to produce high-income products to increase the productivity of the cubic meter of water and to pay the full cost of water with no subsidy.	✓	✓	×
	▪ Private sector participation in providing services for infrastructure development. Started with Amman Management Contract and continuation depends on the evaluation of the performance of the LEMA in Amman	✓	×	×

[1] Main implications if no Disi project
[2] Executed, ongoing, and proposed projects and actions if Disi Project is implemented or not
[3] Cost affordability now and near future
[4] Check for supply potential
[5] Check for satisfying future demand
× Short in satisfying the requirement
✓ Fulfill the requirement completely or for some extend

5.1 Introduction

Securing a reliable supply of water, adequate in quantity and quality, is one of the most challenging issues facing Jordan today. Given the lessons of the past and the prospects for the future, the full potential of Jordan's surface and groundwater resources must be developed based on economic feasibility and consideration of relevant social and environmental impacts. Planning and policy formulation for the supply and utilization of water resources must be based on comprehensive and reliable data, including data on water quantity, quality, and utilization. The supplies of surface water, groundwater, and treated wastewater, and their utilization must be carefully monitored. The importance of shared surface water supplies and ground water aquifers demands careful and consistent assessment and monitoring of these resources.

Jordan's renewable water resources that are economically developable are considered to be limited to approximately 505 MCM of surface waters and 275 abstraction of groundwater. In 2002, abstraction of groundwater resources (approximately 100 MCM/year) from the Disi aquifer system is planned through the proposed project. An additional 43 MCM/year of non-renewable groundwater resources partially are being obtained from other aquifer systems (e.g., Azraq and Jafer Basins). Other water sources include:

- **Reclaimed Wastewater** (approximately 75 MCM/year at present and increasing to more than 245 MCM/year by 2020).
- **Brackish Ground Water**. A study of brackish groundwater resources between the Dead Sea and Deir Alla in the Jordan Valley indicated that about 50 MCM/year may be economically developable using desalination technologies, but only for domestic and industrial purposes.
- **Seawater Desalination** technologies are being considered for future augmentation of Jordan's water resources. These technologies initially will be considered in the Aqaba area where Jordan has an outlet to the Red Sea.
- **UFW Reduction** is another potentially inexpensive resource that can be tapped. Efforts to reduce UFW have already begun in Amman, Irbid and the south through the rehabilitation of the existing networks.

According to the above discussion regarding Jordan's water problem and available water resources, the following key provisions are the most effective measures to secure the water needs:

- **Institutional Development**
  Reorganization of the water agencies comprising the Ministry of Water and Irrigation (MWI) is advocated. The MWI will continue as a governmental organization and will be responsible for policy formulation, decision-making, national water planning, water resources monitoring and studies, and integrating Water Information Systems (e.g., GIS, databases and national water data bank). The Water Authority of Jordan (WAJ) will begin separating its bulk water supply and retail delivery functions and move these functions and services toward private sector and commercial enterprises. WAJ will monitor retail supply contracts and will become more involved in the operational monitoring of several management contracts with private sector utilities and providers. The Jordan Valley Authority (JVA) will continue to be responsible for the integrated development of the Jordan Rift Valley (JRV). However, JVA's specific role will be refined as the development of the JRV is reassessed. It is anticipated that future JRV development will focus on tourism, industry, manufacturing, and advanced technologies.

- **Private Sector Participation**
  The Government of Jordan intends to transfer infrastructure and services from the public to the private sector in order to improve performance and efficiency in the water sector. The use of management contracts and other private sector participation in water utilities is envisioned. The principles of build/operate/transfer (BOT) and build/operate/own (BOO) are being considered for private sector participation.

- **Water Pricing and Cost Recovery**
  The MWI is committed to setting municipal water and wastewater tariffs at a level, which at a minimum will recover the costs of operation and maintenance. Recovery of capital costs also will become part of on-going pricing actions. The MWI will attempt to establish differential pricing for different qualities of water and end uses. Profitable markets (e.g., tourism, industry) will be expected to pay the full, fair water cost.

- **Water Resource Management**
  An integrated approach to water resources management will be adopted by the MWI. Supply enhancing measures will be adopted for surface waters (e.g., surface/subsurface storage, reducing evaporation/seepage losses, protection of water quality). Groundwater abstractions will be controlled and reduced to within the safe yield of the aquifers and enforcement will be strengthened. Wastewater will be collected, treated, managed, and used as a resource in an efficient and optimized manner. Treated wastewater will comply with national standards and will be treated to a level appropriate for agriculture and possibly for groundwater aquifer recharge. A wastewater master plan will be developed for unserved areas of the country. The potential technical and economical feasibility of developing brackish groundwater resources will continue to be assessed throughout Jordan.

- **Water Ouality and the Environment**
  A comprehensive water quality-monitoring program for all water resources will be maintained. Upgrading and strengthening both water quality standards and their enforcement will be pursued.

  Regulations are strictly adhered to with respect to quality of disposed wasewater into wadis. Quality of treated industrial waste is checked on regular basis by different Governmental and non-governmental authorities to ensure compliance with effluent standards before discharging into a wadi. In addition, minimum flow is maintained at the outlet of all conrtolling structures across wadis to maintain the ecosystem downstream of these structures.

- **Service Levels**
  Existing water distribution systems and services will be improved and expanded including their technical support and management. Old and damaged supply and distribution systems will be rehabilitated, and inadequacies (e.g., high pressures, underdesign of pipes) will be corrected. Specific service issues include:

  - Maintaining water quality in the distribution networks
  - Frequency of water supply delivery to customers
  - Response time for repair of network leakage, etc.
  - Reduction in waiting times for water and wastewater connections
  - Reduction in waiting times for resolution of customer complaints

- **Investment**
  Options for increasing the water supply are limited and development costs are expensive largely because all renewable supplies have been developed. New development will require substantial investments. Consequently, setting investment priorities has become extremely important in water resources planning. Investment criteria currently are being developed but will rely partially on private sector participation.

5.2 Analysis of Alternatives

This section provides a assessment of alternatives for providing additional reliable water supply to Amman through the development of new sources, demand management and other actions. It includes examination of the following approaches:

- No-action scenario.
- Development of surface and groundwater sources.
- Efficient management of water consumptions.
- Implementation schedule for alternatives and their implications.

The data was collected from studies prepared by the GOJ and World Bank. This was achieved through the meetings and interviews of the key persons in the MWI. In planning extraction from any new water resource, thought must be given to the best strategy for utilising the source to insure that optimum use is made in conjunction with the municipal demands required and other available resources.

At present, water demand exceeds supply in most areas of Jordan, so that over extraction of groundwater is very common. To alleviate some of this over extraction, rationing programmes of municipal water supplies have been applied in summer seasons since the mid 1980s.

The total renewable safe yield of the groundwater sources in the whole of Jordan is around 275 MCM per year as estimated by many studies. Extraction from renewable sources in 1998 as an example was 416 MCM of which 173 MCM was for municipal use. To compare with year 1994, the extraction was 445 MCM of which 162 MCM was for municipal use. The reduction in groundwater extraction was about 7%, while the increase in the municipal demand was about the same 7%. Even with this efficient management, WAJ has not been able to meet the substantially increasing demands and the resulting mining of these sources.

One of the best-known cases of this scenario is the Azraq Oasis, which has suffered adverse environmental impacts over the years. MWI management has recognised this problem and as a result the reduction in abstraction described above was undertaken. Over the years, there has been a general decrease of other over extracted sources. These reductions combined with the continuing increase in demand could be balanced out to an extent by:

- Al Wehdeh Dam on Yarmouk River and Peace Treaty Rights.
- Integrated Project of Wala, Mujib, and Tanour Dams.
- Disi Water.

Several scenarios were worked out by JVA and studies commissioned by JVA showed that the water leftover in the Yarmouk River at the Wehdeh Dam site after Syrian uses would not be enough to justify the construction of a dam of the height originally envisaged. Therefore, lower height and less capacity were considered for ongoing construction of the dam. On the other hand,

where Jordan's other neighbouring state of Israel is concerned, and as a result of the Jordan-Israel Peace Treaty, existing and potential storage schemes have been investigated as follows:

- Construction of a diversion weir on the Yarmouk River at Adassiya to increase flow through the tunnel into the King Abdullah Canal.
- Development of a storage system and flood pond for floods from the Jordan River and rising of the Wadi Arab Dam. The flood pond in the King Abdullah Canal is being tendered for construction.
- Diversion weir and convey system for Jordan River floods were designed to convey floodwater to Karama Dam.
- The Deir Alla-Amman supply is at present 40 MCM per year.

Three dams in the southern part of the Kingdom have already started storing floodwater from the wadis of Wala, Mujib and Hasa. Fedan Dam on Wadi Fedan has been tendered for construction. The municipal water use allocated from these integrated sources is about 15 MCM. The balance of the water will be for industry, tourism, and agriculture.

However, even with the potential of these new surface water resources, Jordan has no option but to choose the utilisation of all these sources and the others listed above, if reducing annual deficit is to be attained. Even with Disi water, MWI would have no choice but to find another new non-traditional source in the next 15 years, which could be desalination from the Gulf of Aqaba or inter-sea project (Red-Dead Sea System).

Close investigation of the reliability of the surface water throughout the year shows the importance of the Disi water. In Jordan, surface water supplies are highly seasonal, available for less than half the year, and require vast storage capacities to achieve a much smaller continuous supply throughout the year compared to Disi water.

5.3 "No-Project" Scenario

This section deals with "No Action Alternative" or "Do Nothing Scenario". The available information has been used to provide an analysis that would be useful for both technical and non-technical readers to understand the implications of not developing the Disi aquifer for use as a source of drinking and industrial water in the Greater Amman region. The presentation discusses these issues in a geographic manner passing from Amman to the Aqaba along the route of the proposed pipeline.

Figure 24 presents a schematic route for Disi-Mudawarra to Amman water conveyance system.

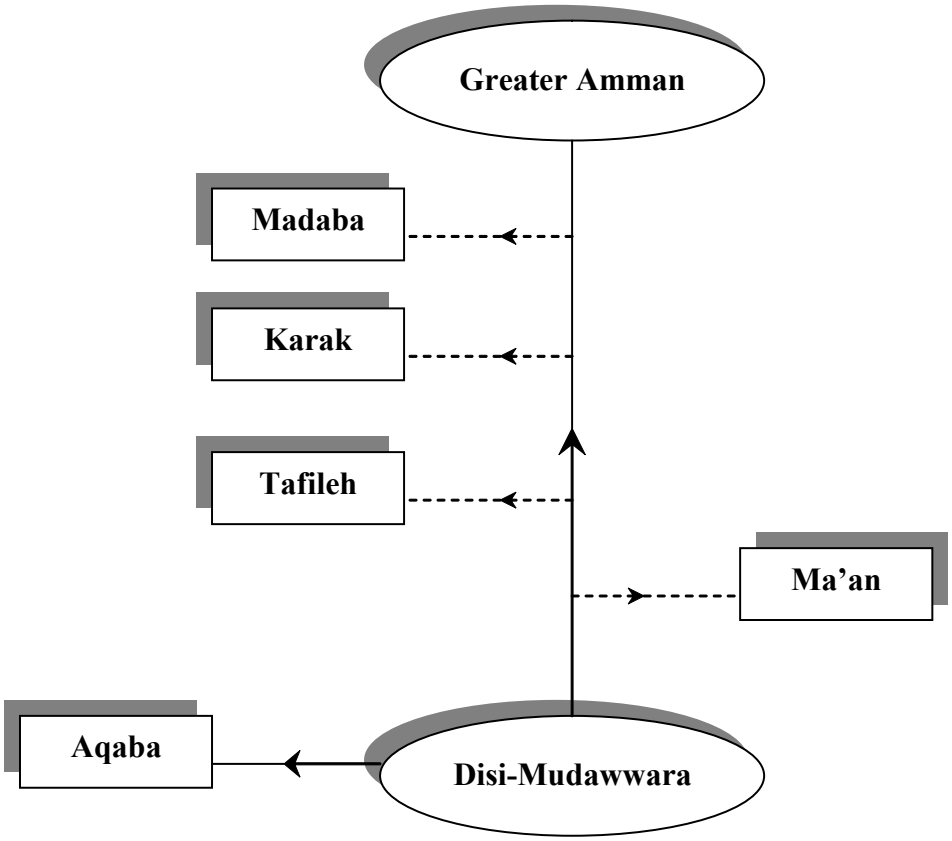


Figure 24: Schematic route of Disi-Amman Conveyance

The demand centres related to the proposed route are Disi-Mudawarra area, Aqaba, Ma'an, Tafileh, Karak, Madaba, and Amman. Abstractions to supply Aqaba and farms in the Disi and Mudawarra districts have increased from 6.9 MCM in the year 1982 to about 75 MCM in the year 1993 and continued in almost constant rate till now. The municipal water supply to Aqaba in the 1994 was 14 MCM per year of which 86 percent was from Disi. Present abstraction to Aqaba could reach 15 MCM per year. Jordan's abstraction cannot be compared with that of Saudi Arabia as only 5% of the total area of this transboundary basin is within Jordan.

In Saudi Arabia, abstraction centres are currently at Halatt Amar, Tabuk, and TADCO farm complex. The abstractions have expanded from 19 MCM in the year 1983 to 650 MCM in the year 1993 (according to the Final Conceptual Study Report, Harza Group, 1996). The abstraction could reach 977 MCM per year at present condition as outlined by Design Review and Optimisation Report (Brown and Root, 2001).

In order to sense the problem/scenario of not using Disi water, **Table 25** presents the domestic water supply by Governorate for the period between the years 1985 up to the year 2001. The growing demand of domestic water could be the most important issue of this impractical scenario.

Table 25: Domestic water supply by Governorate (MCM/Year)

Year	Governorate								
	Amman + Madaba	Zarqa	Mafraq	Irbid +Jerash +Ajlon	Balqa	Karak	Tafileh	Ma'an+ Aqaba	Total
1985	52.6	9.4		16.1	2.6	4.4		8.0	**93.0**
1986	59.4	11.9	14.0	23.2	8.2	3.9	1.7	12.4	**134.6**
1987	68.2	12.6	11.6	27.8	9.1	4.8	1.8	14.5	**150.5**
1988	74.6	14.7	13.4	30.0	10.3	5.0	2.0	14.7	**164.8**
1989	73.1	17.1	13.3	30.2	13.1	5.7	2.3	15.5	**170.2**
1990	75.2	21.8	15.1	30.1	12.5	5.9	2.2	15.9	**178.6**
1991	74.8	22.2	13.7	30.3	13.1	6.3	2.3	15.8	**178.6**
1992	98.3	22.7	14.2	31.5	15.5	7.0	2.4	16.5	**208.2**
1993	98.6	25.6	13.3	34.5	19.4	7.0	2.5	17.7	**218.5**
1994	93.7	27.7	13.6	35.3	20.4	7.2	2.2	19.8	**219.9**
1995	106.5	32.8	16.5	39.4	20.4	7.2	2.2	21.2	**246.1**
1996	102.5	31.6	17.1	39.3	19.2	8.5	2.0	22.1	**242.3**
1997	100.8	31.5	18.4	37.5	18.9	8.7	2.3	21.8	**239.9**
1998	97.0	32.4	19.2	39.0	19.1	9.3	2.3	23.2	**241.5**
1999	96.9	31.8	19.0	36.6	17.9	9.2	2.2	23.6	**237.4**
2000	96.9	31.8	18.5	37.5	16.2	9.2	2.4	22.7	**235.2**
2001	99.5	32.7	18.9	37.9	15.2	9.5	2.2	24.5	**240.5**

Source: WAJ Files

Figure 25 shows the domestic water supply to the demand centres outlined by **Table 25**. These demand centres are along the route of the proposed conveyance system as mentioned earlier. Aqaba water includes the supply for industries such as the Thermal Power Station and Fertilizer Company.

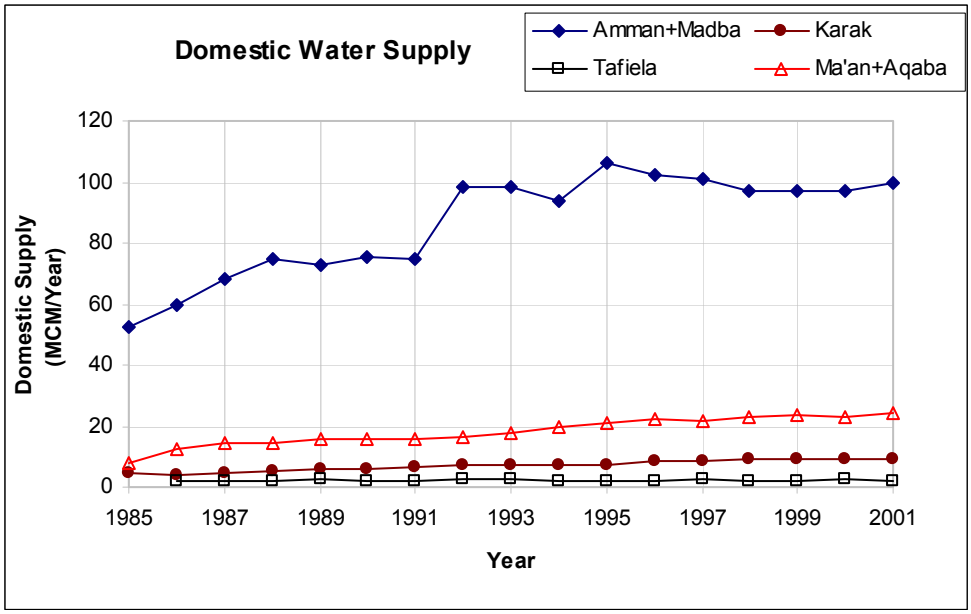


Figure 25: Domestic water supply to selected Governorates

Karak, Tafileh, and Ma'an have their own resources with good quality water that is reliable under normal conditions. **Table 26** shows the water resources for the three governorates with the production percentages out of the total in the year 2001.

Table 26: Water resources for Karak, Tafileh, and Ma'an with percent production (2001)

Karak		Tafileh		Ma'an	
Al-Sultani Wells	44.6%	Al-Harir Water Well	7.3%	Al-Tahoonah Wells	29.4%
Al-Ghwir Well (1)	1.2%	Jorph Al-Daraweesh	2.3%	Al-Qa'a Station	11.4%
Al-Ghwir Well (2)	3.7%	Aapoor 6 Well	1.8%	Al-Shobak Station	16.4%
Ain Sara Spring	9.2%	South Al-Tyanah	0.4%	Al-Mrighah Station	5.8%
Al-Shahabia Spring	1.3%	Al-Tanoor Station	0.6%	Al-Phajij Station	4.8%
Ain Al-Yarot Spring	0.1%	Al-Hasa Well	6.4%	Al-Jafir Wells 29	3.9%
North Al-Qatranih (1)	3.4%	Aapoor 7 Well	9.5%	Adroh 7	3.6%
North Al-Qatranih (2)	2.2%	Aapoor 8 Well	2.2%	Al-Manshiyya	0.5%
North Al-Qatranih (3)	3.5%	Zobdah Wells	66.2%	*Al-Mudawarra Wells**	*0.9%*
South Al-Qatranih (1)	4.6%	Al Hasa Project	3.3%	Al-Jotha Wells	9.3%
South Al-Qatranih (2)	2.5%			Tal Barma Wells/Irrigation	8.0%
Al-Wadi Al-Abyad Well 1	1.2%			Al-Arja Wells/Irrigation	5.7%
Al-Wadi Al-Abyad Well 1	2.0%			Aoohida Wells/Irrigation	0.3%
Al-Mazra'a Well (2)	2.5%				
Al-Mazra'a Well (3)	1.9%				
Phipha Well (2)	1.2%				
Al-Safi Well (14)	3.2%				
Al-Safi Well (4)	3.0%				
Amraq Well (2)	0.1%				
Mahi Wells	5.0%				
Shihan	3.7%				

Source: WAJ Files
* Imported Water

The only demand centre that needs increased access to the high quality Disi water is Amman. **Table 27** presents the water sources for Amman with the percentage production out of the total in the year 2001, which indicates that 64% of the resources are imported from outside Amman area.

Table 27: Water resources for Amman with percent production (2001)

Amman			
Ras Al-Ain Spring	1.7%	*Zay/Deir Alla**	*38.9%*
Al-Mohajirin Well	2.3%	*Al-Zarqa Gov./Kho**	*20.7%*
Wadi Al-Seer Spring	1.5%	*Balqa/Fuhis**	*0.4%*
Mahatit Al-Taj Wells	8.9%	*Al-Wanah Project**	*3.9%*
Yajooz Well No. 1	0.3%	*Total Imported*	*64.0%*
East Syaqa Wells	6.3%		
West Syaqa Wells	1.7%		
Al-Qatraneh Wells	3.3%		
Al-Msitbah Wells	0.7%		
Al-Qastal Wells	1.6%		
Yajooz Well No. 6	0.4%		
Ain Ghazal Wells	4.4%		
Wadi Saqrah Well	0.4%		
Arinbah Well	0.4%		
Wadi Al-Qitar Well	0.05%		
Al-Moyaqar Well	1.3%		
Al-Yadodih Well	0.5%		
Abdoon Well	0.3%		

Source: WAJ Files
* Imported Water

Renewable groundwater resources represent the main part of the current water supply to Amman as indicated by **Table 26**. Amman receives its water supply for domestic use mainly by mining the groundwater of the main adjacent groundwater basins specifically Amman-Zarqa Basin and Mujib Basin, and partly from the treated Yarmouk River Surface water at Zai water treatment plant. The main aquifer systems in these groundwater basins are highly overexploited whereas the Upper Aquifer Complex in the Sara Basin is over pumped by more than twice its safe yield capacity. Similar situation can be said for the Amman-Zarqa Basin.

During the last two decades the water table had dropped by tens of meters in the above mentioned two basins where the discharge of the natural water springs had been stopped, i.e. the two Azraq North and South springs, which were supplying the internationally recognized Azraq Oasis (wetland), also Ruseifa and Sukhna springs in the Amman-Zarqa Basin.

Additionally, many hand dug wells in the Azraq Basin were dried up completely. It is worth mentioning that the water quality in these two basins had been deteriorated by the continuous water table withdrawal. The water quality deterioration the Azraq basin was associated by the irrigation of the salty water in the Sabkha at the centre of the Azraq basin. Such salt-water intrusion is expected to increase by the further shallow aquifer over pumping for domestic and agricultural uses taking into consideration that the present groundwater abstraction exceeds the safe yield by 236%.

Consequently the salinity of some groundwater wells have been increased from few hundred milligrams per litre to more than few thousands of milligrams per litres, on the other hand the groundwater salinity in the Amman-Zarqa Basin has also increased from few hundreds of milligrams per litre in the early eighties to more than few thousands by milligrams per litre at the time being specially in the area of the industrial activities in Sara city.

Increasing the pumping rates or even continue pumping with the present rates from these two basins (Azraq and Amman-Zarqa Basins) to meet the future water demand in greater Amman will adversely affect the water resources in these two basins to a point where the two basins will be completely destructed and consequently rehabilitation and restoration process will be not reached for a very long period of time. This heavy price should be paid as the result of “do nothing” scenario.

The future reduction at different rates in the groundwater abstraction from these basins to the safe yields will improve the water quality and quantity. Such a situation cannot be reached unless other sources for Amman water supply are put in operation such as Disi water. As an example, three different affected wells in Azraq and Amman-Zarqa basins were investigated at different scenarios for each Basin:

1- Azraq Basin:

a. “Do Nothing or No Action” which assumes the abstraction of the year 2002 to be continued without changes.
b. “AWSA 0%” Scenario which assumes stopping abstraction from AWSA well field starting with the year 2008 “the expected year for Disi Project operation”.
c. “AWSA 50%” Scenario which assumes reducing abstraction from AWSA well field by 50% starting with the year 2008 “the expected year for Disi Project operation”.

2- Amman Basin:

a. "Do Nothing or No Action" Scenario which assumes the abstraction of the year 2002 to be continued with no changes.
b. "50%" Scenario which assumes reducing the abstraction from the whole Amman-Zarqa Basin by 50% on the year 2008 "the expected year for Disi Project operation".
c. "75%" Scenario which assumes reducing the abstraction from the whole Amman-Zarqa Basin by 75% on the year 2008 "the expected year for Disi Project operation".

The above scenarios are presented in **Table 28** and **Table 29** for Azraq basin and in **Table 30** for Amman-Zarqa basin.

Table 28: Water level and water quality conditions of Azraq Observation well AZ-10 at different scenarios

Scenario	Do Nothing		AWSA zero		AWSA 50%	
Year	WL[1]	EC[2]	WL	EC	WL	EC
1985	509.88	2942	509.88	2942	509.88	2942
1990	508.71	2942	508.71	2942	508.71	2942
1995	506.35	3149	506.35	3149	506.35	3149
2000	503.90	3285	503.90	3285	503.90	3285
2004	502.40	3420	502.40	3420	502.40	3420
2008	500.80	3450	500.80	3450	500.80	3450
2012	499.20	3490	499.23	3496	499.21	3496
2016	497.70	3560	497.79	3562	496.34	3562
2020	496.20	3577	496.46	3576	496.34	3577
2030	493.00	3579	493.72	3574	493.37	3576
2050	487.90	3583	489.84	3579	488.87	3579

[1] WL = Water level in meters above sea level
2 EC = Electrical conditions in μs/m

Table 29: Water level and water quality conditions of Azraq Observation well AZ-12 at different scenarios

Scenario	Do Nothing		AWSA zero		AWSA 50%	
Year	WL	EC	WL	EC	WL	EC
1985	508.77	618	508.77	618	508.77	618
1990	504.77	646	504.77	646	504.77	646
1995	502.02	702	502.02	702	502.02	702
2000	499.31	789	499.31	789	499.31	789
2004	497.20	798	497.20	798	497.20	798
2008	495.30	812	495.30	812	495.30	812
2012	493.70	823	502.69	810	498.23	803
2016	492.10	831	503.72	809	498.02	814
2020	490.70	838	504.35	807	497.68	842
2030	487.30	847	504.95	803	496.56	819
2050	481.60	858	504.93	796	494.16	812

Table 30: Water level and water quality conditions of Amman-Zarqa observation well (AD1300) at different technical scenarios

Scenario	Do Nothing		50%		75%	
Year	WL	EC	WL	EC	WL	EC
1985	531.59	932	531.59	932	531.59	932
1990	528.14	960	528.14	960	528.14	960
1995	525.50	1000	525.50	1000	525.50	1000
2000	523.83	1037	523.83	1037	523.83	1037
2004	522.68	1060	522.68	1060	522.68	1060
2008	521.85	1067	524.28	1062	523.08	1057
2012	521.13	1081	524.55	1078	522.86	1067
2016	520.48	1087	524.51	1074	522.52	1073
2020	519.86	1104	524.37	1088	522.16	1086
2030	518.53	1121	523.94	1103	521.29	1094
2050	516.35	1123	523.16	1108	519.84	1103

Another adverse result of the "Do Nothing" scenario is to continue to provide the future water supply to Amman from the present low quality groundwater resources which will affect indirectly the quality of produced municipal wastewater.

The present water salinity of the supplied water to Amman ranges between 700-900 mg/l. This salinity is still within the Jordanian drinking water standards by taking into consideration the maximum limit of the water salinity for conditions of unavailable water. Using high salinity water (above 500 mg/l) will affect the health on the long run. In addition it will cause deterioration to the water conveyance systems and house appliances.

At present, the quality of the wastewater flowing into As-Samara Wastewater Treatment Plant (SWWTP) is adversely affected by the high salinity of the municipal drinking water used in the Amman region. This inflowing wastewater is considered to be very heavy with a salinity of more than 1,800 mg/l which is further increased by the treatment process to more than 2,000 mg/l. This treated wastewater with its high salinity is blended with other flows in the King Talal Dam and released into the Jordan Valley for agricultural use south of Deir Alla. The treated discharges from the SWWTP provide extra water for agricultural uses; however, due to their high salinity they contribute to the degradation of water stored in the reservoir of the King Talal Dam.

5.4 "With Project" Scenario

Water resources in Jordan could be the scarcest resource in the world. Jordanians, whether public or government, are acting accordingly and using wisely each drop of water over the semi arid country. The water shortage has been continuously getting worse, which has forced Jordan to work hard in order to tap all potential water supplies. These supplies could be divided according to different categories, such as:

- According to demand quantities:
    - Small amounts of water to be consumed as:
        - Domestic water
        - Low consuming industries
    - Large amounts of water to be consumed as:
        - High consuming industries

- Irrigation water

Priority is being given to provision of water for small consumption uses due to the importance of these uses and high impact of shortages. Therefore, all projects are delegated to provide domestic water and low consuming industries. Priorities for allocation of water to low consuming industries were set according to the production value of each cubic meter of water.

- According to supply source:
    - Conventional water
        - Surface water
        - Groundwater
            - Renewable
            - Non-renewable
        - Demand management savings
        - Treated wastewater reuse
    - Non-conventional water
        - Marginal water
            - Fresh to Brackish
            - Grey water
        - Desalination water
            - Brackish groundwater desalination
            - Sea water desalination
    - Regional water
        - Inter-Sea project (Red-Dead project)
        - Import water from outside the region
    - Dry water as import of grains and other agriculture products

The conventional waters are the most developed sources in Jordan due to the low investment cost required for such development. This fact created an impact on the renewable groundwater, which leads to over exploitation of the source beyond its safe yield. Tapping shallow aquifers requires the lowest investment cost, which leads to salinity of the aquifer and high drawdown. The other source which is close to that is the surface water, which can be divided mainly into two parts:

- Internationally Shared water-Yarmouk and Jordan Rivers
- National Waters-Rivers, Streams and Wadis in Jordan

Shared water was developed further through treaties and negotiations with Syria and Israel, which lead to execution (or on the way) of the following projects:

- Adassiya Diversion Weir to increase the supply of water through the tunnel to the King Abdullah Canal (completed in 2001)
- Adassiya pond (ongoing project) to capture flood water from catchment in-between Wehdeh Dam and Adassiya

- Wehdeh Dam (ongoing project) to capture flood water from Yarmouk upper catchment

In order to maximize available water, the MWI views all surface water sources as potentially being subject to development in order to save and efficiently use every drop of water. All proposed projects to mobilize these resources are subject to detailed feasibility studies that include evaluation of their technical, economic, environmental and social aspects.

Demand management savings could be the cheapest source of water according to many studies (example GTZ 1997). The cubic meter of water could cost as low as 20 cents. Demand management needs low investment and eases the running cost. Therefore, Jordan considers this option with high priority and is undertaking a variety of actions to support demand management.

The social constrains make the reduction of the agricultural demand very sensitive to be handled at the political level. Jordan has no other alternative but to cut from fresh water and to replace it with treated wastewater. This option was implemented with high care due to its environmental impact issue. The treated wastewater has already proven to be suitable for a variety of uses in agriculture and will become a more important source of water in the future.

Jordan is working hard to develop these options, which cannot close the gap between the demand and supply but only reduce it. A schematic figure was prepared to give a clear picture of these options as shown in **Figure 26**. Accordingly, Jordan has already started to develop the non-conventional waters, such as using marginal water for irrigation and desalination water for domestic. The first large-scale desalination plant was awarded to a contractor on Design-Built-Operator basis. It will be constructed near the Dead Sea to desalinate collected brackish water from side wadis along the Dead Sea in order to supply Amman and the Dead Sea resorts with domestic water. **Table 31** presents the planned water development projects, which reflects Jordan enormous plans to bridge the gap.

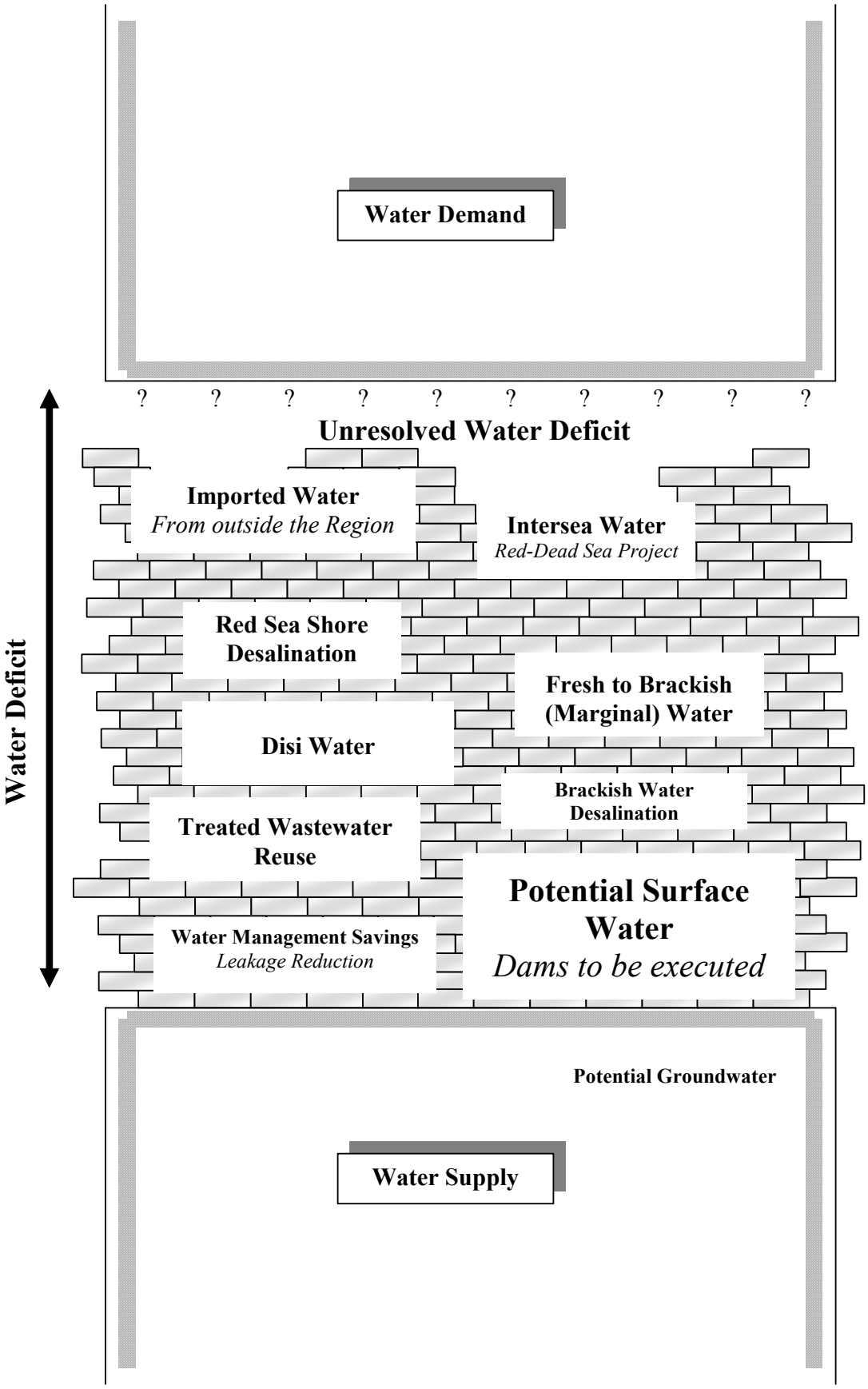


Figure 26: Jordan Water Gap and Bridging Options

Table 31: Planned water development projects and development amount (MCM/yr)

Resource Type	Main Project Name	[1]Existing Develop Amount	Short Term 2001 - 2005	Mid Term 2006 - 2010	Long Term 2011 - 2020	[2]Incremental Develop. Amount during 1998-2020	Total Develop. Amount by 2020 (1+2)	Estimated Cost (JD)/m^3	Remarks
Surface Water	Existing Development Amount	303	-	-	-	-	303		Already Executed
	Wehdeh Dam	-	93	-	-	93	93	145	Feasibility, design and tender documents Completed.
	Mujib Dam (including base flow) flow (develop.)	-	12	-	-	12	12	26	Ongoing
	Tanur Dam	-	8	-	-	8	8	23	Completed
	Wala Dam	-	5	-	-	5	5	13	Just completed
	Small Dams (Ibn Hammad, Karak, and Middien)	-	-	7	-	7	7	12	Finance is not secured
	Fidan Dam	-	3	-	-	3	3	8	Feasibility. and Tender Document Completed
	Water Harvesting	-		-	15	15	15		Field investigations completed
	Total	303	121	7	15	143	446	227	
Peace Water	Desalination Conveyor to Urban Jordan	33	27	-	-	27	60	-	-
	Storage on Jordan River and Sides Wadis	-	-	30	-	30	30	--	
	Total	33	27	30	-	57	90	100	Ongoing Financing is being sought
Renewable GW	Reduction of the Abstraction	420	-52	-31	-62	-145	275	-	-

Table 31: Planned water development projects and development amount (MCM/yr) (contd.)

Resource Type	Main Project Name	[1]Existing Develop Amount	Short Term 2001 - 2005	Mid Term 2006 - 2010	Long Term 2011 - 2020	[2]Incremental Develop. Amount during 1998-2020	Total Develop. Amount by 2020 (1+2)	Estimated Cost (JD)/ m^3	Remarks
Fossil Fresh Groundwater	Deep GW investigation			-	-	-	-	13	Finance is not secured
	Disi	70	-5[a]	27	38	60	130	420	BOT, Updated Feasibility. Designs and Tender.doc. completed
	Lajoun Wells	-	(11)*	-	-	(11)*	(11)*	13	Completed
	Total	70	-5	27	38	60	130	446	
Brackish Groundwater Desalination (including brackish spring)	W. Zarqa Ma'in/Zara Conveyance Project	-	20**	20**	-	40**	40	70	Feasibility. Completed and awarded as DBO
	El-Lajoun Desalination Project	-	-	13	23	36	36	-	Not yet
	Deir Alla (Abu Ez-Zighan) Desalination Plant	-		-	9	9	9	5	Ongoing
	Total	-	20	33	23	85	85	75	
Sea water Desalination	Aqaba Sea Water Desalination	-	5	-	12	17	17	14	A feasibility study is ongoing
Reuse of Treated Wastewater	As-Samra TP	46	21	-6[b]	22	37	83	105	BOT Feasibility, design and tend. Doc. Comp. Secured. Finance
	Wadi Zarqa TP	-	-	40	14	54	54	59	Feasibility. and design completed
	Existing 5 TPs	2	2	2	2	6	8	-	Feasibility. and design completed
	Aqaba wastewater project	16	25	29	31	85	101	25	Stage 1 comp. Stage II ongoing. Secured Finance
	Total	64	48	65	69	182	246	189	
Ground Total		890	164	131	104	399	1,289	1037	
Total Amount by Target Year		890	1,054	1,185	1,289	-	1,289	1037	

Source: Updated Investment Program 2002 to 2011 and JICA Management Plan 2001

Implementation of all of the options reviewed above will still result in a short fall in bridging the water supply gap in Jordan. **Table 32** extracted from GTZ study 1997 presents the water gap expected at year 2010 and 2040. The water demand could be more than 30% unsatisfied. Therefore, regional projects could be the only solution for Jordan's future need of domestic water. The proposed inter-sea project of the Red-Dead that would provide for hydropower generation and desalinization of water may prove to be more feasible than some of the other proposed projects from a technical, economic, environmental and social viewpoint. **Table 33** developed by GTZ 1997 study, estimates the unit cost for such options.

Table 32: Water-Demand,-Supply and Gap for the Base Scenario (MCM/yr)

Year	2010	2040
Domestic	488	1209
Industrial	129	170
Irrigation	1088	1088
Total demand	1705	2467
Supply	1083	1669
Deficit (%) of Demand	-622 (36.5%)	-798 (32.3%)

Table 33: Non-conventional options for Jordan to ease the water problem

Option	Sub-option	Quantity MCM/yr	Delivery Point	Unit Cost US $/m^3	Total Unit Cost to Amman
Seawater Desalination	Single RO Desalination Plant	50	Med Coast	0.68	0.97
	Red-Dead Intersea	850	Dead Coast	Not available	1.01
	Med-Dead Intersea	800	Dead Coast	0.42	0.72
Water Import by Sea	Used Tankers	200	Med Coast	0.83	1.12
	New Water Tankers	200	Med Coast	1.12	1.41
	Large Vinyl Bags	200	Med Coast	0.55	0.84
Water Import by Land	Pipeline from Turkey	150	Lower Jordan River	1.44	-
			Amman	1.65	1.65
		200	Lower Jordan River	1.36	-
			Amman	1.54	1.54
	Pipeline from Iraq	150	Lower Jordan River	0.94	-
			Amman	1.13	1.13
	Pipeline from Lebanon	150	Lower Jordan River	0.15	-
			Amman	0.68	0.68

The above discussion indicates that Disi water is part of the groundwater option, which can be divided into two main parts:

- Renewable-all aquifers except Disi and Jafer
- Non-Renewable-Disi and Jafer

Renewable groundwater resources represent the main part of the current water supplies in Jordan. The capital Amman receives its water supply for different purposes but solely for domestic uses mainly from:

- Groundwater basins adjacent to Amman specifically Amman-Zarqa Basin, Azraq, and Mujib Basins.
- Treated surface water from Yarmouk River at Zai Water Treatment Plant.

The main aquifer systems in these groundwater basins are highly overexploited whereas the Upper Aquifer Complex in the Azraq Basin is over pumped by more than twice its safe yield capacity. Similar situation can be said for the Amman-Zarqa Basin. During the last two decades the water table had been dropped by tens of meters in these basins whereas discharge of natural water springs had been stopped. For example:

- The two Azraq North and South springs, which were supplying the internationally recognized Azraq Oasis (wetland).
- Ruseifa and Sukhna springs in the Amman-Zarqa Basin.

Additionally, many hand-dug wells in the Azraq Basin were dried up completely. It is worth mentioning that the water quality in these two basins had been deteriorated by the continuous decline of the water table. The water quality deterioration at Azraq Basin was associated by the irrigation of the salty water in the Sabkha at the centre of the Azraq basin. The present groundwater abstraction exceeds the safe yield by more than 230%.

Consequently the salinity of some groundwater wells has been increased from few hundred milligrams per litre to more than few thousands of milligrams per litre. The groundwater salinity in the Amman-Zarqa Basin has also increased from few hundreds of milligrams per litre in the early eighties to more than few thousands by milligrams per litre at the time being specially in the area of the industrial activities in Sara city.

Increasing the pumping rates or even continued pumping with the present rates from these two basins (Azraq and Amman-Zarqa Basins) to meet the future water demand in greater Amman will adversely affect the water resources in these two basins to a point where the two basins will be completely destroyed and consequently rehabilitation and restoration will not be achieved for a very long time.

The future reduction of the rates of groundwater abstraction from these basins will result in sustainable yields and booth increase the quantity and improve the quality of these groundwater resources over the long term. Such a situation cannot be reached unless other sources for Amman water supply are put in operation. The present water salinity of the supplied water is ranging between 700-900 mg/l. This salinity is still within the Jordanian drinking water standards by taking into consideration the upper limit of the water salinity in the standards which is 1,500 mg/l, which is the expected case of future quality of the supplied water if no other resources of water are used to supply Amman. The continued use of the present sources of groundwater for Amman will also negatively affect the quality of the municipal wastewater prior to and after treatment due to its high salinity.

In order to supply Amman with necessary water supplies, the MWI has drilled deep wells in the Lajoun area to tap a portion of the Disi aquifer. The water quality from these drilled wells is not similar to that in the Disi area which is further south in Jordan. The salinity of the water from these wells is about double the value of wells in the Dubaydib area and the presence of iron and

manganese in the water requires that it be treated by aeration prior to use for water supply. In addition, the quantity of the discharge from these wells is lower than those in southern Jordan.

In the case of water supplies being provided to Amman from the Rum Aquifer (Dubaydib well field), which has a salinity of less than 300 mg/l, the wastewater will be significantly less saline which will allow for a better quality effluent from the SWWTP. In addition, if alternative treatment technologies were adopted at the SWWTP such as the use of mechanical treatment, a better quality treatment could be obtained than from the currently used natural stabilization ponds. When combined these changes would allow for the collected flood and treated wastewater in the King Talal reservoir to be acceptable for use on most crops in the Jordan Valley.

The proposed project has been given the highest priority by the MWI for construction because it will provide water of excellent quality to Amman at a time when there is great need to reduce overdraft of water from rechargeable aquifers on the plateau. Besides, the Disi pipeline will be an important link in the development of a national pipeline network. Should the Red-Dead or an alternative water transfer project be developed in the future, the Disi pipeline would be critical for the transfer of water back to the south. This would be done to conserve the Disi reservoir for emergencies or to supply water to the south if the Disi reservoir by then has been fully exploited.

5.5 Review of Additional Alternative Actions

The following alternatives have been considered by the Government of Jordan in order to address management of the current and future water gap. Many of them are under full or partial implementation while others are the subject of on-going or proposed feasibility studies.

The options discussed in the following sections will not satisfy the future water gap but will to some extent ease the water problem.

5.5.1 Development of Groundwater Resources

The groundwater basins in Jordan comprise more than one aquifer system. As indicated in **Table 10**, eleven basins of the twelve-groundwater basins include three aquifer systems, which are the Upper, Intermediate and Deep aquifer systems. Only the Mudawarra- Southern Desert groundwater basin comprises a single unified aquifer system. The renewable aquifer systems in most basins are mainly in combination with the other Mesozoic sandstone rocks the Deep aquifer system in the other eleven groundwater basins. The renewable aquifer systems in most basins are mainly the Upper aquifer system and partly the Intermediate aquifer system, which is in some localities, is interconnected with the Upper one or exposed in the Eastern Highlands. The safe yield of the groundwater basins is represented in **Table 11**.

The present abstraction from the different aquifers exceeds the safe yield of the groundwater basin corresponds and value 175% of it. Due to the over exploitation in these aquifers, the water quality has deteriorated in addition to the noticeable drawdown in the water table in some basins. This applies to Azraq and Amman-Zarqa Basins, which supply Amman with water for the different uses. These two basins are highly overexploited. This has led to salt water intrusion and accordingly to deterioration of the water quality.

On the other hand, the Intermediate and Deep aquifers in the Azraq Basin are both of poor quality and cannot be used directly for domestic, industrial and agricultural purposes. This is due to the confined nature of these two aquifers, where the drawdown of the piezometirc heads of these

aquifers below the water level in the Upper aquifer lead to vertical leakage from the upper to the lower aquifers resulting in indirect overexploitation of the Upper aquifer. A similar situation is expected to occur in Amman-Zarqa Basin if the Deep or Intermediate aquifers are abstracted to supply Amman with water.

The development of the Deep aquifers in the other adjacent groundwater basins is associated with water quality since the salinity of the water ranges between 3,500 mg/l and 14,000 mg/l. Due to this utilization pattern, the water from this aquifer requires a desalinisation process which will result in problems with the disposal of brine generated from this treatment process. In addition, vertical leakage from the Upper and Intermediate aquifers will occur especially when the water level (piezometirc head) of the Deep aquifer becomes lower than that of the overlying aquifers.

Due to these conditions, the development of the Deep aquifers and partial development of the Intermediate aquifers in the Azraq, Amman-Zarqa as well as other adjacent groundwater basins will not be able to provide an effective alternative solution to the development of Disi for provision of high quality water to greater Amman.

5.5.2 Water Demand Management

Currently in Jordan 75% of the total available water supplies is used for irrigation and about 30% of this percentage is used for agriculture in the uplands. The irrigation water used in upland areas is drawn from groundwater resources that are under extreme pressure. This contributes to declines in groundwater levels as well as water quality deterioration from overexploitation and from return flows from irrigation. The use of the upland aquifer for agricultural purposes is contributing significantly to the reduction of the renewable groundwater reserve which limits the available water for municipal and industrial supply. Taking into consideration three basins of the upland aquifers which are the Yarmouk, Amman-Zarqa and Azraq Basins, it is found that the safe yield of these basins is 151 MCM/year, the amount of water utilized for irrigation is 124 MCM/year and the amount abstracted water for domestic and industrial purposes is 126 MCM/year.

From these figures, it is clearly indicated that these basins are overexploited by 165% of the safe yield. Due to this, it is recommended not to expand the groundwater utilization in irrigation in order to save the groundwater for municipal uses. In addition, it is highly recommended to reduce the area of irrigated lands, limit the volume of abstracted water for use in agriculture as recommended by the MWI. Beside this, it is recommended to change the crop patterns, introduce crops of low water consumption, and change the irrigation practices to save as much as possible the overexploitation of the groundwater aquifers in the upland.

Generally, conservation of water in the municipal uses will be very limited since Jordanians are very conservative in water consumption in their homes and they are adopting water conservation devices which are suggested the Ministry of Water and Irrigation. Public awareness has been discussed earlier for all sectors and NGO’s are contributing to these efforts.

Other activities which are carried out by the Ministry of Water and Irrigation to reduce the adverse effects of groundwater over drafting and quality deterioration are the replacement of the old water supply networks with new ones, the determination of the illegal connection and the new water tariff water (higher prices for higher consumption).

5.5.3 Wastewater Reuse (Municipal and Industrial)

As-Samra is the largest natural stabilization wastewater treatment plant in the Amman-Zarqa Basin. As-Samra WWTP treats the wastewater produced in Amman, Ruseifa and Zarqa cities where more than 60% of Jordan's population live. The reuse of the treated wastewater is not a common practice in the Amman-Zarqa Basin. Most of As-Samra effluent flows naturally and is stored in the reservoir of King Talal Dam. After that, it is diluted by floodwater collected in the reservoir and then used for irrigation in the Jordan Valley. The effluent of the SWWTP is not of an adequate high quality to be used directly for agricultural purposes. But if the effluent were of good quality, it will be reused for agricultural purposes. In this case, it will help in reducing the water level decline of the Upper aquifer in the Amman-Zarqa Basin where more than 60 MCM/year are exploited for irrigating farm lands in the basin.

5.5.4 Taping the Disi Aquifer in the Areas not Far from Amman

In order to bridge the gap in the water supply to Amman, the Ministry of Water and Irrigation drilled many deep wells in Lajoun area (near Karak), and in Hisban and Zarqa River (Jordan Valley). The salinity in the Lajoun area is almost double the salinity in Dubaydib area, in addition the water contains high content of iron, manganese and hydrogen sulfide, while in Hisban and Zarqa River the salinity of the Deep aquifer was 10-20 fold higher than that of Dubaydib area. Due to this, the water of Lajoun area is to be aerated before usage while in Hisban and Zarqa River the water needs desalination before usage which will result in a need to properly dispose of brine wastes form this process. Generally, the water quality of the Disi (Rum) aquifer varies from south towards north where the water salinity increases along the flow paths from south toward north – northwest.

5.5.5 Brackish Water Desalination

Brackish water normally occurs in most of the Intermediate and Deep aquifer systems of all groundwater basins except the Mudawarra-Southern Desert basin. Adjacent to Amman, the groundwater basins, which contain brackish water, are Dead Sea, Zarqa, Azraq and the Jordan Valley. The well-studied brackish groundwater is located in the Jordan Valley in the aquifer corresponding to the Disi aquifer in association with Triassic and Jurassic Rocks. The salinization of the groundwater in this area is attributed to the lithological characteristics of the Triassic rocks that contain evaporite rocks. The brackish water is mainly located in Hisban, Kafrein and Zarqa River at Abu Zeighan area.

JICA (1995) indicated the possibility of desalinating about 70 MCM/year from the Jordan Valley. The most serious problem associated with the abstraction and desalination of 70 MCM/year beside the brine disposal is the drop in the piezometric head of the Deep aquifer below the water level of the Upper and Intermediate aquifers. This will cause vertical leakage and water loss from the Upper and Intermediate fresh water aquifers to the Deep aquifer. Similar problems will occur if brackish water of the Intermediate aquifers is exploited in Azraq and the Deep aquifer in Amman-Zarqa Basin. Due to these problems, this alternative will not be an efficient long-term solution to Amman water supply.

5.5.6 Seawater Desalination

Jordan's only access to the Red Sea is located at a distance of 380 km southeast of Amman. The present cost of seawater desalinization is still very expensive due to investment and operational costs and is not currently affordable by Jordanians at a large scale. In addition to the desalination cost, the produced water needs to be conveyed to Amman from sea level to more than 800 m above sea level. This project is not feasible at present but will be an acceptable project if associated with other projects such as the Red-Dead Sea Canal where desalination is going to be carried out at the Dead Sea shores and the brine discharged to the Dead Sea in order to maintain the Dead Sea water level.

5.5.7 Red-Dead Sea Canal

The Red-Dead Sea project is a very large project that cannot be executed unless there is cooperation with Israel and Palestine and financial support of international agencies. The development of such a project will provide Jordan with a significant amount of desalinized seawater, maintain the Dead Sea level and stop the environmental problems associated with the drop of Dead Sea level. Such a project is a long-term solution of the water supply problem in Jordan but requires preparation of a detailed feasibility study and environmental assessment, a long construction period and a regional cooperation.

5.5.8 Water Imports

Many regional projects were suggested during the last two decades to export water from water rich countries such as Turkey, Lebanon and Iraq. The most prominent suggested project is to import water from Turkey from the Syhan and Ceyhan Rivers to the Middle East countries and the Gulf States through the Peace Pipeline. The political situation in the region has prevented the execution of this project. The other proposed project is to import water from Iraq through a pipeline from Euphrates. Also due to political and water scarcity in Euphrates, this project has not proven practical to pursue beyond feasibility studies.

5.6 Delayed Implementation of the Disi Project

This scenario was carried out by Jordan actually for some time now. The Disi water was exploited partially in 1982 for agricultural activities with minimum investment regarding water resource transfer. Saudi Arabia started at the seventies to use Disi water for grain production. Therefore, Disi water for domestic use has been really delayed now for more than 20 years. This delay in implementation has had the following impacts in Jordan:

- domestic water quality in Amman, which had adverse effect on health and water system.
- reuse of low quality treated wastewater, which damaged soil in Middle Jordan Valley.
- deterioration of the quantity and quality of water in upland aquifers due to over exploitation to close the water gap.
- rationing due to water availability problem, which increased the investment in water storage tanks and usage problems due to timing.

It should be noted that the proposed project has been delayed for a number of years, especially since the mid-1990s when the current design began to be developed. This is the result of the need to both carry out detailed feasibility studies and an environmental and social assessment, mobilize international and domestic funding and to seek the participation of the private sector.

6 SPECIFIC AND CUMULATIVE IMPACTS

This section addresses the direct and indirect water sector impacts and influences from implementation of the proposed project. The provision of reliable high quality water to Greater Amman will have a significant positive impact on the economy of the region, improve the public health of the water users and contribute to better environmental conditions. These improvements in water quantity and quality will in turn improve the quantity and quality of wastewater water flows to the Jordan Valley following their treatment at the SWWTP and contribute to increased agricultural production in the Jordan Valley. This source will be of high quality and of high reliable quantity.

The above implications will continue like a chain reaction on the treated wastewater consumed in the Jordan Valley. The treated wastewater will be of better quality and of reliable quantity again due to the characteristics of the Disi source. A side product for such consumption is a relief of the other currently overexploited sources such as the highland and Azraq aquifers. The reduction in abstraction will enhance the opportunity to rehabilitate and restore these aquifers. The Azraq aquifer and associated wetland is a good example of such process. These benefits were discussed in detail through **Section 5.4**.

Before addressing the detailed specific and cumulative impacts of the Disi project on the water sector, an overview about the project stakeholders is presented below.

6.1 Project Stakeholders

In Jordan, the policy for water allocation considers the following water stakeholders: domestic, industrial, touristic, and agricultural sectors. The water allocation priority goes first to the domestic sector, followed by the industrial and touristic sectors and last to the agricultural sector. **Table 34** presents the priority of Disi water consumption according to stakeholder shares and importance. The shares and importance were developed mainly according to the following:

- Local availability of water;
- Present accessibility to Disi water;
- Water use; and
- Legal issues.

In terms of the Disi water, the stakeholders are the users of this water which include:

- Amman city which will utilise the Disi water for domestic needs and for which the allocation of the Disi water will help in relieving the upland aquifers used to supply Amman with required domestic water;
- Locals at Disi area who use the Disi water for their various activities including domestic uses and livestock raising;
- Aqaba city which utilizes at present the Disi water for its domestic needs;
- The Disi farms which utilize the Disi water for irrigation. However, those farms will be closed once their permits are expired; and
- The cities along the Disi conveyor route will be provided with emergency turn outs. But at present those cities have no need for the Disi water since they already have their own water resources that are of good quality.

Table 34: Priority of stakeholders with respect to Disi water consumption

Stakeholder	Total Priority Rate (Sum)	Priority Conditions				
		Present Consumption of Disi Water	Availability of Other Sources	Water Needs		
				Near Future (Up to 2010)	Future (Up to 2020)	Far Future (Up to 2040)
Amman City	********	-	**[2]	**	**	**
Locals at Disi area	****	*	-	*	*	*
Aqaba City	***	*	-	*	*	-[3]
Disi Farms	***	*	-	**	-[4]	-[4]
Cities along the Conveyor Route [1]	*	-	-	-	-	*[5]

[1] Cities along the pipeline: Madaba, Karak, Tafileh, Ma'an and Aqaba.
[2] Almost all domestic water is imported from outside Amman.
[3] Other sources will be available (e.g. intersea project)
[4] Contract Expiry
[5] Local sources will not fulfil the growing demand.

6.2 Specific Impacts

Figure 27 presents a summary of the expected positive impacts due to the Disi water conveyance project.

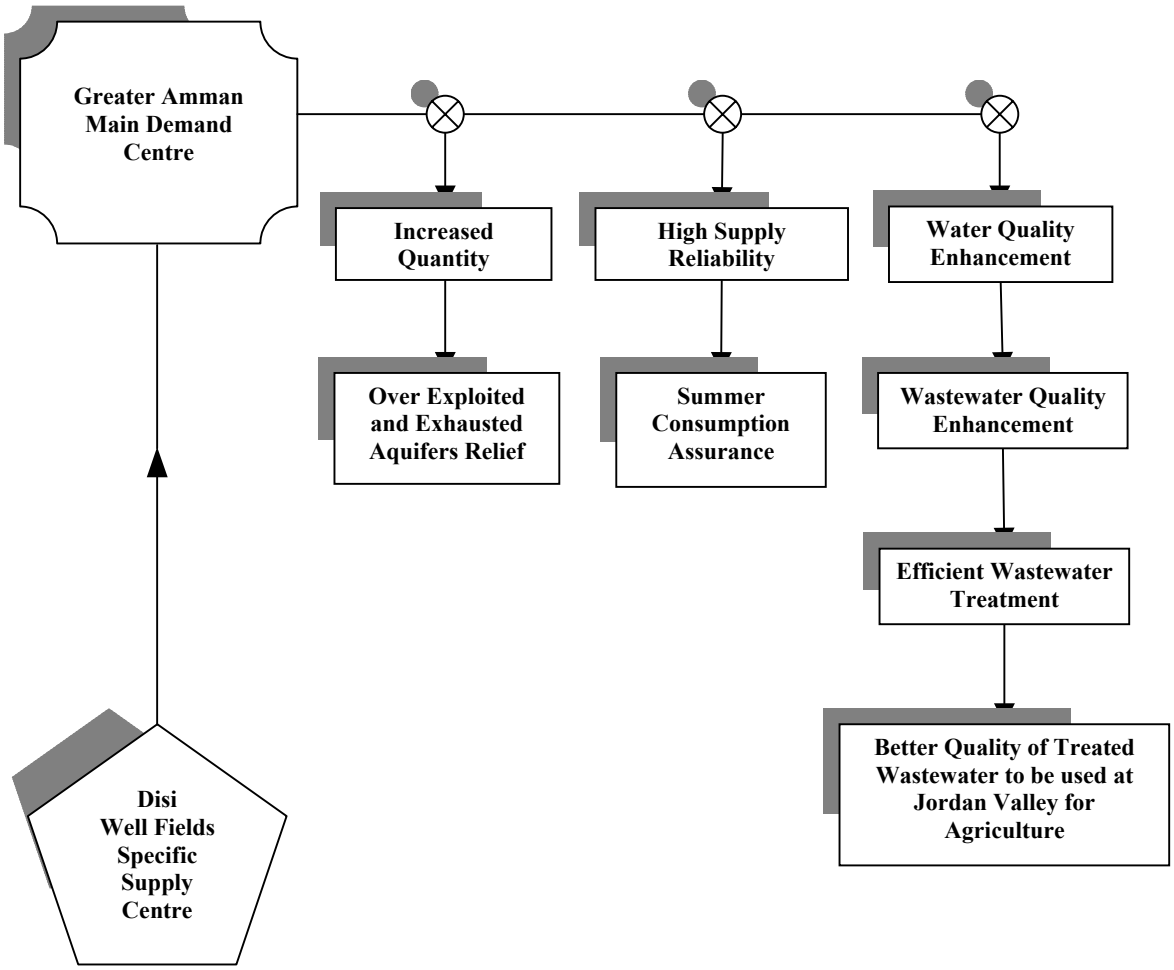


Figure 27: Illustration of the reason for conveying Disi Water to Amman

A summary of the potential impacts of the Disi-Mudawarra Water System on the Water Sector in Jordan is presented in **Table 35**.

Table 35: Potential impacts of the Disi-Mudawarra Water System on the Water Sector in Jordan

	Direct	Indirect	Cumulative
Physical	▪ Supply additional domestic water to the Greater Amman Area and increase the share of per capita for domestic demand ▪ Relieve the over exploited aquifers and elevate the water table level in the relieved aquifers	▪ Reduce the damage in quality of groundwater in the relieved aquifers where the high water table will lower the hydraulic gradient between the fresh water and the lower quality	▪ Improve the quality of water in the relieved aquifers
Biodiversity	▪ The reduction in the abstraction will increase the baseflow of streams which in turn would enhance the biodiversity at wetlands associated to the streams	▪ The reduction in the abstraction will enhance the renewable process of the Azraq aquifer and associated wetland as an example which in turn would enhance the biodiversity at Azraq Oasis	▪ Enhance the wetlands condition in many areas of Jordan
Agricultural	▪ Reduce the salinity at irrigated lands due to reduction in salinity accumulated in soil column ▪ Enhance soil characteristic for more profitable condition for better growing crops	▪ The treated wastewater will be of better quality and of reliable quantity again due to the characteristics of the Disi source and the treated wastewater in KTDR will be acceptable for irrigation purposes for most crops planted in the Jordan Valley	▪ Improve the cropping condition at southern Ghour
Social	▪ A reliable quantity and a better quality of water will have positive implications on health aspects of the society	▪ Increase in the reliability of the system will decrease the losses and enhance the water consumption share for poor households	▪ Improve the health condition of consumers due to reliable and good quality water consumed

The Water Sector Environmental and Social Assessment identified the following potential impacts associated with the proposed project:

- It would withdraw fossil water from the Disi aquifer and convey it to Greater Amman for domestic water supply and industry
- The Disi water would provide Greater Amman with access to a reliable high quality source of water that improve public health and overall environmental conditions
- The use of Disi water will improve the quality of wastewater conveyed to the SWWTP and later to the King Talal Dam Reservoir which will in turn allow for an enhanced treated effluent for agricultural use in the Jordan Valley
- The use of Disi water would provide an opportunity to relieve the overexploitation of upland aquifers and provide an opportunity for their rehabilitation and restoration
- Important hydrological benefits would occur to the Azraq aquifer and its associated wetland of international significance that have been very adversely impacted by excessive withdrawal of groundwater

- Although the Disi project would provide significant amounts of water to Greater Amman, it would not close the gap in water demand and will need to be complemented with actions to both mobilize additional water resources and to address demand management especially non-traditional sources.

6.2.1 Impact of Withdrawing Groundwater from Disi Aquifer

The maximum design discharge from the well fields is 150 MCM/year. This volume will be pumped from wells penetrating the Rum aquifer in its unconfined part only or in its unconfined and confined part. The estimated average well discharge is 70 l/s. In order to reach to the necessary volume of 150 MCM/year, 68 wells should be operated on a 24 hours basis. In order to properly operate and maintain the well field, an additional 10 percent of the wells will be drilled. Thus, the final number of drilled wells should be at least 75 wells.

This number of wells will be located either in one well field area or in two well fields. It was suggested by Harza to drill two well fields; the first in Dubaydib area (Dubaydib well field) and the second in Batn El-Ghoul area (Batn El-Ghoul well field). The first well field is located in the unconfined aquifer area of Rum aquifer and the second is located in the confined aquifer area of Rum aquifer where the Khreim Group is the confining layer. This planning was changed by Brown & Root during optimisation of the design and Dubaydib well field has been proposed only to be used. The MWI has already drilled three monitoring wells in that field.

Most of the studies carried out on the Disi Mudawarra groundwater resources restricted the well field location to Dubaydib area in the unconfined aquifer. The detailed study was the Scott Wilson (1995), where two abstraction scenarios concentrating on the Dubaydib well field were studied. These scenarios are as follows:

- **Scenario 1:** abstraction of 120 MCM/year from Dubaydib well field in addition to the current abstraction of 75 MCM/year rising to 87 MCM/year (for Aqaba domestic and industrial purposes, local supply and agricultural activities) and 977 MCM/year in Tabuk in Saudi Arabia. This scenario was carried out for 50- and 100- year development periods.

- **Scenario 2:** additional abstraction of 150 MCM/year from Dubaydib well field beside the other existing abstractions in Disi-Mudawarra area as well as in Saudi Arabia in Tabuk. This scenario was also carried out for 50- and 100- year development periods.

The estimated drawdown results due to the first scenario for the 50-year and 10-year abstraction periods are 24 m and 81 m, respectively. The maximum drawdown due to 100-year abstraction period is corresponding to 190 m below ground level. This level is still above the feasible economic water depth, which is 250 m below ground level. On the other hand, the estimated drawdown resulting from the second scenario for the 50-year and 100-year abstraction periods are 140 m below ground level and 210 m below ground level, respectively. The latter pumping level is still higher but closer to the economic pumping level.

In the above two scenarios, where 120 MCM/year or 150 MCM/year are to be abstracted from Dubaydib well field, the drawdown in the water level will not exceed the economic level taking into consideration the continuous present abstraction from the Rum aquifer for agricultural, domestic and industrial purposes. But, if the abstraction for agricultural purposes is terminated after the set period of operation according to the original contracts, the estimated drawdown in the Dubaydib well field will be less than the estimated levels. As indicated by the tested boreholes

drilled through the Rum aquifer, the whole water column is almost of the same quality from top to bottom. In this case the water quality during the whole period of abstraction will not be changed dramatically and the variations will not exceed couple of hundreds of µS/cm. This means that the electrical conductivity will not exceed 500 – 550 µS/cm. The maximum allowable limit is 850 µS/cm as outlined by the Jordanian Standards of year 2001. Regarding other chemicals, the water contains relatively small amounts of Fe and Mn (less than 1 mg/l). Such concentrations need no treatment whereas pumping into a collection reservoir will be enough to oxidize them and produce a good water quality.

When using the two well fields in Dubaydib and Batn El-Ghoul to produce the required water quality, the drawdown in the water level will be less giving more feasible operating costs. In addition, the higher yields of the wells in the confined aquifer in Bath El-Ghoul can act to shorten the collectors lengths and maintenance costs. But due to the lateral lithological variations in the Rum aquifer, the water in Batn El-Ghoul contains higher Fe and Mn concentrations (more than 5 mg/l), which needs treatment to be removed since pumping into a reservoir is not sufficient to remove these quantities, as pointed out with Dubaydib well field.

Such a problem can be bridged if mixing in appropriate portions between Dubaydib well field water with Batn El-Ghoul well field water is carried in order to reach a value within the Jordanian Drinking Water Standards. The Standards of year 2001 indicate maximum allowable content of Fe and Mn by 1 and 0.2 mg/l, respectively.

The other most important problem, which might occur due to abstraction from Batn El-Ghoul well field, is the expected water quality deterioration due to the downward leakage from the Khreim Group (containing highly saline water) as development proceeds. To prevent such a process from occurring, a limited volume of water is to be abstracted from this well field keeping the water level of Rum aquifer higher than the confining layer of the Khreim Group. This decision is based on a study carried out by El-Naser and Gedeon (1996) and published in the publications of *International Atomic Energy Agency*. In this study, the authors showed the expected water quality changes of the Rum Aquifer due to different mixing ratios with the Khreim Aquitard water.

It is suggested that Dubaydib well field be operated to produce the needed water amount where good water quality can be pumped during the whole period. But, if Batn El-Ghoul well field is going to be operated, good management should be carried out to preserve a good quality of the water to be conveyed to Amman.

The problem associated with the pumpage from the confined aquifer in Batn El-Ghoul is the vertical leakage of poor quality water from the Khreim Group to Disi Aquifer whereas in this case the pumped water will be changed dramatically according to the percentage of mixed Khreim-Disi water ratio as well as the salinity of the leaked water which is normally of wide range. A selected example (Haiste and Scott Wilson, 1995**)** showing the effect of the induced leakage of poor quality of Khreim Group on the Rum aquifer is presented in **Table 36** taking into consideration different mixing ratios (ranging between 1-10% of Khreim water). The detailed analysis is presented in **Annex C13**.

Table 36: Initial and mixing results between Khreim Group Water with Disi water (Haiste and Scott Wilson, 1995)

Parameter	Initial Results		Mixing Scenarios			
	BH5 Well	BH5A Well	BH5	BH5	BH5	BH5
	Rum Aquifer	Khreim Aquifer	1%	2%	5%	10%
Date	*7/3/94*	*7/3/94*				
pH	7.42	7.73	7.42	7.42	7.44	7.47
T ^{o}C	42	35	41.8	41.7	41.2	40.3
Ca mg/L	34.10	443.69	38	42.4	54.4	75.2
Mg mg/L	7.29	602.94	13.2	19	37	66.5
Na mg/L	27.14	1909	46.2	65.1	122	217.1
K mg/L	1.56	38.71	2	2.3	3.5	5.3
Cl mg/L	48.92	3200	80.9	112.5	208	365.7
SO_4 mg/L	40.32	2893.44	70.6	99.9	188.2	335.2
HCO_3 mg/L	84.21	296.56	86.6	88.5	95.2	105.5
TDS mg/L	234.4	9380.1	336.1	427.7	704.2	1164

Table 36 addressed the water quality changes due to mixing with the poor water quality of Khreim Group. It indicates that the mixing from both Khreim and Disi will result in poor quality water and, in case of higher mixing ratios, more deterioration of Disi water quality will occur.

Due to this, it is highly recommended to have only one well field in Dubaydib area where better quality water will be produced during the operation period.

6.2.2 Impacts on Aqaba

The main water source of Aqaba is the groundwater abstraction from Disi area (Rum aquifer) and Wadi Yutum (Alluvial aquifer). The annual quantities of water that supplied Aqaba during the period 1995-2001 are shown in **Table 37**.

Table 37: Aqaba annual quantities of water supply

Year	Annual Quantity (m^3)
1995	16,787,338
1996	15,338,871
1997	15,077,000
1998	15,033,101
1999	16,488,600
2000	15,161,430
2001	14,950,095

The water supply pipeline extending from Disi area to Aqaba has a capacity of 17.5 MCM/year. The Aqaba water supply pipeline is operating for the time being in its full capacity. The pumped water to Aqaba is of excellent quality with an EC-value of less than 350 µS/cm. This water quality corresponds to the Dubaydib unconfined aquifer.

It is clearly indicated that the amount of water abstracted from Qa Disi for Aqaba use is limited to the carrying capacity of the transition line (17.5 MCM/year), which is consistent with WAJ policy. Most of the abstracted water is used by the municipal and industrial sectors. The second major source of fresh water supplying the Aqaba region is the Wadi Yutum Aquifer east of Aqaba city, which supply approximately 2 MCM annually.

Another groundwater source is the Southern Wadi Araba aquifer, which in Aqaba is mostly used for the Palm Irrigation Project. This aquifer is estimated to provide a safe yield of 5.5 MCM/year. The water of this aquifer is almost utilized for irrigation purposes and partly for domestic purposes of local settlements. It is worth mentioning that the water of Wadi Yutum is now being used for irrigation, where an irrigation system was recently installed and connected to the Wadi Yutum pipeline in the northern part of Aqaba and the water is used to irrigate public areas including green belts and traffic medians along the main road into town.

6.2.3 Treated Wastewater Reuse for Irrigation in Aqaba

The Aqaba Wastewater Treatment Plant is a natural stabilisation pond to treat typical domestic wastewater. This treatment plant was constructed in 1987 with a design capacity of 9,000 m^3/day. The general status of the plant indicates that it is hydraulically overloaded according to the year 2001 where the hydraulic inflow to the plant was 9,300 m^3/day. This can be solved through expression of the existing plant or the construction of a new plant.

The effluent of Aqaba stabilisation ponds contains a high amount of total suspended solids (about 400 mg/l), which consequently reflects the high BOD5-values of the effluent (about 100 mg/l). As mentioned in Montgomery Watson et al. (2000) report on the environmental assessment of Aqaba, the treated wastewater coming out of the treatment plant is disposed of by evaporation (20% of inflow), percolation to the groundwater and/or for reuse in the area of the Gulf of palm trees and other ornamental plants (80% of inflow). Reuse is currently covering 1,900 dunum. The existing reuse is limited to gardening and palm irrigation by governmental organisations. The treated wastewater effluent is used to irrigate the following areas: the Date Palm Forest Project, the Hag Farm, the Peace Garden, Green Belt and Air Port Forestation and Wind Breaks around the treatment plant. In addition, there are many schemes for treated wastewater reuse in the Gulf of Aqaba as well as future areas to be irrigated with the treated wastewater effluent such as: trees along streets and roads east of the plant, Arab Date Palm, and Royal Garden. The additional areas represent 6,300 dunum. It is clearly indicated that there is a potential of utilising the produced treated wastewater in irrigation in Aqaba Region. Therefore, treated wastewater could be reused for irrigation and the sum of 7.5 MCM per year at Wadi Yutum and Wadi Araba aquifers will be used merely for domestic purposes to overcome the future growing demand.

6.2.4 Improved Water Quality for Users in Amman

Amman domestic water is abstracted mainly from over exploited aquifers, which are suffering from low quality water. The salinity, as an example, is high and above maximum allowable limit set by Jordanian Standards for the year 2001. **Figure 28** presents the average salinity of Amman domestic water. Jordanian standards allow up to 500 ppm salinity as maximum limit and could be exceeded up to 1,500 ppm in very dry conditions.

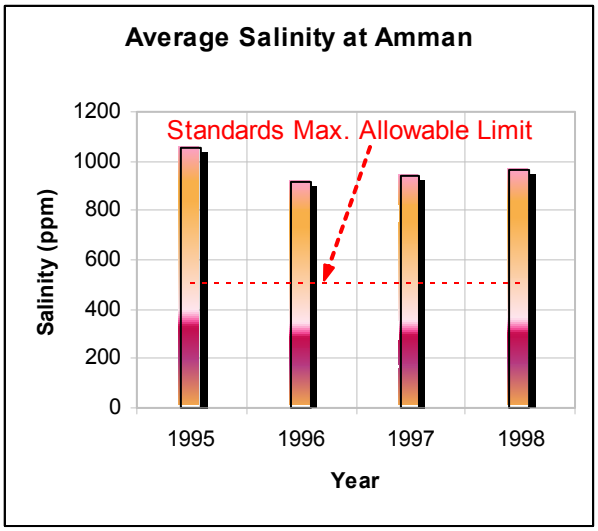


Figure 28: Average quality of Amman domestic water

The high salinity can be detected visually at household appliances, which are continuously suffering from scaling problems. This salinity is also associated with health problems. Disi water will dilute the chemicals in Amman system to much lower concentrations and this will enhance the water quality to levels close to the set standards. This problem is not detected at other governorates such as the governorates along the Disi pipeline route. **Figure 29** shows Tafileh average domestic water quality against Amman domestic water quality.

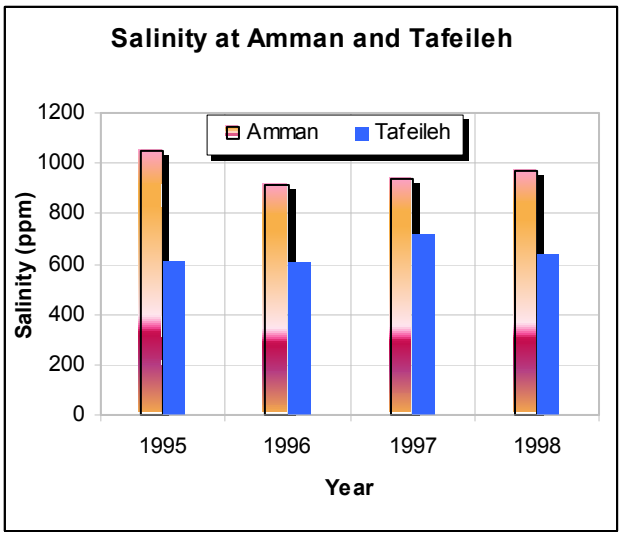


Figure 29: Tafileh domestic water quality against Amman domestic water quality

6.2.5 Equitable Access of Central and Southern Areas

As discussed in other places of this report, the following is a list of the governorates that can benefit from the Disi pipeline as an extra source of domestic water:

- Madaba
- Karak
- Tafileh
- Ma'an

The above governorates are supplied with domestic water out of groundwater resources within their perimeter. These sources are exploited to a volume within their safe yield. The produced water can cover their present needs and the future requirements. **Table 38** presents the water budget for the above governorates along with that of Amman domestic water.

Table 38: Water budget of Disi pipeline route governorates against Amman domestic water in MCM per year

Year	Madaba			Karak			Tafileh		
	Import	Export	Net Supply	Import	Export	Net Supply	Import	Export	Net Supply
1995	-	-	-	0	0	7.45	0.80	0	2.24
1996	6.89	5.34	12.89	0	0	8.48	0.76	0	2.04
1997	5.95	5.86	11.98	0.18	0	8.73	0.66	0	2.30
1998	5.77	5.91	11.74	0.22	0	9.33	0.52	0	2.35
1999	3.82	5.77	8.75	0.23	0	9.17	0.56	0	2.21
2000	0.61	5.58	5.58	0.22	0	9.21	0.58	0	2.41
2001	0.59	4.36	5.94	0.27	0	9.46	0.49	0	2.62

Year	Ma'an			Amman		
	Import	Export	Net Supply	Import	Export	Net Supply
1995	-	-	-	52.31	1.07	106.37
1996	0	0.76	6.76	58.28	7.79	89.62
1997	0	0.66	6.71	57.60	6.62	88.78
1998	0	0.52	6.87	53.73	6.48	85.21
1999	0	0.56	7.16	55.94	4.60	88.18
2000	0	0.58	7.55	58.58	0.91	91.34
2001	0	0.49	7.73	24.78	5.22	93.60

The above table indicates that Karak, Ma'an, and Tafileh fulfil their own water requirements with very limited import. Tafileh imports water from Ma'an and the imported amount decreased from 0.76 MCM in 1996 to 0.49 MCM in 2001. Karak imports a very small amount and Madaba exports amounts more than the imported volumes after year 1999.

Therefore, these governorates need no domestic water from Disi pipeline and could be that they require some in the far future. This reason leads to designing the Disi pipeline with turnouts for the above governorates, which could be used in emergencies to fulfil certain conditions without laying pressure on their resources.

6.3 Cumulative Impacts

In order to define the problems of groundwater withdrawal and deterioration in upland aquifers, namely Azraq and Amman-Zarqa basins, the groundwater flow and solute transport models of the two basins were simulated taking into consideration the positive cumulative impacts from the operation of Disi-Mudawarra conveyance system.

In order to show the cumulative impacts of Disi-Mudawarra project on the groundwater resources of Amman-Zarqa Basin, the present abstraction will continue till the expected year at which Disi water will reach Amman and then 25% and 50% reduction of the abstracted amount up to the year 2050. Reducing the abstracted amount by 25% showed that the water level will rise by 15 meters and the water quality (EC) will be reduced by 45%. The second part of this simulation is to reduce

the abstraction rate by 50%. The water level in this case will rise by 25 m and the water quality (EC) will be reduced by 62%.

As for Azraq Basin, the model simulated the same above reduction of its present abstraction rate from the AWSA wells. The results of the two options mentioned above show that the water level will be recovered by 8 meters while the EC-values will stay the same as in the present.

6.3.1 Reduced Pressure on Upland Aquifers and Azraq Oasis

The highland aquifer systems correspond to the upper aquifer systems of the rock formations of Upper Cretaceous Tertiary and Quaternary, which form the upper and intermediate aquifer systems in the eastern highlands and in the Desert plateau basins. These are utilized to supply Greater Amman with domestic and industrial water.

Generally, the Greater Amman gets the necessary domestic and industrial water from many sources. These are mainly repeated below:

- The Upper Aquifer (Basalt and Rijam Aquifer Complex) in the Azraq Groundwater Basin.
- The Upper and intermediate Aquifer Systems (Amman Wadi Sir (B2/A7), Hummar (A4) and Fuhais (A1/2) of Amman-Zarqa Basin.
- The Upper Aquifer System (Amman - Wadi Sir (B2/A7) of Mujib or Dead Sea Basin.
- Surface water (King Abdalla Canal) through Zai Treatment plant.

Special emphasis will be given to actions for the highland aquifer systems what are the most highly over exploited groundwater basins of Amman-Zarqa and Azraq.

The Amman-Zarqa Basin represents the lower part of the Zarqa Basin that incorporates with the Zarqa River drainage in Amman-Zarqa area. The total area corresponding to this basin is 850 km^2. The long-term average safe yield of the Zarqa River Basin is 87.5 MCM/year. This value is distributed to Amman-Zarqa Basin, the Upper Zarqa Basin and Dhuleil-Hallabat area. The abstracted volume of water from the whole Basin is 137 MCM/year, distributed to 68 MCM/year for domestic purposes, about 6 MCM/year for industrial and 63 MCM/year for agricultural purposes. This means that the groundwater resources are overexploited by more than 155% of the safe yield.

The lithology of Wadi Sir Formation is mainly carbonate rocks, which are mainly composed of massive limestone and dolomitic limestones, while the lithology of Amman Formation is mainly chert and limestone intercalated with each other. The alluvium deposits are restricted to the wadi courses and mainly composed of limestone and chert fragments. The Hummar Formation is mainly composed of limestone, dolomite and dolomitic limestone. Fractures produced from tectonic activities are the main responsible factor for the secondary porosity and permeability of the upper aquifer and intermediate aquifer. The latter is partially affected by karstification. The high permeable zones occurring in both upper and intermediate aquifers are responsible for the high well discharge in certain localities and also help to transmit pollutants from the ground surface to groundwater bodies. Generally, the groundwater flows from west-south west towards east-northeast are almost parallel to the Zarqa River passing through Amman City.

The area extending from Amman through Ruseifa to Zarqa is the most highly populated area in Jordan where more than 60% of Jordan's inhabitants live. In addition, most of the industries are concentrated within the Amman-Zarqa Basin and the largest semi-sanitary landfill in Jordan is

also located in the southern part of the basin near Ruseifa. Human activities associated with groundwater exploitation were considered to be the main responsible factors for the groundwater withdrawal and deterioration.

The simulated results of the groundwater flow and solute transport model of the Amman-Zarqa Basin are represented in **Figure 30** and **Figure 31**.

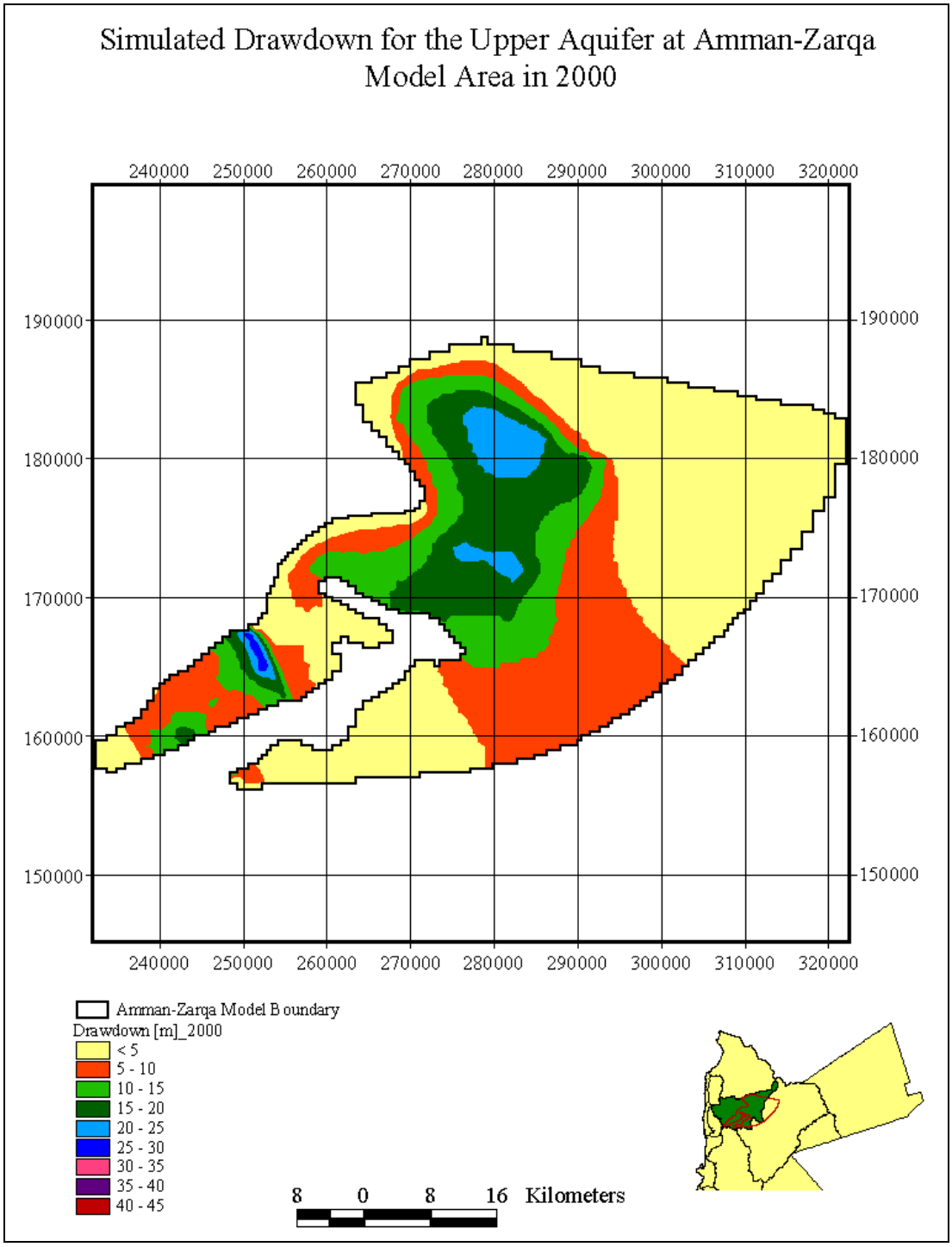


Figure 30: Simulated drawdown for the Upper Aquifer at Amman-Zarqa Model Area in 2000

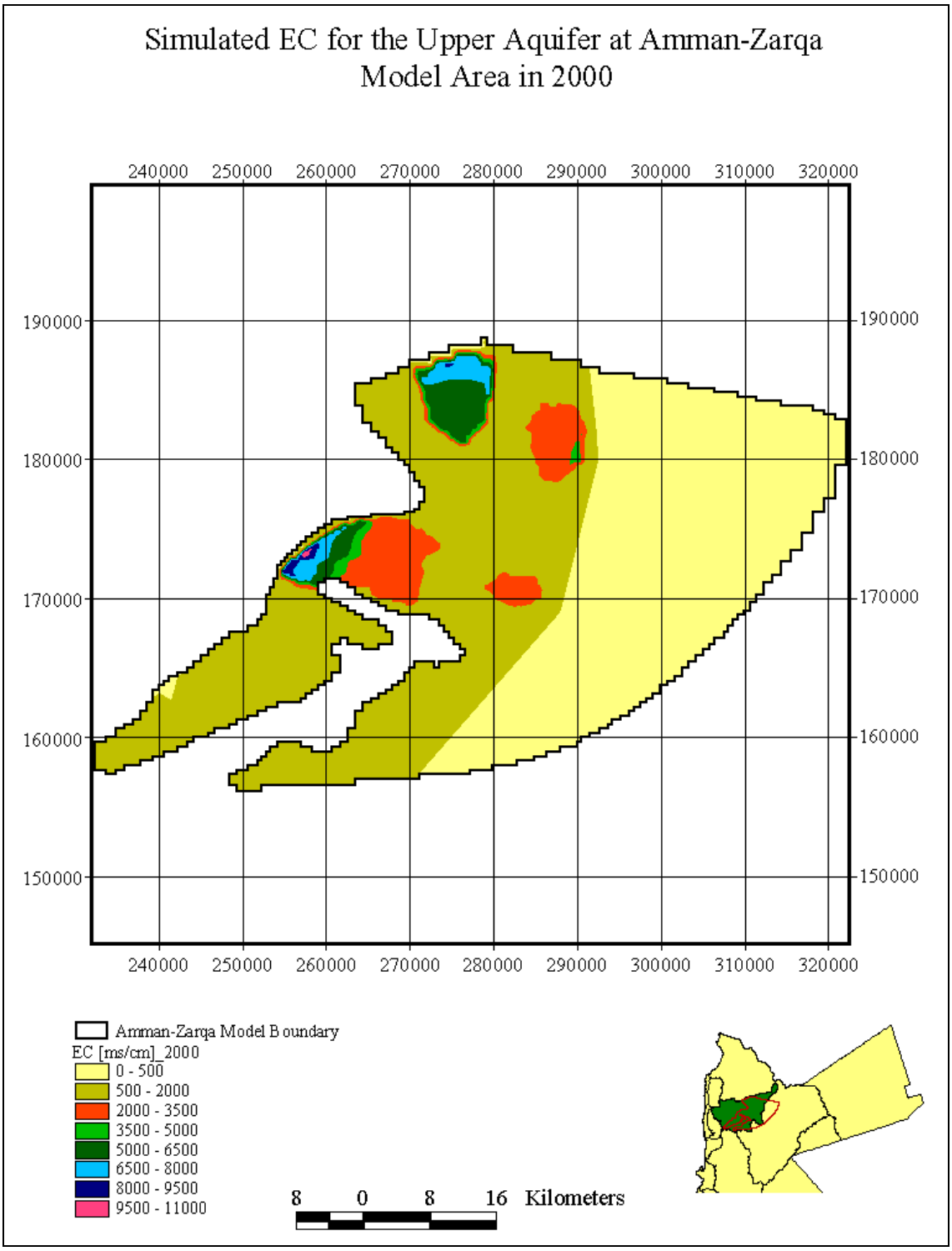


Figure 31: Simulated EC for the Upper Aquifer at Amman-Zarqa Model Area in 2000

In order to stimulate the positive impact of Disi-Mudawarra project on the groundwater resources of Amman-Zarqa basin, two main scenarios were carried out as discussed earlier. These are:

- **Scenario 1**: In this scenario the groundwater abstraction remains constant as in 2000 up to 2050.

  Simulated water table contour maps for the periods 2000, 2020, 2030 and 2050 are shown in **Figure 32**, **Figure 33**, **Figure 34** and **Figure 35**, respectively. The water level

withdrawal will exceed 45 meters and the electrical conductivity of the groundwater will reach 10,000 µS/cm by the year 2050.

- **Scenario 2**: In this scenario, the groundwater abstraction of the year 2000 will be continued up to the proposed date of operation of Disi project which is year 2008 and then reduced by 25% and 50% by the year 2050.

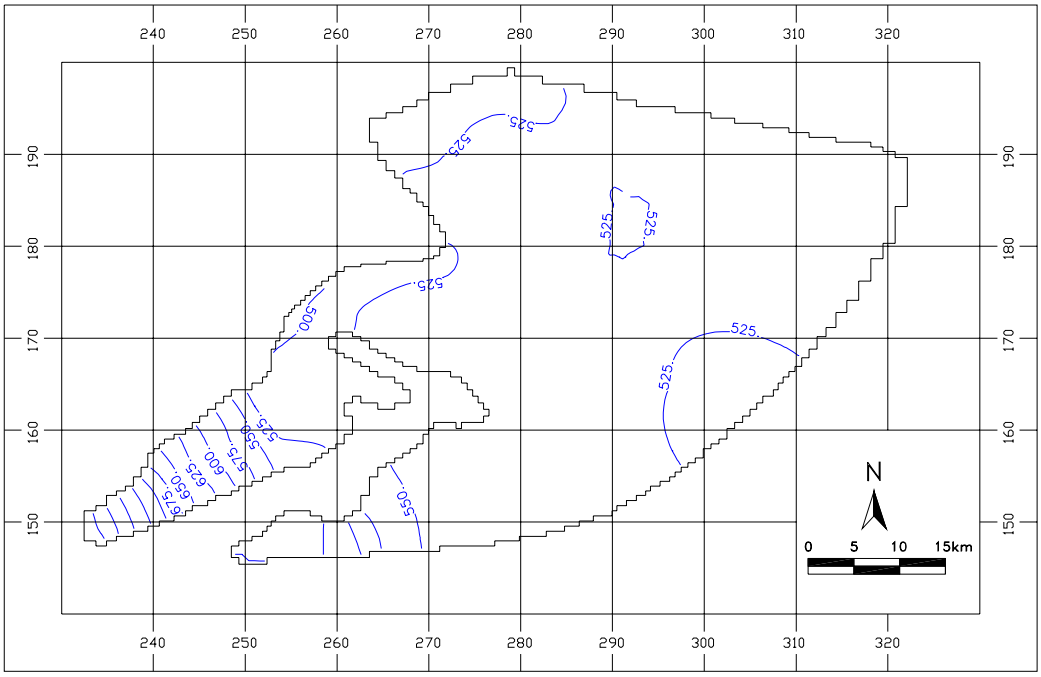


Figure 32: Present water level contour map at year 2000 for Amman-Zarqa

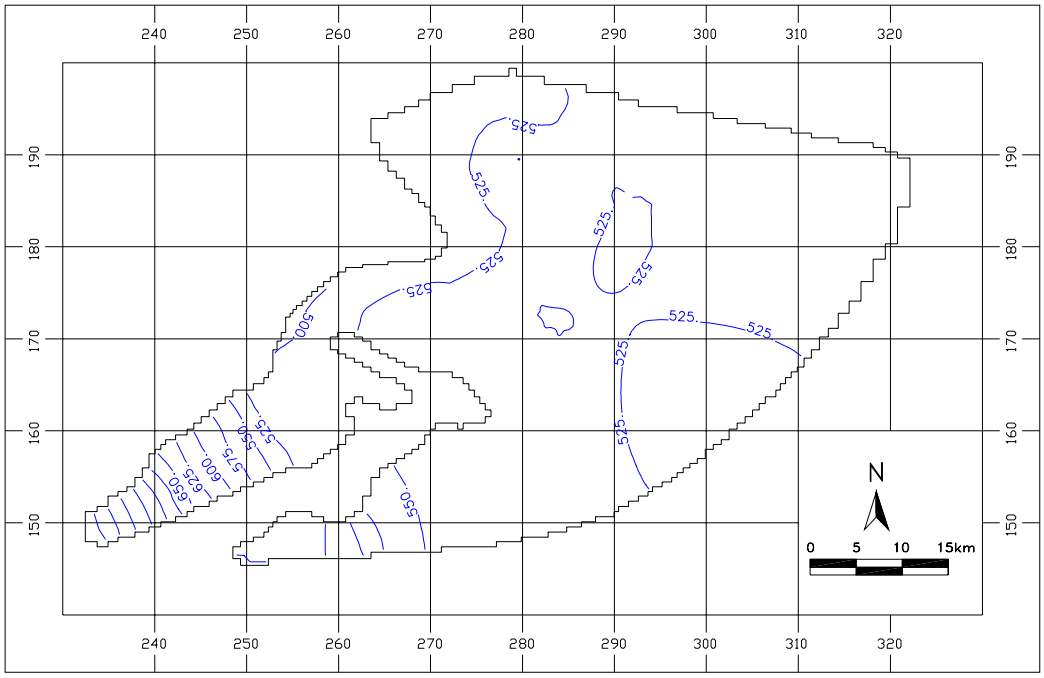


Figure 33: Predictive water level contour map at year 2020 for Amman-Zarqa

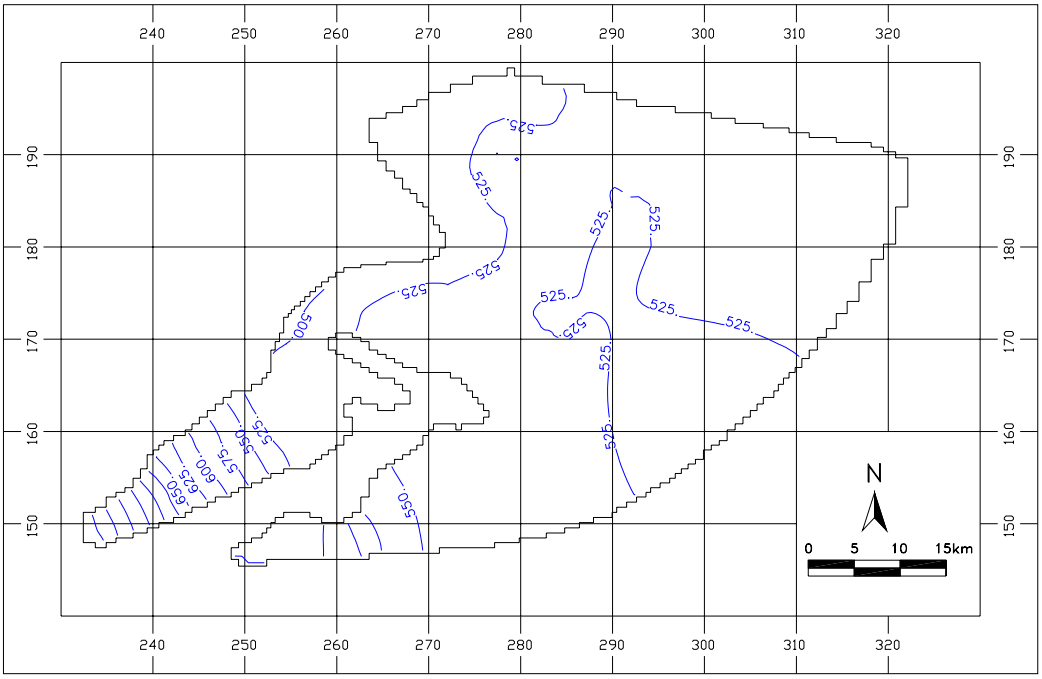


Figure 34: Water level contour map at year 2030 for Amman-Zarqa

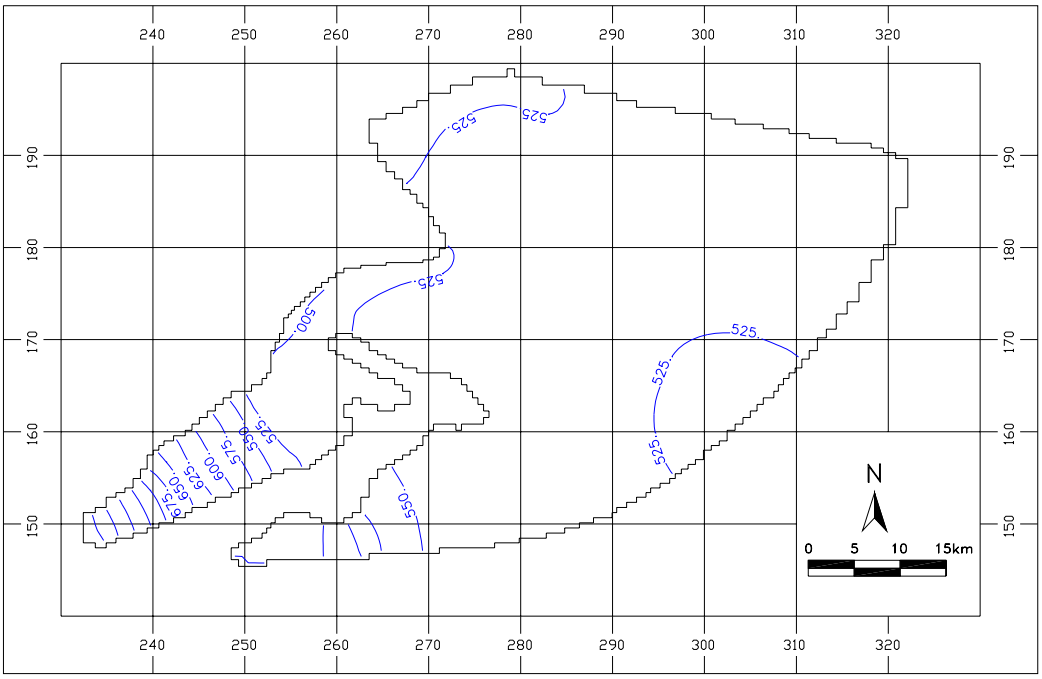


Figure 35: Water level contour map at year 2050 for Amman-Zarqa

The groundwater level results of the simulated reduction of the abstraction by 25% are shown in **Figure 36**, **Figure 37**, and **Figure 38** for the years 2008, 2020 and 2050, respectively.

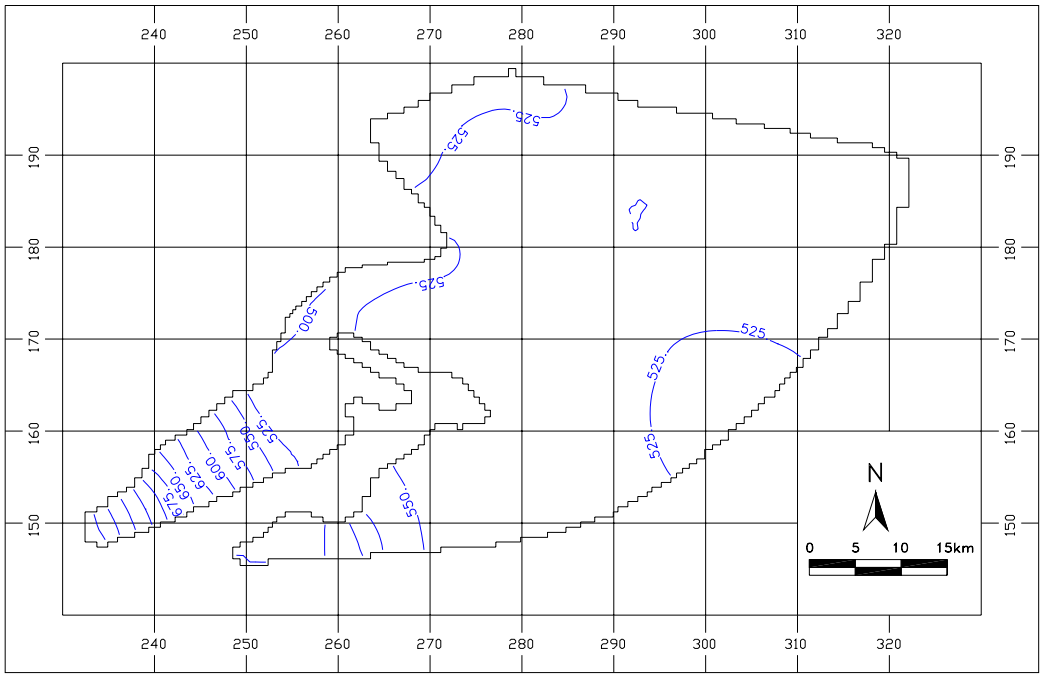


Figure 36: Water level contour map at year 2008 for Amman-Zarqa (Abstraction is assumed to be 75% of the year 2000 quantity)

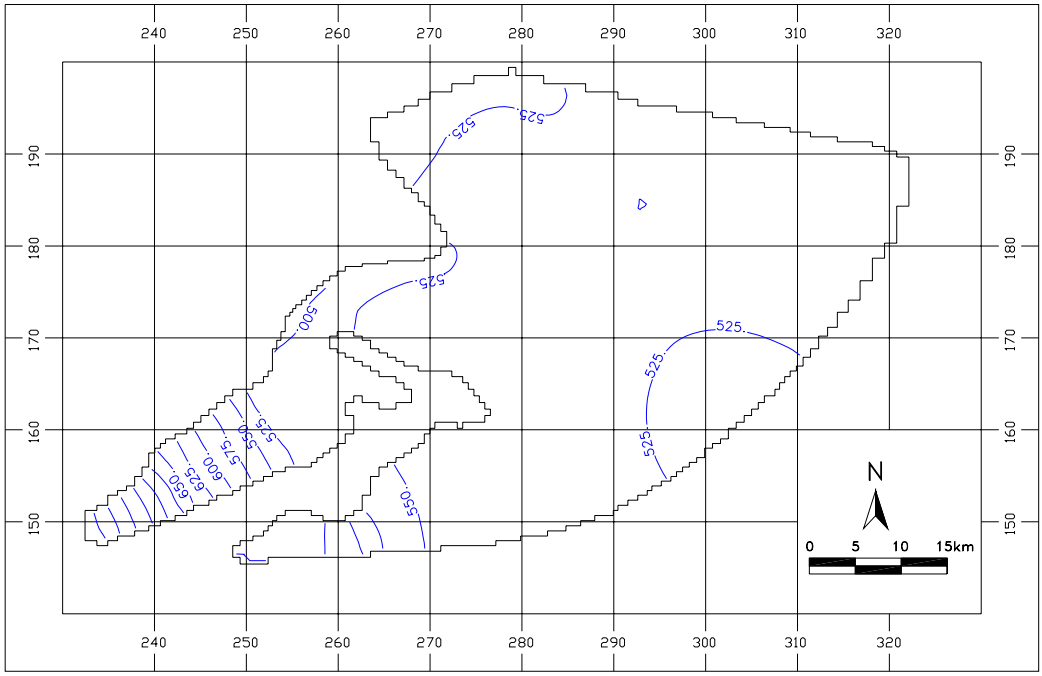


Figure 37: Predictive water level contour map at year 2020 for Amman-Zarqa (Abstraction is assumed to be 75% of the year 2000 quantity)

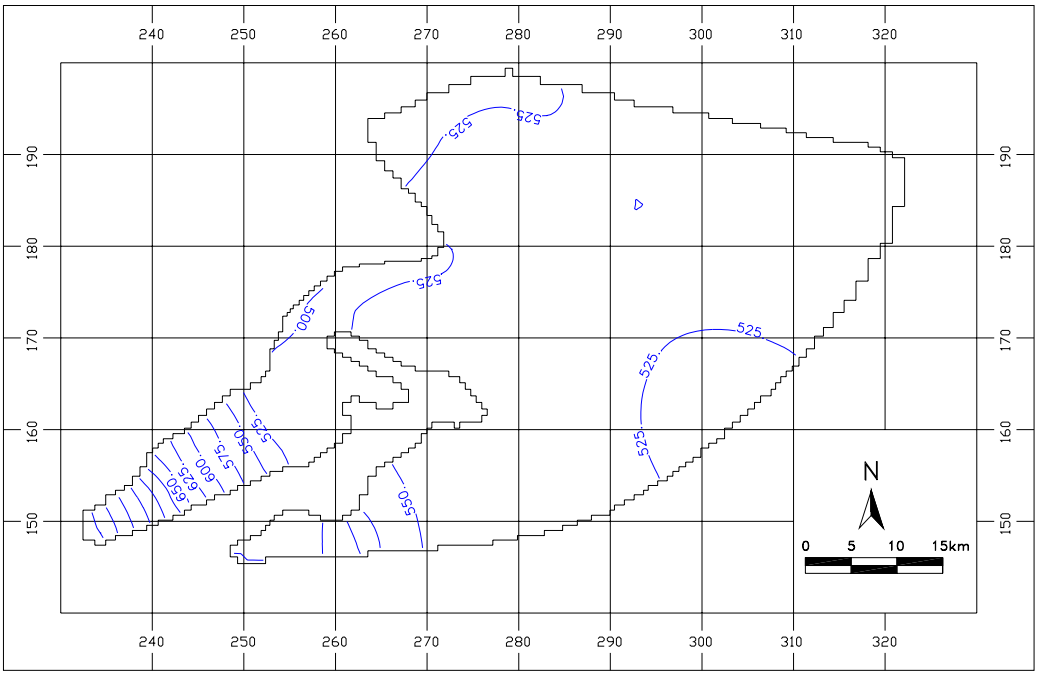


Figure 38: Predictive water level contour map at year 2050 for Amman-Zarqa (Abstraction is assumed to be 75% of the year 2000 quantity)

The water level will rise by 15 meters and the water quality (EC) will be improved by 45%.

The second part of this scenario is to reduce the abstraction rate of the year 2000 by 50 percent up to the year 2050. The results of the simulated groundwater levels for the periods 2008, 2020 and 2050 are presented in **Figure 39**, **Figure 40**, and **Figure 41**, respectively. The water level in this case will rise by 25 m and the water quality (EC) will be improved by 62%, as discussed earlier.

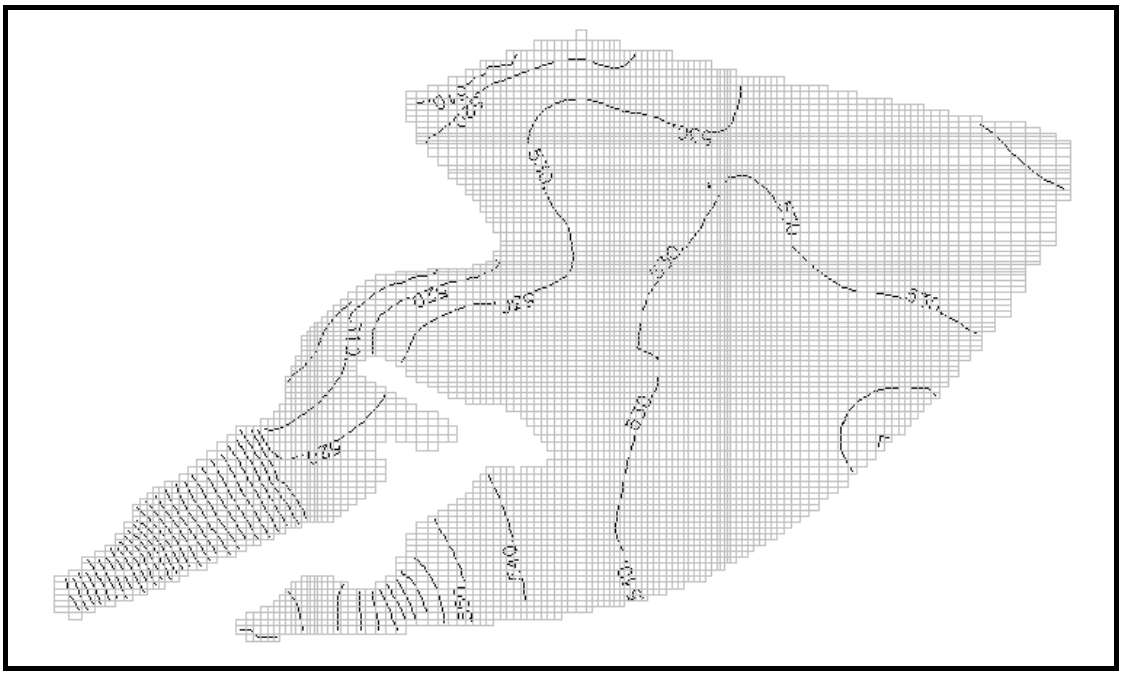


Figure 39: Predictive water level contour map at year 2008 for Amman-Zarqa (Abstraction is assumed to be 50% of the year 2000 quantity)

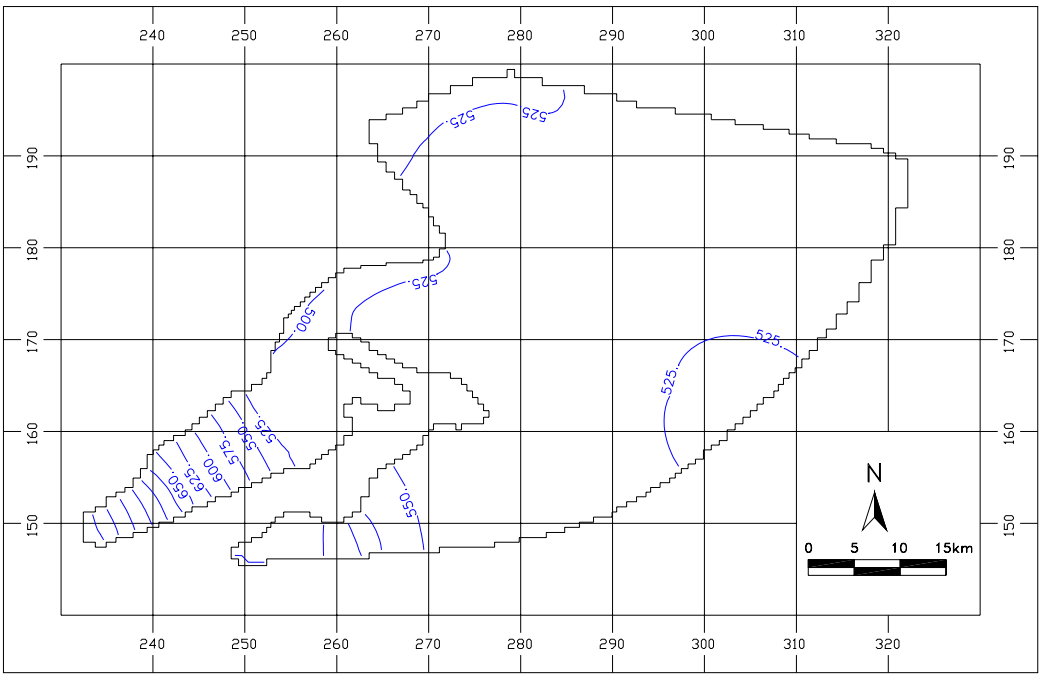


Figure 40: Predictive water level contour map at year 2020 for Amman-Zarqa (Abstraction is assumed to be 50% of the year 2000 quantity)

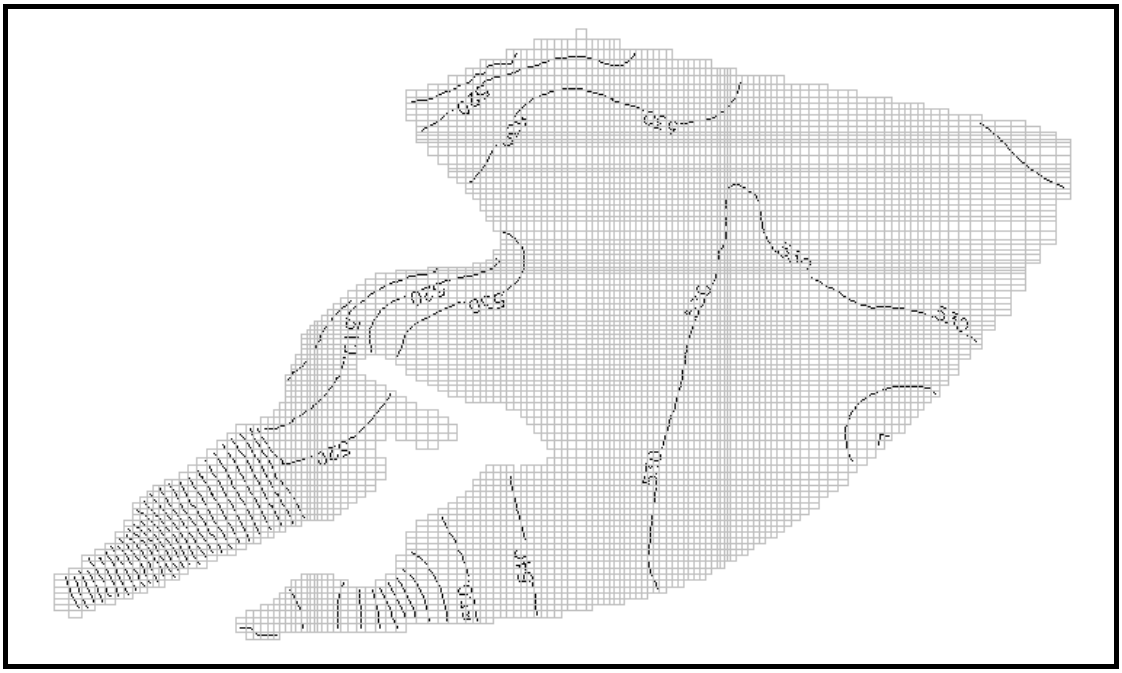


Figure 41: Predictive water level contour map at year 2050 for Amman-Zarqa (Abstraction is assumed to be 50% of the year 2000 quantity)

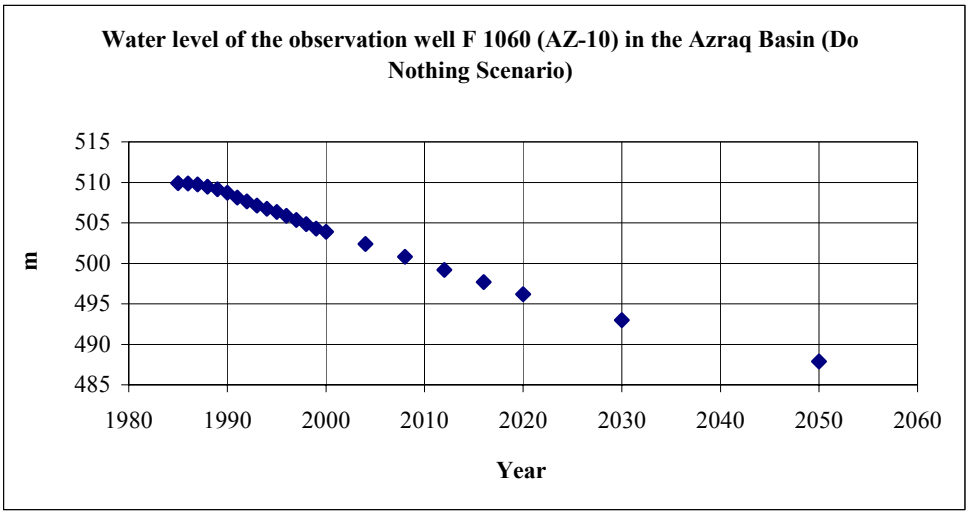
Azraq Basin is considered as one of the groundwater basins in Jordan, which suffered heavily from overexploitation. In early sixties, a transmission pipeline was constructed to transmit water from the Azraq springs (Oasis) to Irbid city with the purpose of enhancing domestic water supply. In 1982, this basin took remarkable importance because the Amman Water Sewerage Authority (AWSA) drilled 15 wells in the upper aquifer system, which is composed of the Basalt and the Rijam Formation (B/B_4). Water pumped from these wells was transferred to supply Amman with

domestic water with a quality of an electrical conductivity of less than 500 µS/cm. The consequent effect of water pumpage from the AWSA wells was that the spring's discharge into Azraq (Oasis) stopped completely since 1991. The most prominent feature of the Azraq Basin is its depression nature where surface water drains in its central part of the basin. It accumulates and saturates the upper aquifer and natural springs forming the Oasis of Azraq. The natural accumulation of surface water and groundwater discharge from the Azraq Springs allow the formation of Azraq Sabkha where the salinity of Sabkha reaches 290 g/l. After the progressive abstraction of the groundwater for agricultural and domestic purposes, the Oasis dried up and the cone of depression enlarged causing partial salt-water intrusion from Sabkha to the adjacent fresh ground water.

In order to simulate the effect of groundwater pumping on the groundwater quantity and quality, a groundwater flow and solute transport model for the upper aquifer was carried out with two different scenarios taking into consideration the continuity of the present situation and with the presence of Disi-Mudawarra Conveyance project.

The groundwater abstraction from the Azraq basin is divided into two sectors. The first corresponds to the agricultural consumption and equals to 34.4 MCM/year and the second corresponds to the domestic consumption and equals to 18.8 MCM/year for the year 2000. The simulated two scenarios of the Azraq Basin are:

- **Scenario 1**: The present abstraction rates for agricultural and domestic purposes remained the same as in the year 2000. The results concerning the water level withdrawal and water quality changes from the year 2000 to 2050 are represented for two observation wells AZ-10 and AZ-12 in **Figure 42** and **Figure 43**, respectively. The estimated drawdown for AZ-10 observation well will increase by more than 15 meters and the water quality will deteriorate by an increment of 600 µS/cm while the drawdown in the Az-12 observation well be more than 17 m and with an increase in EC of about 100 µS/cm.



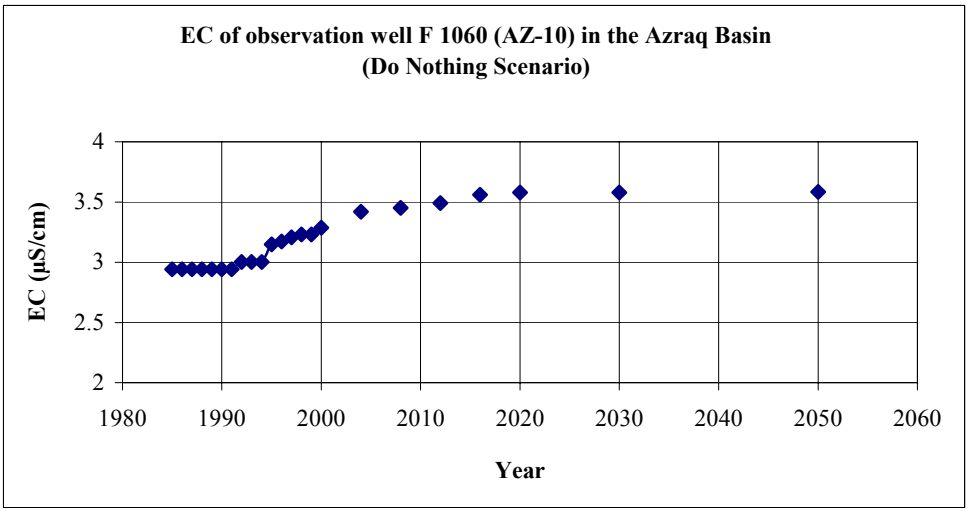
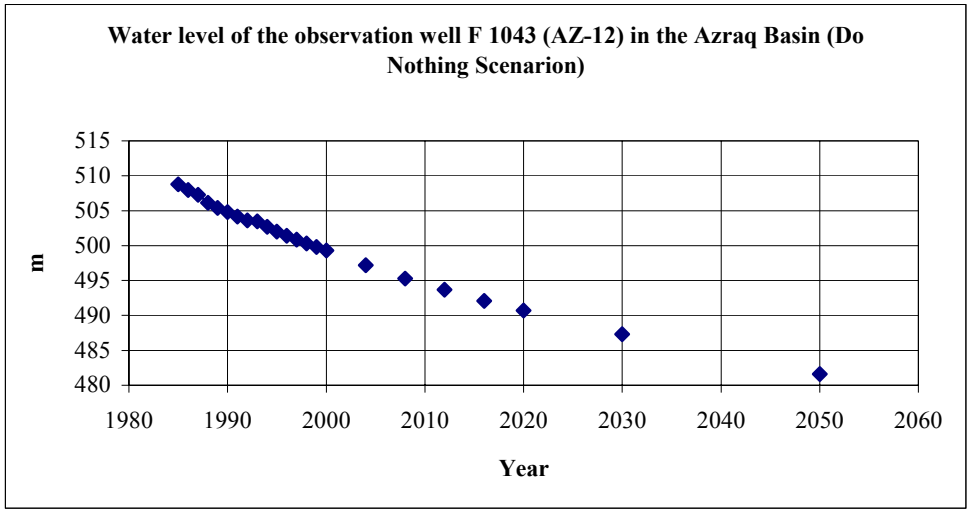


Figure 42: Water level and EC values of observation well AZ-10 in Azraq Basin



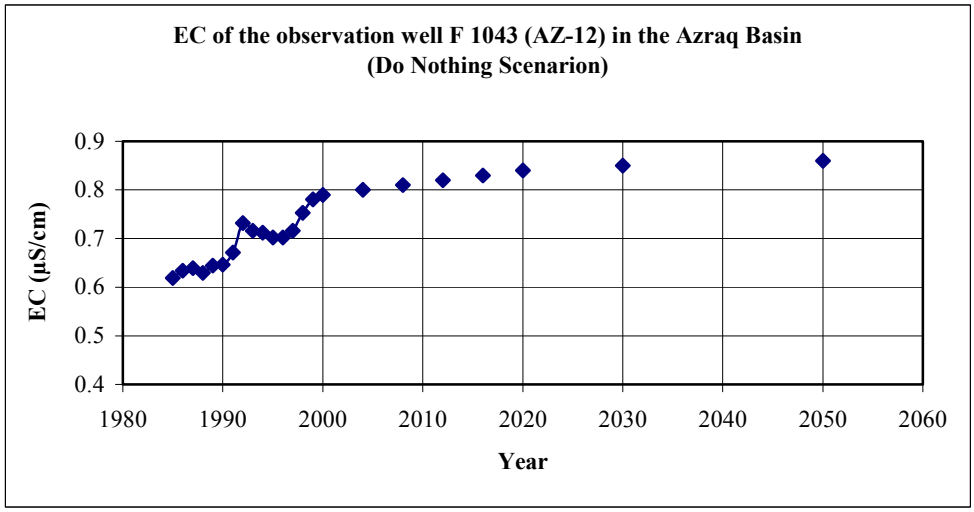
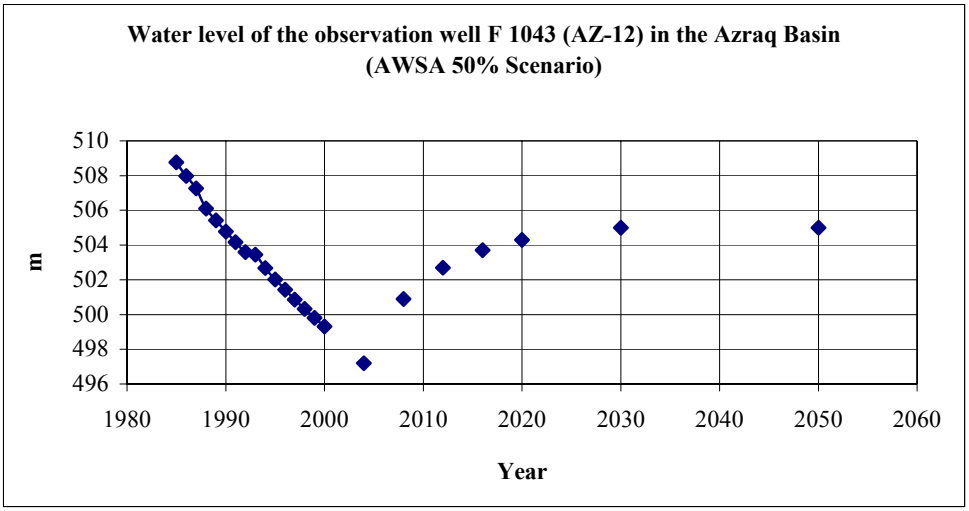


Figure 43: Water level and EC values of observation well AZ-12 in Azraq Basin

- **Scenario 2**: In this scenario the abstraction rate from the AWSA wells (domestic purposes) will be reduced by 50% and 25% of its present abstraction rate. The results of these two options are presented for water level and EC values of the observation well AZ-12 in **Figure 44** and **Figure 45**.



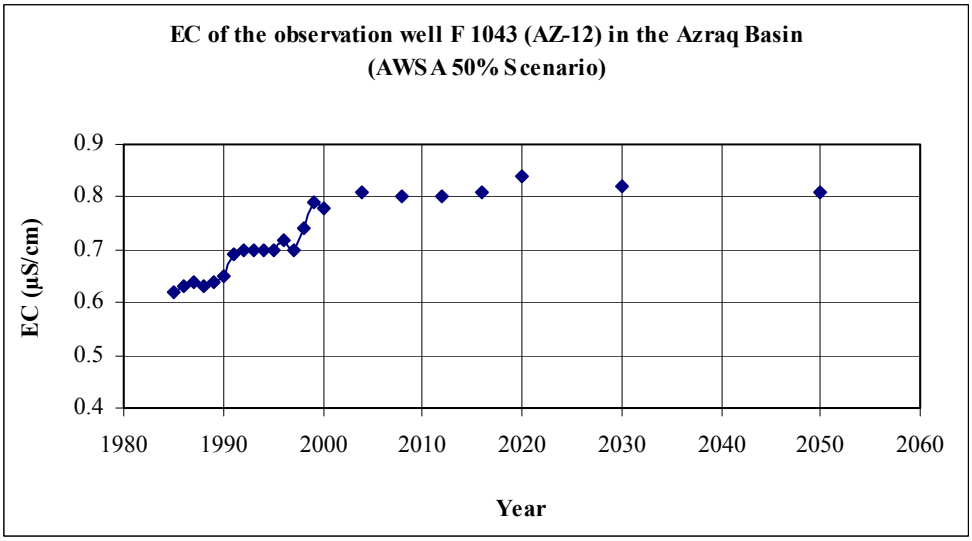
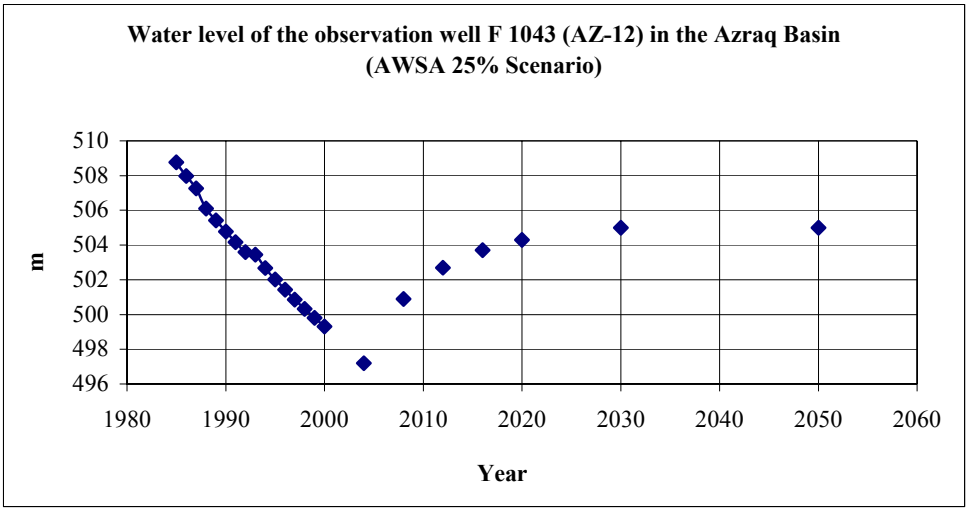


Figure 44: Water level and EC values of observation well AZ-12 in Azraq Basin (with 50% reduction)



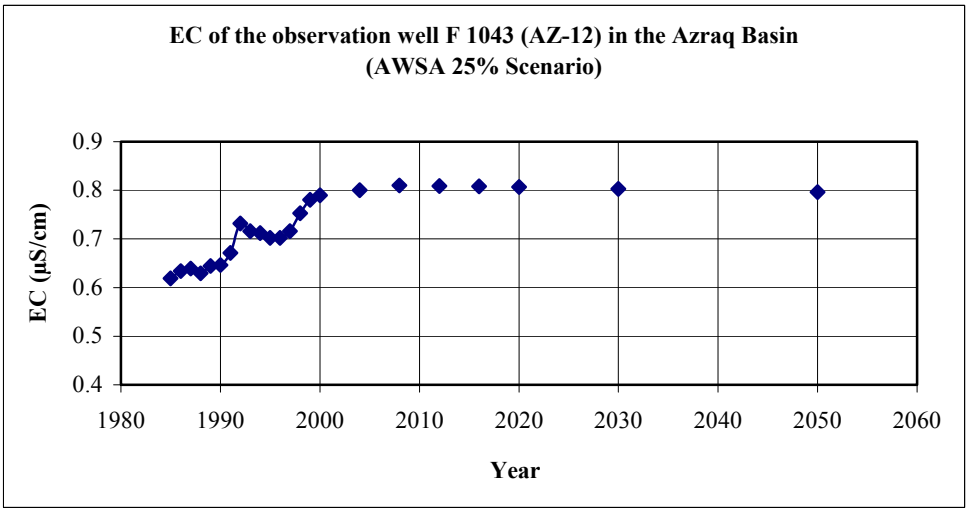


Figure 45: Water level and EC values of observation well AZ 12 in Azraq Basin (with 25% reduction)

Figure 44 shows that by the reduction of AWSA wells abstraction by 50 percent, the water level will be recovered by 8 meters while the EC-values will stay the same as in the year 2000. Similar value in **Figure 45** was found when abstraction rates of AWSA wells are reduced by 25%.

6.3.2 Impacts on Demand for Wastewater Treatment and Jordan Valley

As-Samra Wastewater Treatment Plant (SWWTP) is the main treatment plant servicing more than 60% of Jordan's population in Amman and Zarqa Governorates. This treatment plant was constructed in 1985 with a design capacity of 68,000 m^3/day and a BOD_5 loading of 526 mg/l. Few years after the construction (operation) of SWWTP, it became hydraulically overloaded and the effluent quality negatively affected the groundwater in the vicinity of the plant and the surface water quality flowing in Zarqa River and, consequently, the King Talal Dam reservoir.

During the period 1985-2001 the ratio between the annual influent to SWWTP to the supplied water to Amman and Zarqa Governorates ranged between 21.7% and 53.8% for the years 1985 and 2001, respectively.

Table 39 shows the volumes of supplied water to Amman and Zarqa and the influent to As-Samra treatment plant. It also indicates that the SWWTP became hydraulically overloaded in 1987 when the annual influent of about 25 MCM/year exceeded the designed load.

The hydraulic overload is highly influencing the efficiency of treatment. **Table 40** shows the simple descriptive statistics of some parameters of the influent and the effluent of SWWTP.

Table 39: Supplied water to Amman and Zarqa Governorates and the produced wastewater in cubic meter

Year of Record	Supplied Water Amman + Zarqa	Influent to SWWTP
1985	73,901,772	16,060,800
1986	71,300,000	20,076,000
1987	80,788,434	25,095,000
1988	89,281,000	30,220,000
1989	90,236,000	33,147,840
1990	95,755,000	35,118,840
1991	96,949,722	35,709,045
1992	121,039,548	46,737,885
1993	124,120,900	46,355,995
1994	121,352,000	47,149,605
1995	133,041,155	52,355,965
1996	121,301,170	54,310,175
1997	120,231,000	57,212,290
1998	117,665,527	61,632,805
1999	118,233,221	60,898,060
2000	123,103,949	62,324,480
2001	126,330,713	67,919,565

Table 40: Descriptive statistics of some parameters of the influent and effluent of SWWTP during the period 1988 and 2001

Parameter	Minimum	Maximum	Average
Influent Average Flow (m^3/day)	69,301	200,977	135,125
Effluent Average Flow (m^3/day)	54,332	164,052	115,503
TDS Influent (mg/L)	616	2190	1185
TDS Effluent (mg/L)	876	1438	1213
TSS Influent (mg/L)	279	2157	970
TSS Effluent (mg/L)	52	1562	594
BOD5 Influent (mg/L)	308	900	651
BOD5 Effluent (mg/L)	56	406	134
COD Influent (mg/L)	970	2200	1533
COD Effluent (mg/L)	200	734	399

Table 40 clearly indicates the hydraulic and organic overload of the treatment plant. Since the SWWTP is natural stabilisation ponds, the water in the ponds is affected by evaporation during the retention periods in the different types of ponds and consequently the total dissolved solids (TDS) increase in the effluent. During the treatment process of the wastewater in the different types of ponds (anaerobic, facultative and maturation), some of the wastewater infiltrates through the bottom of the ponds to the groundwater. Due to this, the groundwater quality in the downstream area of the SWWTP has been deteriorated and most of the groundwater wells were

abandoned where the salinity had increased from 700 mg/l (before 1985) to more than 7,700 mg/l (in 1990) such as is the case in Tillawi well. In addition to the salinity increase in the groundwater, some other pollutants, such as NO3, PO4, COD and Faecal coliform, appeared in high concentrations in the groundwater.

Since the effluent of SWWTP flows along 45 km in Zarqa River course to the King Talal Dam Reservoir (KTDR), partial self-purification may occur, but this process is not sufficient. Due to this, when the effluent enters KTDR, it mixes with the flood water collected from the catchment area of Zarqa River and consequently adversely affects the quality of the collected water in the reservoir. According to the Annual Reports of the Royal Scientific Society (1987-1999) on the monitoring of SWWTP and KTDR water quality and submitted to the JVA of the Ministry of Water and Irrigation, the contribution of As-Samra effluent to the total inflow of KTDR ranges between 10 to 66%.

Generally, the King Talal Dam water is used for irrigation purposes in the Jordan Valley. The water quality of the dam water was deteriorated after the construction of SWWTP in 1985 and onwards where the salinity of the water has increased from 400 mg/l in 1979 to more than 1,650 mg/l in 2001. This salinity increase has affected the types of crops to be planted (in a semi saline soil due to the presence of Lisan Marl) and irrigated with such water.

In the case of supplying Greater Amman with water from the Rum aquifer (Dubaydib well field) with a salinity of less than 300 mg/l, the produced wastewater will be much diluted than the present wastewater since the present supplied water to Amman from the different sources has a salinity ranging between 600 and 1,000 mg/l.

In addition to this, and taking into consideration the changes which are being approved by the government to change the wastewater treatment practice in the proposed treatment plant to be constructed instead of SWWTP, mechanical wastewater treatment plant will be constructed instead of the present natural stabilisation ponds of As-Samra. These changes will produce a treated wastewater that complies with the standards for reuse. Under these conditions, the collected flood and treated wastewater in KTDR will be acceptable for irrigation purposes for most crops planted in the Jordan Valley.

6.3.3 Overall Cumulative Impacts

Cumulative impacts include all individual or collective impacts that will affect positively or negatively the society concerned and economic activities during the project life. Those impacts comprise the different stages of the project set-up from construction, operation and maintenance and administration during the concession period.

The policy adopted by the Ministry of Water and Irrigation is to build the Disi Conveyance System on BOT basis (Build, Operate and Transfer). The project assets will be transferred to the MWI following the termination of the Concession Period of 40 years including the construction phase of about 4.5 years. The project implies the establishment of a competent private company with long outstanding experience in similar projects to undertake the following process:

1- Production of 100-120 MCM from Disi aquifer including the digging of 65-85 ground wells.
2- The construction and maintenance of the pipe.
3- The utilisation of the five turnouts to supply the five other governorates with water in case of emergency.

4- The Administration of the system through the project life.

The role of the Contractor is to supply water to WAJ terminal reservoirs of Abu-Alanda and Dabouq. The distribution of water through the existing network and collection of water fees will be the responsibility of WAJ. It is expected that the same personnel of WAJ, offices and collection system will continue through the Concession Period.

The Disi Conveyance System will ultimately provide continuous water supply of best quality to Amman residential area. It will have positive cumulative impact on the public health in the region as well as on other areas in the direct zone of influence where salinity is increasingly affecting drinking water supply from underground resources. A clean water supply combined with good public awareness will have direct and cumulative impact on the household health conditions overtime. It is expected that substantial decline in water borne diseases will occur as a result of the Disi water quality. The wastewater produced will be of better quality due to the quality of the consumed water. This will be reflected on the treatment process and the quality of the treated wastewater. The treated wastewater will enhance the condition of irrigated land in the direction of more profitable cropping.

Over extraction of ground water from Azraq, Amman-Zarqa basins in the last 20 years to cover water shortages in the cities of Amman, Zarqa and Irbid has substantially affected water tables in all aquifers at both basins. Mining of groundwater aquifers at Azraq has far exceeded recharge to the extent that Azraq ponds and their associated wildlife and vegetation have been significantly reduced in size and their quality degraded. A large portion of the Azraq Oasis which served as a sanctuary for migrating birds, turned now been turned into desert. It is expected that water tables in these aquifers may be restored to normal within 10-15 years should the present level of extraction come to end. The supply of Disi water resources to Amman would eventually assist in the restoration of depleted aquifers and in the case of Azraq allow for partial restoration of the oasis and its wetland functions.

7 ENVIRONMENTAL AND SOCIAL MANAGEMENT PLAN: MEASURES TO STRENGTHEN THE WATER SECTOR

The Disi water resource is a very valuable one and efficient management of it is therefore critical. This high standard of management is needed in order to maximise the benefits of staged development of the resource and onward conveyance system to Greater Amman. (Harza Group-Executive Summary, 1996)

In general, it is crucial that the Water Authority of Jordan to be equipped with the manpower capacities and capabilities especially to co-ordinate various imminent major projects. As this project is of a complex nature and will also be the largest water conveyance scheme to be implemented in Jordan, it is imperative that a "Project Specific Office" be established as soon as possible within the Water Authority of Jordan. This will ensure that the competent professionals to be assigned to this office are involved at the outset with the formulation and development of system components of not only this project but also other pending projects.

7.1 Mid and Long Term Institutional Strengthening

The Ministry of Water and Irrigation including its two authorities the Water Authority of Jordan and the Jordan Valley Authority have extensive programmes for capacity building of their employees. A training centre was established where regular training is carried out for all employees and in particular for engineers and technicians to keep them well informed of new techniques and improve their skills in operation and maintenance of the different facilities in the water sector.

The special unit for training is called "The Administrative Development and Training Unit". The unit became a directory in 1998. Its main responsibility is the continuous search for methods and procedures that assures the development and training of the ministry human resources in a continuous manner. This training is also available for trainees from outside the ministry.

The objectives of having such training plans are:

- To achieve the objectives set by the Ministry of Water and Irrigation of Jordan.
- To assist the Water Authorities in responding to its needs by building the capacities and setting plans for the available personnel.
- To encourage and motivate the employees in exerting their best efforts in achieving the public objectives.
- To change the behaviour of the individuals so that they become responsive to crisis events and able to find appropriate solutions for problems faced.
- To achieve best use of available human resources by redistributing the employees in order to have them in positions suitable to their capabilities.
- To provide the trainees with the knowledge, experience and recent methods for developing their work performance, building their administrative and functional capacities, and enhancing their productivity.
- To assist the trainees in achieving their ambitions towards personal development and advancement.
- To assist in attracting human resources and maintaining them for the longest possible time period.
- To enhance career planning of which training constitutes a main support.

- To assist in finding new leaders in the sector.

Table 21 presents the number of trainees for the period between 1994 and 2001 with the percentage to the total number of employees in the Ministry. The percentage is depending on the financial situation and the international aids. The percentage could be around 10 % in average for the eight years, which reflects the importance of human resources in the water sector. The importance could be resulted from the challenge of water problem in Jordan.

Table 41: Training of Ministry of Water and Irrigation Employee

Year	1994	1995	1996	1997	1998	1999	2000	2001
Outside Jordan	54	79	87	62	45	30	39	41
Inside Jordan	295	822	756	997	499	269	399	664
Total	349	901	843	1059	544	299	438	705
Total Employee	6872	7300	7431	7414	7460	7762	7869	7709
% to Employee	5.1 %	12.3 %	11.3 %	14.3 %	7.3 %	3.9 %	5.6 %	9.1 %

7.1.1 Needs

In order to determine the training needs, the training centre depends upon various sources including:

- Job analysis records in order to determine the level to which the employee capacity has to be raised in order to perform the job well.
- Opinions of supervisors and head of departments.
- Annual reports of individuals and rating of performance.
- The reorganization and developments that are applied to the work.
- The feedback from the trainees.
- Scientific and technological advancements.

7.1.2 Types of Training

Job training is a continuous process provided to the employees by the training centre through supplying the employees with the needed knowledge and skills in order to react with the other employees and the public. This training may be provided within the centre or outside the centre. Hence, there are two types of training:

1- On-job training: trainees get the instructions and procedures from the administration of the training centre.
2- Training outside work setting: trainees stop coming to work for a given period of time in order to join a specialised training centre inside or outside the country or to participate in public or private programs that comply with the job description and the employees' specialty.

Training programs held during the year 1998 include:

1- A special training program on polyethylene pipes as he Water Authority of Jordan has changed to this type of pipes.
2- A special training program on pumps especially with respect to methods of daily maintenance of pumps.
3- A special training program on electricity and approaches to maintenance of electrical boards.
4- A training program on the usage of chlorine and safeguard against its hazards.
5- A training program on using personal computers for the employs at the development and training unit.
6- Development of cooperation with public and private universities in order to attract students into working in the development of the government.

These training sessions were held at Governorates of Aqaba, Tafileh and Irbid.

In 1999, the centre conducted the following training sessions:

- 22 sessions on water networks, electricity and pumping stations in which a total of 170 of the Water Authority employees participated in them.
- Specialised sessions in management of projects and contracts and in which 99 managers and engineer participated. These sessions were held in cooperation with Ministry f Water and the American Project.

These training sessions were held at Governorates of Balqa, Aqaba, Tafileh, Irbid, Karak and Madaba.

In 2000, the centre organized 6 training programs and implemented them through 43 training sessions with the participation of 399 trainees from the technical employees at the water authority offices in eight Governorates. **Table 42** summarizes these training programs.

Table 42: Training programs held during the year 2000

No.	Training Program Name	Training Program Subject	Number of Related Training Sessions	Number of Governorates at which training was conducted
1	Water Networks	Laying and maintenance of high density polyethylene pipes	4	4
2	Water Networks	Laying and maintenance of ductile pipes	9	6
3	Water Networks	Method of use and operation of drilling machines	1	1
4	Electric Works	Safety equipment/Electricity Boards	12	8
5	Pumping Works	Lifting and submerging submersible pumps	12	8
6	Public Safety	Chlorine and the use and maintenance of breathing equipment	5	4
		Total number of training sessions:	**43**	

In 2001, the centre participated in several workshops, courses and conferences inside and outside the country (see **Table 43**). These were mainly related to keeping up with:

- Recent developments in the water and environment sector;
- Protecting water resources from pollution, recent methods of studying the water resources and sustainable management of groundwater resources;
- Using geographic information system (GIS), remote sensing and modelling for water systems;
- Reuse of treated wastewater; and
- Tendering.

Table 43: Number of participation in the different types of activities

Courses	Seminars	Conferences	Workshops
5	2	3	4

Also, in the same year, the training unit managed to implement 14 training programs: 10 programs within country and 4 programs outside the country. These programs resulted in the training of more than 300 employees of the Ministry of Water and Irrigation, Water Authority of Jordan and the Jordan Valley Authority.

The following are the reasons that the Water Authority is emphasizing the training of the employees:

- Assistance in achieving the objectives of the Water Authority.
- Increasing the knowledge of the authority's staff.
- Use of technological advancements in achieving the Water Authority objectives.

7.1.3 Scope of Training Programs for Key Institutions

Several workshops and seminars are held yearly in cooperation with the different universities in Jordan and abroad as well as with the major donors in the water sector including USAID, GTZ, and EU. In fact most of the projects include training of the ministry's employees as part of the project. The following are samples of recent projects which included training of employees:

- Water Sector Intervention Project in Karak and Tafileh financed by EU. Three months courses were held for training engineers and technicians on design, operation and maintenance of water and wastewater treatment plants, pumping stations, electrical supply and effluent reuse. These courses were attended by employees from different parts of the Kingdom.
- Collection, Treatment and Effluent Reuse System in North Jordan Valley financed by USAID. Training was carried out on hydraulic design of the system using the latest software and in this case "Mouse", and training on using GIS software.

7.2 Mid and Long Term Monitoring

The Water Authority of Jordan has identified the several elements that can be implemented to enhance the Environmental and social Management Plan in the Water Sector; the following are some of these elements:

- Implementing the rationing program for water supply all over the Kingdom;
- Implementing comprehensive programs for rehabilitation of water supply networks to reduce losses;
- Replacing the fresh water by marginal water in irrigation;
- Limiting the water provided for agriculture and preventing any expansions;
- Implementing projects for desalination of brackish water for domestic use;
- Implementing training programmes for capacity building of its employee;
- Conducting public awareness campaigns related to availability of water and its wise use;
- Monitoring the water Quality at the sources;
- Monitoring abstractions from wells by installing meters;
- Prevention of new wells without prior licensing;

7.2.1 Management of the Disi Water

The specific elements related to the management of the Disi Project are as follows:

- The implementation of the Disi project should remain on schedule and not to be deferred;
- Emergency turnouts should be provided on-route;
- Using the Disi water only for domestic consumption in Greater Amman.
- No agriculture water from Disi after the end of ongoing contracts.
- Disi area and Aqaba will continue to use Disi water for domestic consumption.
- After the operation of the Disi conveyor, the monitoring results to be used to conduct a groundwater solute transport model, which is normally constructed on the flow model, in order to simulate the future water quality changes due to water abstraction from Dubaydib area only or Dubaydib and Batn El-Ghoul well fields.

Table 44 below presents the main responsible parties in the project.

Table 44: Parties responsible

Key Institution	Responsibility
Ministry of Water and Irrigation	Development of integrated management of different user sectors
Water Authority of Jordan	The construction, operation and maintenance of water supply and sewage facilities
Jordan Valley Authority	Implementing water supply services in the Jordan Valley and replacing the fresh water by treated wastewater in irrigation
Ministry of Environment	Environment protection (monitoring & mitigation)
Ministry of Health	Monitoring water quality of the source
Ministry of Municipal Affairs	Urban planning, and solid waste collection
Department of Antiquities	Monitoring and protection of archaeological sites
Royal Society for Conservation of Nature	Protection of reservation sites along the corridor (if any)

8 CONCLUSIONS AND RECOMMENDATIONS

8.1 Conclusions

The main conclusions related to the water sector and to this project address clearly the main issues, which were discussed through the study. These are listed below.

Project Need

- The Disi water is very valuable and needs efficient and effective management in order to maximise the benefits of development of the resource and the conveyance system.
- It has been clearly shown that due to municipal demands being in excess of all sources available, the Disi conveyance system is required now.
- Even with all developed conventional resources, it can clearly be seen that, if Jordan's deficits are to continue being nullified, within few years MWI will have no choice but to find another new non-traditional source such as the Red-Dead Inter-Sea Project.

General Project Benefits

- Disi water could relieve over extraction of aquifers which supply domestic water to Amman.
- The good quality of Disi water will enhance the water distributed to users in Greater Amman and will improve public health and even the performance of household appliances.
- The use of Disi water will improve the quality of wastewater conveyed to the SWWTP and later to the King Talal Dam Reservoir which will in turn allow for an enhanced treated effluent for agricultural use in the Jordan Valley.
- The water conveyance from Disi-Mudawarra to Amman will not affect the water supply to Aqaba quantitatively or qualitatively

Upland Groundwater Management

- Most of the renewable groundwater basins in Jordan are overexploited where some basins are overexploited with more than 150% with respect to their safe yield.
- The Highland Aquifer Systems supplying Amman for the time being, especially Amman-Zarqa and Azraq, are extensively overexploited quantitatively and degraded and salinized qualitatively.
- Further utilization of the Highland Aquifer System in Amman-Zarqa and Azraq Basins will accelerate the water quality degradation and salinization in these basins.

Project Design

- The Rum Aquifer System in Mudawarra-Disi area is the only promising aquifer system which may supply Amman with the necessary water for the different purposes
- Recharge volume is questionable and too small to be considered in the Disi water budget.
- The crossing sections for flanking wadis are too deep and flood flow of 10-year return period is of shallow water depth.
- Turnouts along the route are for emergency due to the availability of the existing water supplies for all main cities crossed by the route.

Hydrogeology

- In the case of reducing or stopping the abstractions from the Highland Aquifer Systems in the basins supplying Amman with water for domestic and industrial purposes, the groundwater in these aquifers will be improved quantitatively and qualitatively.
- The geological and hydrogeological characteristics of the Rum Aquifer System in Dubaydib area as indicated from the recently drilled wells (DB1, 2 and 3) are found consistent with the findings obtained in Qa Disi Aquifer Study in 1995.
- The water quality of the Rum Aquifer System in Dubaydib area in DB1 and DB2 as well as the wells used for irrigation purposes in Disi and Mudawarra area showed no significant water quality deterioration.
- The water quality occurring in the confining layer of Khreim Group is highly deteriorated and salinized. Due to the presence of such a confining layer in Batn El-Ghoul area, future water quality deterioration of the Rum Aquifer System in the area may occur due to downward leakage in the case where the piezometric head of the Rum Aquifer becomes lower than the water head of the Khreim Group water.
- The Dubaydib area contains no Khreim Group deposits and consequently the water quality will not be deteriorated taking into consideration the consistent water quality all over the Rum Aquifer sequence.
- In the case of drilling two well fields in Dubaydib and Batn El-Ghoul to convey water to Amman**,** future water purification (removal of Fe and Mn) for Batn El-Ghoul well field may be a necessity before blending with Dubaydib well field water to be conveyed to Amman.
- The hydrogeological situation and the hydraulic characteristics of the Rum Aquifer in Dubaydib area indicate the possibilities of drilling one well field only which is capable to supply the conveyance system to Amman with necessary water without actual water quality variations.
- After the operation of the Disi conveyor, the monitoring results can be used to conduct a groundwater solute transport model, which is normally constructed on the flow model, in order to simulate the future water quality changes due to water abstraction from Dubaydib area only or Dubaydib and Batn El-Ghoul well fields.

8.2 Recommendations

Based on the findings of the water sector study team the following major recommendations have been developed:

- The implementation of the Disi project should remain on schedule and not to be deferred.
- Turnouts should be provided on-route just for emergency.
- Disi water is recommended as good quality water just for domestic consumption of Greater Amman.
- No water from Disi to large-scale agricultural farms after the end of the ongoing contracts.
- Disi area and Aqaba will continue to use Disi water for domestic consumption.
- Crossing bridges is the best solution for the pipe alignment to cross the flanking wadis.

ANNEXES

ANNEX B1
MINISTRY OF WATER AND IRRIGATION
WATER SECTOR ACTION PLAN 2002-2006

Ministry of Water and Irrigation
ACTION PLAN

	Issue Description / Action	Implementation Period				
		2002	2003	2004	2005	2006
1	INSTITUTIONAL AND LEGAL ISSUES					
1.1	Institutional Reform MWI Establishment of Regulatory Body					
	Phase I: Study on assesment of options for structural reform in the water and sanitation sector. The objective of the study is to identify an appropriate structure for the water sector in Jordan which will encompass greater private sector participation in service provision, a reorientation of the role of the government, and the development of an appropriate structural framework.					
	Phase II: Preparation of a time bound implementation plan and the development of draft legislation for the sector which will facilitate the implementation of the new institutional structure, identifying Regulation, responsibilities.					
	Phase I					
	Inception Report					
	Review of Sector Performance and Restructuring Option Report					
	Water Sector Regulatory Framework Report					
	Phase I Final Report					
	Decision of the Regulatory Body					
	Phase II / Optional					
	Draft Sector Restructuring Legislation Report					
	Final Sector Restructuring Legislation Report					
	Restructuring of the Organizational Chart					
	Establishment of a new unit for planning and follow-up PSP projects					
	(modifications of laws & by-laws) According to the outcome of the Study					
	WAJ					

	Legal Definitions of Responsibilities (WAJ)					

Ministry of Water and Irrigation
ACTION PLAN

	Issue Description / Action	Implementation Period				
		2002	2003	2004	2005	2006
	(modifications of laws & by-laws) According to the outcome of the Study					
	Restructuring of the Organizational Chart (according to the outcome of the Study					
	Design and implementation of an accrual-based automated financial accounting system for WAJ					
	Autonomous commercialized entities at governorate level for retail services for specified Governorates					
	JVA Legal Defenitions of Responsibilities (JVA) (modifications of laws & by-laws) According to the outcome of the Study					
	Structural reform of JVA to reflect the new mandate and to identify the future role of JVA (functions, responsibilities ...)					
	Implementation of a new Financial Accounting System					
1.2	**Legal Issues** **MWI** Modifying Ministry Establishment's By-Law					
	WAJ Amendment to WAJ law to enhance PSP / and allow for the establishment of the public owned companies run on commercial basis.					
	A new bylaw for groundwater monitoring to reduce and control over drafting and illegal wells and provide for substantive penalties for illegal use					
	Amendment to WAJ law to enhance enforcement measures with regard to removing any violations and contraventions of the laws.					
	Ammendments to bylaw pertaining to wastewater regulations in order to allow for the smooth implementation of wastewater networks through private lands and plots					

Ministry of Water and Irrigation
ACTION PLAN

Issue Description / Action	Implementation Period				
	2002	2003	2004	2005	2006
Amendment to wastewater by-law. Wastewater connection fees are now to be determined and set by WAJ based upon criteria approved by the Council of Ministers in order to enhance financial viability and cash flows					
Establishment of a new tariff for groundwater abstraction for agricultural use.					
Enforcement measures with regards to illegal drilling have been strengthened by the recent legal amendments					
JVA Implementation of modified JVA law and preparation of instructions & regulations to explain the items of the modified law. The modifications allow for private sector participation and the management of projects on commercial basis (excluding water resources and irrigation). Sanctions against illegal water use are being enforced.					
Amendment to JVA law to allow for the operations under commercial basis for all projects in the Jordan Valley					
Restructuring of the laws pertaining to the sale of land in the Valley to allow for the sale of property in order to allow agriculture farm units to be consolidated up to 250 dunums in order to assure enhanced economic viability					
Preparation of management contract document for O & M and supporting activities.					
Implementation of the management contract for O&M					
Conducting a strategic planning program for JVA. This program includes editing a vision, mission, goals, objectives, strategy and action plans for the next 5 years					
Implementation of the action plan resulting from the strategic planning program					

	Issue Description / Action	Implementation Period				
		2002	2003	2004	2005	2006
	Farmers participation in retail water management. A pilot project funded by GTZ Improvement of Irrigation Water Management (IWM) is being implemented .					
2 2.1	**AGRICULTURAL WATER USE** **Irrigated Areas** **MWI** **No expansion of irrigated areas / reduction of groundwater abstractions for irrigation purposes** Groundwater allocations for all purposes in the uplands shall be based on groundwater sustainability principles. The GOJ has made recent policy decisions to stop the abuse of critical water resources and promote better management of those resources. A recent GOJ policy calls for massive reduction in ground water abstractions to prevent the loss of some highland aquifers.					
	MWI & WAJ **Reduction of Groundwater Abstractions** Implementation of new ground water monitoring by-law					
	Equipping private wells with water meters					
	JVA **No Expansion of Irrigated Areas** Decision is being taken to limit the irrigated area in the Jordan Valley by 427,000 Dunums which represent the current situation & immediate plans in the Jordan Valley					
	Ban Summer Crops in order to preserve scarce water resources (in drought years) Amount of water saved 15 MCM/yr					

A reduction of irrigated water for Summer time through a water rationing program
Amount of water saved 15 MCM/yr

Ministry of Water and Irrigation
ACTION PLAN

	Issue Description / Action	Implementation Period 2002	2003	2004	2005	2006
	Rent lands from farmers in order to prevent them from planting any crops Amount of water saved 15 MCM/yr					
2.2	**Use of Marginal Water (brackish, treated waste water) in agriculture**					
	MWI Increase the use of marginal water in agriculture / continue coordination with concerned parties					
	WAJ & JVA A Study financed by KfW on wastewater reuse					
	Substitute fresh water with marginal water, wherever possible					
	Wastewater Reuse Plan *					

Existing TPs	Expected Eff. Till 2005 m3/yr
As-Samra	67,459,840
Irbid Central	2,386,075
Aqaba	3,870,083
Salt	2,010,944
Jerash	1,015,401
Mafraq	698,457
Karak	614,350
Tafila	453,569
Ramtha	1,342,611
Ma'an	550,030
Madaba	1,636,171
Kufranja	1,304,952
Wadi Al-Sir	278,450
Fuheis	594,620
Wadi Arab	4,079,662
Planned TP	
Wadi Hassan	497,895
Wadi Mousa	669,399
Al-Jeeza	1,752,426
Deir Alla	1,784,415
Aqaba South Coast	154,527
South Amman	5,685,928

North Jordan Valley	2,311,175
South Shuna	1,134,533

* this plan till year 2005, to be followed by another plan for the year 2010, 2015, and 2020

Ministry of Water and Irrigation
ACTION PLAN

Issue Description / Action		Implementation Period 2002	2003	2004	2005	2006
Wadi Shallala	3,287,234					
Dead Sea Coast	560,312					
Total	**112,212,607 MCM**					
Wastewater reuse strategy Direct irrigation reuse for Upland/Mid land for Irrigation 30 MCM/yr up to the year 2005						
Reuse for industrial purposes 15 MCM/yr up to the year 2005						
Direct & Indirect Reuse in Jordan Valley (without Aqaba) 59.2 MCM/yr up to the year 2005						
Reuse in Aqaba MCM/yr up to the year 2005	4					
Total	**108.2 MCM/Yr**					
The Planned Projects: **Wadi Shallala TP/ Irbid II**						
Detailed Design and Tender Documents						
Award of the contract						
Construction						
Rehabilitation and Extension of Karak TP						
Feasibility Study						
Detailed Design and Tender Documents						
Award of the contract						
Construction						
Rehabilitation and Extension of Kufranjeh TP						
Feasibility Study						
Detailed Design and Tender Documents						
Award of the contract						
Construction						
Rehabilitation and Extension of Ma'an TP						
Feasibility Study						
Detailed Design and Tender Documents						
Award of the contract						

	Construction	

Ministry of Water and Irrigation
ACTION PLAN

	Issue Description / Action	Implementation Period 2002 2003 2004 2005 2006
	Mafraq Wastewater Facility	
	Feasibility Study	
	Detailed Design and Tender Documents	
	Award of the contract	
	Construction	
	Aqaba Wastewater System	
	Tendering & Awarding	
	Construction	
	Small Communities Treatment Plants	
	Preparation of TOR	
	Study & preparation of Contract Documents	
	Construction	
	JVA Preparation of guidelines to help farmers use brackish water for irrigation according to water salinity, soil salinity and crop type through the Brackish Water Project.	
	New activities are being planned to expand the area of the project to cover Southern Ghors and to include treated waste water	
	Study for the use of Jordan River floods to be stored at Karama dam	
	Construction of desalination plant at King Talal Dam after the rehabilitation of As-Samra treatment plant in order to reduce water salinity.	
3	**Cost Recovery**	
	WAJ	
3.1	**Water Tariffs**	
	Implementation of additional surcharge on all water bills issued by WAJ of 0.5 JOD for consumption < 20 cum and 1.5 JOD for consumption > 20 cum for all bills issued inside Greater Amman area. 1.00 JOD for bills issued outside the capital	

	Increase in groundwater tariffs for water transported by tankers up to 250 fils/cu.m for municipal and indsrial consumption and 100 fils/ cu.m for non-potable water					

Ministry of Water and Irrigation
ACTION PLAN

	Issue Description / Action	Implementation Period				
		2002	2003	2004	2005	2006
	Increase in the price of water sold by private tankers up to 1.75 JOD/cu.m for water sold outside the capital and 2 JOD/cu.m for water sold within Greater Amman area					
	Increase in the price of water sold by WAJ tankers up to 1.5 JOD/cu.m					
	Treated wastewater existing at the As-Samra plant will be sold to the new plant for electricity at 100 fils/cu.m, it is expected to purchase up to 7 McM/yr					
	Raw water tariff for industrial usage by Arab Potash Co. has been set at 530 fils/cu.m. The groundwater tariff for water abstracted have also been increased from zero to 250 fils/cu.m, and 100 fils/cu.m for saline water.					
	Implementation of the new regulation related to the industrial and commercial wastewater affluent to the public network, any excess of the certain parameters will be paid for according to a formula.					
	Implementation of latest Cabinet's decision to enforce water tariff for extraction charges from the public and Governmental wells					
3.2	**Investments in the Rehabilitation of the Water Supply Systems**					
	Greater Amman Capital Investment Program					
	Feasibility Study					
	Detailed Design and Tender Documents					
	Award of the contract					
	Construction					
	Water Loss Reduction in Irbid and Jerash					
	Feasibility Study					
	Detailed Design and Tender Documents					
	Award of the contract					
	Construction					
	Water Loss Reduction Program in Karak					
	Feasibility Study					

	Appraisal Report and Loan Agreement					
	Detailed Design and Tender Documents					
	Construction					

Ministry of Water and Irrigation
ACTION PLAN

	Issue Description / Action	Implementation Period				
		2002	2003	2004	2005	2006
	Rehabilitation of Zarqa Water Network					
	Detailed Design and Tender Documents					
	Award of the contract					
	Construction					
3.3	**Increase Effeciency**					
	Increase PSP Involvement					
	Personnel Optimization					
	No. of employees to be reduced by 1% annually.					
	Training Measures(GTZ, USAID, and local Institutions financed by WAJ)					
	Public Awareness Program					
	Increase of water tariff by 8% in year 2005 and another increase by 8% in the year 2006					
	Target O&M Cost Recovery (%)	125	147	139	135	148
	Target O&M +Debt Cost Recovery (%)	101	113	104	103	112
	JVA					
	Water Tariffs Differentiation of irrigation water tariffs based on water quality, high water consuming crop.					
	Investments in the Rehabilitation of the Irrigation Water Supply Systems					
	Rehabilitation of Southern Ghors Irrigation Project: Stage 1 Construction					
	Rehabilitation of Southern Ghors Irrigation Project: Stage 2 Construction					

Rehabilitation of the Hisban-Kafrein Irrigation Project Construction	

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Issue Description / Action	Implementation Period 2002	2003	2004	2005	2006
Rehabilitation of Middle Ghors & Zarqa Triangle Irrigation Project: Stage 1 Construction					
Rehabilitation of Middle Ghors & Zarqa Triangle Irrigation Project: Stage 2 Construction					
Rehabilitation of wadi Arab Complex Irrigation Project Construction					
Wadi Arab: Installation of a pump to transfer water directly to the irrigation network to reduce operational costs. Construction					
Rehabilitation of North Coversion Irrigation Project - Stage 1 Construction					
Rehabilitation of North Coversion Irrigation Project - Stage 2 Construction					
Rehabilitation of the Damieh Irrigation Project Construction					
Construction of the SG II Irrigation Project Construction					
Greater Collection Effeciency					

	Using modern irrigation techniques in the Jordan Valley to raise effeciency	
	MC for irrigation System (USAID)	

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	Issue Description / Action	Implementation Period 2002	2003	2004	2005	2006
	Irrigation Advisory Services					
	Public Awareness Program					
	Target O&M Cost Recovery (%)	46.6	46.5	155.1	143.9	137.8
4	**PRIVATE SECTOR PARTICIPATION** **Further development of private sector involvement for water supply and wastewater disposal**					
	Several steps have already been taken to improve water and sanitation services by introducing PSP. Multi & bilateral agreements have attracted advisors & investors into Jordan in ever-increasing numbers. Projects below are PSP projects:					
	Amman Management Contract Transaction Advisor Publishig tendering document Award of the contract Start of the operator's contract Public-Owned Company runs on commercial basis					
	Northern Governorate MC Transaction Advisor Publishing tendering document Award of the contract Start of the operator's contract					
	Public-owned Company at Aqaba Preparation Implementation					
	Wadi Mousa Water and Wastewater MC Transaction Advisor and Awarding					

Start of the operator's contract

As-Samra BOT Project

Award of the contract

Start of the operator's contract

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	Issue Description / Action	Implementation Period 2002	2003	2004	2005	2006
	Zara - Ma'en Desalination plant and Conveyor DBO Project Award of the contract Start of the contractor's contract Operation					
	Disi Amman Water Conveyor Detailed Design and Tender Documents Publishing tendering document Award of the contract Start of the operator's contract					
	Middle Governorates PSP Preliminary Study Preparation of PSP Involvement Decision					
5	**INFORMATION SYSTEMS** **MWI** **Progress on the compatibility of data and information systems** Use of the common object data catalogue in water authorities Implementation of a centralized information system to have complete data related to water and wastewater resources.					
	Data Information System - WAJ Implementation of a new Customer Information System, this system will interface with other systems in use					

	Implementation of a new Archiving System in order to archive technical and administrative data related to well permits, drilling data, and deposits.					
	Implementing centralized GIS to have complete data related to water & wastewater projects.					

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	Issue Description / Action	Implementation Period				
		2002	2003	2004	2005	2006
	Data Information Systems - JVA GIS project to be expanded for Southern Ghors and use of remote sensing.					
	Automation of administrative procedures and process mapping, archiving of documents					
	Wide area network (WAN) to link JVA headquarters with other sites in Amman and Jordan Valley					
6	**ADAPTATION OF INTERNATIONAL CONVENTIONS** **Translation on Biodiversity and Convention to Desertification into national legislation & regulation**					
6.1	**Biodiversity** Jordan National Biodiversity strategy and action plan was completed by the end of 2001, which contains 50 projects awaiting finance.					
6.2	**Desertification** GOJ has set a strategy and action plan for desertification. The objectives of the project are to establish a mechanism for all the sector in Jordan, to motivate planning and operation for the projects which will be implemented for this purpose and to reduce the negative impact of this phenomenon.					

P. S. Item No. 6 is General Corporation for the Environment Protection's Responsibility

Successful Implementation of this Action Plan is subject to the continuous Support from the Donors

ANNEX B2
LIST OF PROJECT TEAM MEMBERS WHO PREPARED THE ESA STUDY AND SUPPORTING DOCUMENTS

ANNEX B2: LIST OF PROJECT TEAM MEMBERS WHO PREPARED THE ESA STUDY AND SUPPORTING DOCUMENTS

No.	Name	Position	Credentials
Technical and Managerial Staff			
1-	Khaled Murad	Project Director	B.Sc. in Civil Engineering
2-	Dr. Sawsan Himmo	Project Team Leader / Water Resources Management	Ph.D. in Civil Engineering (Hydraulic Structures) B.Sc. in Civil Engineering
3-	Ghassan Khateeb	Deputy Team Leader / Environmental Planning and Management	Masters of Engineering Administration B.Sc. in Mechanical and Aerospace Engineering
4-	Dr. Lee Harding	Project Advisor/Environmental Specialist	B.Sc. in Wildlife Management Ph.D. in Wildlife Toxicology
5-	Suhair Khateeb	Core Team / Public Consultation-Communications-Public Participation Team Leader	M.Sc. in Industrial Engineering B.Sc. in Electrical Engineering
6-	Dr. Saleh Sharari	Environmental Legal and Policy Specialist	Ph.D. in Environmental Law Master's Degree in Environmental Law
7-	Mona Khateeb	Management and Institutional Development	M.Sc. in Biomedical Engineering B.Sc. in Industrial Engineering
8-	Dr. Adnan Al-Salihi	Core Team / Water Sector-Water Management Studies Team Leader	Ph.D. in Civil Engineering (Hydraulic Structures and Dam Engineering) M.Sc. in Civil Engineering (Irrigation and Hydraulics) Diploma of Engineering in Civil Engineering (Irrigation and Hydraulics) B.Sc. (Honour) Civil Engineering
9-	Dr. Omar Rimawi	Hydrogeologist	Ph.D. in Hydrogeology, Hydrochemistry and Isotope Hydrology M.Sc. in Geology and Mineralogy B.Sc. in Geology and Mineralogy
10-	Naser Manaseer	Water Systems- modelling	M.Sc. in Hydrology and Water Resources B.Sc. in Geology
11-	Ruba Khoury	Water Study Team	B.Sc. in Civil Engineering
12-	Adnan Budeiri	Core Team / Biotic Environment Study Team Leader	Master's Degree in Biological Sciences / Hydrobiology and Ecology
13-	Majdi Salameh	Biodiversity - Fauna	M.Sc. candidate in Environmental Science and Management B.Sc. in Genetics and Molecular Biology
14-	Sharif Jbour	Biodiversity - Avifaunal	B.Sc. in Biological Science
15-	Dr. Ibrahim Khader	Biodiversity - Flora	Ph.D. Candidate in Biological Sciences B M.Sc. Degree in Plant Taxonomy B.Sc. in Biological Sciences
16-	Ahmad Abu Hejleh	A-Biotic Environment	M.Sc. in Geology (Water Resources and Environment) B.Sc. in Applied Geology (Water Resources)

ANNEX B2: LIST OF PROJECT TEAM MEMBERS WHO PREPARED THE ESA STUDY AND SUPPORTING DOCUMENTS (CONTD.)

No.	Name	Position	Credentials
17-	Abdel Kareem Bourini	Core Team/Team Leader/Social Scientist-Resettlement and Land Acquisition / indigenous People Specialist	B.Sc. in Comm. Major Economics Diploma in Demography
18-	Dr. Issa Masarweh	Social Studies Team	Ph.D. in Sociology / Demography
19-	Mahmoud Hishmeh	Social Studies Team	M.Sc. in Population Studies B.Sc. in Sociology
20-	Abdel Rahman Jaber	Social Studies Team	B.Sc. in Civil Engineering
21-	Rola Quba'a	Environmental Health	M.Sc. in Environmental Technology B.Sc. in Environmental Health
22-	Lama El-Awad	Environmental Health	M.Sc. Environmental Management B.Sc. in Environmental Health
23-	Dr. Raoul Nasr	Core Team / Land use Planning - Regional Economist	Ph.D. in Agricultural Economics M.Sc. in Agricultural Economics B.Sc. in Agricultural Economics
24-	Baker Qudah	Agriculture and Rural Development	Postgraduate Diploma in Remote Sensing and Land Evaluation Postgraduate Diploma in Aerial Photo Interpretation and Remote Sensing for Soil Survey and Land Classification B.Sc. in Agriculture
25-	Dr. Mohammad Waheeb	Cultural Heritage - Archaeology Studies Team Leader	Ph.D. in Archaeology M.A. in Archaeology B.A. in Archaeology
26-	Niveen Hashash	Cultural Heritage - Archaeology	M.A. in Archaeology B.A. in Archaeology
27-	Mofid Hamza	Remote Sensing Specialist	Diploma in Geomorphology and Remote Sensing Engineering Geology
28-	Saed Aqel	GIS and Remote Sensing Specialist	B.Sc. in Civil Engineering M.Sc. in GIS Training courses
Support Staff			
29-	Hasan Naseef	Biotic Environment Studies	B.Sc. in Civil Engineering
30-	Husam Hawwari	CAD/GIS Specialist	Diploma in Drafting
31-	Rawshan Ramadan	Social Studies Survey Team	M.E. in Civil Engineering B.Sc. in Civil Engineering
32-	Ahmed Yousef	Public Consultation Team	B.Sc. in Civil Engineering
33-	Rami Salameh	Project Specific ESA	B.Sc. in Water and Environmental Management
34-	Hala Mesmar	Project Specific ESA	B.Sc. in Water and Environmental Management
35-	Raja' Al-A'araj	Project Specific ESA	Diploma – Secretarial Work

ANNEX B3
LIST OF REFERENCES

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