This plan has been authored by the Water Sector Planning Support Project in the framework of cooperation between the Ministry of Water and Irrigation and GTZ, with support from AHT, BGR, Engicon, Dr. Fritz Käser and Siegfried Holtkemper.
The National Water Master Plan

Objectives

Without water, there is no life. Individuals, private companies and public institutions are taking great efforts to make water useable for their needs - be it drinking water, pastoral needs, industries, agriculture or others. In order to coordinate these activities, and to safeguard that the resources are also available for future generations, a common planning framework is needed. This framework is given by the Water Master Plan.

According the United Nations, the primary objective of a Water Master Plan is to establish a basic framework for:

- orderly and integrated planning and implementation of water resources programs and projects; and
- a rational water resources management consistent with overall national socio-economic development objectives.

(Guidelines for the preparation of National Water Master Plans, Water Resources Series No. 65, UN, N.Y. 1989)

Background and Principal Components

The Formulation of a Water Master Plan is a principal task of the state. In the Hashemite Kingdom of Jordan, this task is performed by the Ministry of Water and Irrigation. The old Masterplan from 1977, which had been formulated with assistance the German Government, needs to be updated and revised. Again, the German Agency for Technical Assistance (GTZ) is supporting the Jordanian Government in this task.

The new Masterplan will not be a static printed document but a Digital Water Master Plan based on an extensive Water Information System (WIS). In close cooperation with the Ministry of Water and Irrigation and GTZ, the German consulting company AHT International has developed the Digital Planning Tools. These software tools are database applications with a GIS (digital mapping) interface that are applied to:

- Assess the present availability, withdrawals, losses and uses of the water resources;
- Formulate alternative development scenarios for water resources and demand/use at various planning horizons;
- Perform the balancing of resources versus demands for the recent past as well as for the alternative development options and
- Identify technical and operational options in order to bridge the gap between resources and demands.
Basic components and functionality of the Digital Masterplan

**Water Information System (WIS)**

The Digital Water Master Plan receives its data from the Water Information System (WIS). This is the central information system at the Ministry of Water and Irrigation, serving the Ministry as well as WAJ (Water Authority of Jordan) and JVA (Jordan Valley Authority). In addition, it is the authorised source for data on water monitoring, management, and planning for external users like research institutions or international donors.

The WIS is a complex system of hard- and software, data and tools as well as people for its operation and maintenance. It can be accessed from all computer workplaces within the Ministry’s network. The majority of data is either stored in ORACLE data base tables or in GIS files. These two data systems are linked, thus permitting both the data selection by inter-active maps and cartographic representation of results.

The WIS contains monitoring data collected in the field either by operators of the water supply and wastewater disposal systems (namely WAJ and JVA), the hydrological service of the Ministry and/or external institutions like the Department of Statistics and the Ministry of Agriculture. In addition to the monitoring data the WIS holds the results of water demand and resources projections.

In order to facilitate data exchange, a unified coding compulsory for all water authorities is under development. This process is coordinated by the *Working Group on Standardization of Data and Information Flows*. 
The two primary user interfaces of the WIS are the **Data Entry and Visualisation Application (DEVA)** and the **Digital Visualisation System (DVS)**. The DEVA (written under Oracle developer) is both used for data entry and the production of reports in a fixed format.

The DVS is specially made for the master plan allowing to produce standard information products in an automated way. It is an MS-Access application with integrated MapObjects GIS modules for spatial selection and cartographic outputs. The DVS is applied to monitoring and forecast data to produce standardized tables, charts and maps under Excel. Thus, its results can be easily post-processed with Office software.
Examples of user-interfaces of the DVS software.
**Digital Planning Tools**

The Digital Planning Tools are a set of interactive software modules applied to forecast water resources and demands for future development scenarios. These forecasts are always using recent monitoring data as a starting point. The results are stored into the so-called Scenario Tables Pool (STP), which is part of the central ORACLE database administered under the WIS. From there, the information on future resources and demands is taken for nation-wide water balancing.

![Modular Structure of the Water Balancing Model](image)

**Principal data flow – from the pre-processing modules to balancing**

The Digital Planning Tools have been developed under MS-Access 2000 in VBA (Visual basic for Applications), the most common programming language under the Windows operating system. The Digital Planning Tools have a modular structure and the software code is open to the IT personnel in the Ministry. This will allow future modifications and extensions with the Ministry’s own resources.

**Examples of user-interfaces of the digital planning tools for resource estimation**
Example of a user-interface for demand estimation (irrigation)

Digital NWMP
A Water Master Plan as a document is consisting of the following principal parts:

- The description of the water resources (surface and ground water plus alternative resources) in quantity and quality
- The description of the present and likely future development of water demands by different user sectors;
- The presentation of the technical (physical) and operational water management measures to fulfil the demands in their temporal and spatial distribution under consideration of social, environmental and economic aspects.

Due to the complexity of the task, a master plan is structured in several layers like executive summary, main report (in several volumes) and various technical annexes and appendices.

A digital master plan is such a document in digital or electronic format. This has several big advantages: portability (the whole document fits to a CD-ROM) and easy navigation within and between the various parts and layers of the document. Most important, however, is the facility to easily update the document.

To obtain that functionality, two additional features are required. First, the document must have a standardized structure of small individual units linked with each other. It was agreed to use in principle the system-independent file formats HTML (hyper text mark-up language, which is commonly used for Internet web pages) and PDF (portable document format). Secondly, an additional software shell is required to convert the “raw documents” into the agreed document formats in order to integrate them into the overall structure of the digital master plan.
Contributions for the NWMP

I. From the Ministry of Water and Irrigation

NWMP Directorate

Director: Eng. Suzan Taha
Environment, Wastewater: Eng. Rania Abdel Khaled
Groundwater Quality, Data Management: Eng. Lana Naber
Demand Forecast: Eng. Rasha Sharkawi
Industrial Wastewater, Demand Forecast: Eng. Nisreen Haddadin
Institutional Issues: Eng. Nisreen Haddadin

Water Resources Directorate

Director: Eng. Edward Qunqar
Monitoring Network: Dr. Issa Nsour
Groundwater Water Monitoring: Dr. Issa Nsour, Eng. Ali Subah
Groundwater Modeling: Eng. Nidal Khalifeh

Project Finance Directorate

Director: Eng. Maysoon Zoubi
Project Cost Assessment: Eng. Hisham Bashir
Investment Programming: Eng. Maysoon Zoubi

MIS Directorate

Director: Eng. Mohammad Bany Mustafa
Database Administration and Programming: Eng. Ibtisam Al Saleh

II. From the Jordan Valley Authority (JVA)

Dams Department, GIS-Department, MIS Directorate, Deir Alla Control Center and Laboratories, JVA
Investment Directorate.

III. From the Water Authority of Jordan (WAJ)
Operation and Maintenance Directorate, Sewage Operation Directorate, Billing Department, MIS Directorate, Ground Water Basins Department.

IV. From the Planning & Management Unit (PMU)

UFW Directorate

IV. Others

Royal Scientific Society, Ministry of Agriculture, Department of Statistics, Ministry of Planning, Ministry of Tourism, Yachiyo Engineering - Japan, BGR - Germany, EMWIS (Euro-Mediterranean Information System on the Know How in the Water Sector), ARD - USA, Richard Allen

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2 Planning Framework

2.1 The Institutional and Legal Framework

The Government of Jordan strives to implement a sound legal and administrative framework to best address the foreseeable striking future water shortage.

2.1.1 Water Administration and Water Utilities in Jordan

Three institutions take responsibility for water administration in Jordan: Ministry of Water and Irrigation (MWI), Water Authority of Jordan (WAJ), Jordan Valley Authority (JVA)

MWI is the official body responsible for the overall water and wastewater system and the related projects, planning and management, the formulation of national water strategies and policies, research and development, information systems and procuring financial resources.

WAJ was established as an autonomous corporate body, with financial and administrative independence linked with Minister of Water and Irrigation. WAJ became responsible for the public water supply and wastewater services as well as for the overall water resources planning and monitoring, construction, operations and maintenance. WAJ's Project Management Unit (PMU) regulates water and wastewater utilities under private management.

JVA has been established for the social and economic development of the Jordan Rift Valley including the development, utilisation, protection and conservation of water resources. The King Abdullah Canal represents the backbone of the JVA water distribution system in the north of the Dead Sea

WAJ and JVA are by law responsible for water supply and wastewater services in Jordan.

The Government of Jordan considers private sector participation and decentralisation as major elements of the reform process fostering the efficiency in the public service sector.

Since 1999 the water supply in Greater Amman is under private management. Major future water and wastewater projects are foreseen for further private sector participation.

2.1.2 Legal Framework for National Water Resources Management

Within the context of the National Water Master Plan the national management level is of particular relevance and plays an important role with respect to information availability,
co-ordination, policy development, planning, the legal framework, and human resources development as required for integrated water resources development and management (compare ICWE, 1992).

2.1.2.1 Principal Legislative Provisions

Legal responsibilities with regard to water resources monitoring and planning exist for MWI, WAJ and JVA. The Jordanian Institute of Standards and Metrology is charged with the duty of issuing standard specifications for the water sector in cooperation with representatives of MWI, WAJ, JVA and representatives of the Ministry of Health and the Ministry of Environment.

With due consideration of the provisions of the Water Authority Law, the Jordan Valley Development Law and any other amending or substituting laws thereof, MWI assumes full responsibility for water and public sewage in the Kingdom as well as for the projects pertaining thereto. MWI prepares the National Water Master Plan and water sector programs, formulates water sector policies and participates in the licensing of water abstractions.

2.1.2.2 Water Resources Management Information

Legal responsibilities for collecting water resources data and water sector planning exist for MWI, WAJ and JVA. The Ministry of Water established a comprehensive national water data bank as part of the Water Information System to support planning and decision-making processes. The major internal data source is the water resources monitoring network operated by the Water Resources Directorate of the Ministry. Water and wastewater production data as well as wastewater quality data are being collected from WAJ and JVA and entered to the WIS in MWI. Surface water quality is monitored by different entities and is not systematically covered by a nation wide monitoring network. Surface water quality is monitored by JVA along the Zarqa River course by the Royal Scientific Society in commission of WAJ.

Water sector project management is presently a task of WMI, WAJ and JVA, while MWI is responsible to pursue planning and monitoring of donor-funded projects. A central project database and a coordinating body for data and information management does not yet exist in the water sector.

2.1.2.3 Human Resources Development

According to the existing legislation MWI, WAJ and JVA manage personnel as internal affairs in line with provisions of the Civil Service Ordinance No. 55 of 2002. The said regulation is posing difficulties on the water authorities in recruiting and sustaining qualified staff with key capabilities in integrated water resources management such as finance management, computer aided water sector planning and information management/information technology.
2.2 The Policy Framework and Water Sector Strategies

Notwithstanding a very difficult regional and international environment, coupled with critical political and economic challenges, the Government of Jordan is undertaking an ambitious economical restructuring process, moving the economy from being public sector oriented into one where the private sector plays an important role.

In accordance with Article 5 of the Water Authority Law No. 18 of 1988 and pursuant to the Council of Ministers approval, the basic strategy and policies for the water sector of Jordan have been formulated and published by the Ministry of Water and Irrigation.

A sustainable use of the scarce natural water resources, in line with a continuous improvement in living conditions for the country's population, is the outstanding development goal for the water sector of Jordan.

2.2.1 Water Resources Strategies

On a per capita basis, Jordan is one of the water scarcest countries in the world. Therefore priority is given to the sustainability of use of the natural resources. On the other hand the full potential of surface water and groundwater shall be tapped to the extent permissible by feasibility, and by social and environmental impacts.

Jordan receives a large share of its water resources from international watercourses, namely Yarmouk River, Jordan River and the trans-boundary aquifers. The rightful shares shall be defended and protected through bilateral and multilateral contracts, negotiations, and agreements. The optimal regional water option and the related necessary degree of cooperation shall be determined by weighing various options under economical, political and environmental considerations.

Wastewater shall not be treated as waste. It shall be collected and treated in accordance with WHO and FAO Guidelines that allow its reuse in unrestricted agriculture and other non-domestic purposes, including groundwater recharge. The existing level of services shall be sustained and promoted.

2.2.2 Allocation and Development Strategies

The priority criterion for project implementation, and for additional water allocation shall be based on economic, social and environmental considerations. First priority will be given to the basic human needs; as such first priority is given to allocation of a modest share of 100 litres per capita per day to domestic water supplies. Expensive additional water has municipal purposes as a first priority in allocation, followed by tourism and industrial purposes.
Existing areas of irrigated agriculture shall be accorded to the chances for sustainability. Sustainability of agriculture shall be compromised only if it threatens the sustainability of groundwater resources. For irrigation purposes, and in the light of the tight water situation, wastewater is considered a resource and cannot be treated as waste.

2.2.3 Water Quality and Pollution Control Strategy

Setting and enforcing national health standards shall be enhanced and sustained, especially in regards of municipal water supply.

Collection and treatment of wastewater is considered obligatory in order to protect public health against water borne diseases. Wastewater shall be collected and treated in accordance with WHO and FAO Guidelines that allow its reuse in unrestricted agriculture and other non-domestic purposes.

Recharge areas of aquifers shall be protected to the maximum extend possible. Conflicts arising out of urbanization shall be addressed, and mitigation measures specified for the urban planners to have them included in the urban planning process. Over-abstraction from the aquifers shall be reduced to sustainable levels.

A network of observation wells shall be installed in each of the groundwater reservoirs or part thereof for the purpose of monitoring and laboratories for pollution controls shall be maintained and properly equipped.

2.3 The Regional Framework

For the regional review of the present utilization and the potential allocation of the water resources, spatial units need to be defined. In addition to natural catchments, which are of priority for allocation plans due to ecological constraints, socio-economic regions and administrative units are of importance in order to consider overall development goals in the water allocation strategy.

In order to assure that the proposed water allocation meets the socio-economic development needs of the country, socio-economic development areas have been delineated. The definition of the socio-economic areas is based on the following criteria: population and population density, irrigation areas, irrigation density and industrial water consumption.

2.4 Water Sector Development

Despite enormous progress in water supply and sanitation, Jordan needs to challenge increases in demand running ahead of water resources developments due to vast population growth and rising per capita demands. These challenges require gaining efficiencies throughout the water sector, namely in institutional development, in water resources development and demand management as well as in water allocation with due
respect of private sector participation. Hence Jordan's water sector development shall follow the principals of an integrated water resources management securing the needs of future generations.

The economical restructuring process, aiming to move the Jordanian economy from its public sector orientation into one where the private sector plays an important role, has strong implications on the institutional development in the water sector. Therefore, the present legal/institutional set-up for the water sector needs adjustments to match the requirements of the future more commercially oriented service sector:

- A lean and efficient administration which is going to oversee water sector development in the light of national socio-economic needs, and environmental and sustainability implications.
- A sound legislation allowing private sector participation, whose operations will be scrutinized for their service orientation and efficiencies, and compliance with the set national development objectives.

The Ministry of Water and Irrigation has elaborated an action plan (MWI, 2002c) in order to address the above-mentioned development goals. This action plan has been approved by the Cabinet of Ministers and shall be updated in due time.

2.4.1 Legislative Development

The Ministry of Water and Irrigation needs to be legally empowered to take the lead in all matters related to national water resources and project management on the national scale to assure a sound water sector development. This scope of responsibility should comprise:

- Water sector legislation and water standards
- National water master planning and policies,
- National water resources and project management,
- Water rights.

The present water legislation is rather meant to define institutional responsibilities than to define an overall comprehensive vision for the national water resources management. Hence, at present overlapping responsibilities arise in between the different relevant water sector institutions. Therefore it is recommended to issue a comprehensive Water Law, which streamlines the existing water sector legislation.

The National Water Master Plan should be legally empowered as superior plan for all water sector development plans to assure consistent orderly planning on all administrative levels in line with the overall national water strategy (UN, 1989). Investment planning should be considered an integral part of the National Water Master Plan.
Water rights and project financing are the major means to implement water sector strategies. Hence, the responsibility in this respect should be with MWI.

### 2.4.2 Institutional Development

MWI, WAJ and JVA shall remain the administrative institutions with an overall responsibility for the water sector in Jordan. The organisational set-up of the institutions is recommended to be restructured for the sake of efficiency improvement and coherence with the proposed responsibilities of the Ministry of Water and Irrigation. The tasks of each institution shall be clearly defined and reflected in an officially introduced business distribution plan with an organisational chart and job descriptions for all staff.

All possible forms of private sector participation shall be in principal applicable for the improvement of service efficiency and viability in the water sector.

Decentralisation shall be applied wherever appropriate in order to increase transparency and customer orientation in all services and to ensure an appropriate participation of local communities in all phases of water management (compare ICWE, 1992).

The operation of water supply and wastewater utilities should be strictly separated from any resources monitoring in order to avoid interest conflicts.

### 2.4.3 Water Resources Development and Allocation

Jordan's renewable natural water resources including Yarmouk River water are estimated to be in the range of 800-850 MCM/a out of which 275 MCM/a are considered sustainable groundwater abstractions from wells and springs (safe yield). The contribution of the Yarmouk River is considered to be 230 MCM/a.

The actual groundwater abstraction exceeds the said safe yield by far and reaches presently approximately 180% of the safe yield. About 50% of the groundwater is used for irrigation purposes. As the present groundwater abstractions are not sustainable, the Government of Jordan envisages to reduce the groundwater abstractions continuously to reach the safe yield level by the year 2020. It is foreseen to substitute groundwater with reclaimed water in agriculture and industrial use. Increasing wastewater collection and appropriate wastewater treatment and reuse are therefore of high priority. Water reuse is expected to exceed 200 MCM/a by the year 2020, while the present reuse is in the range 70 MCM/a. It is worthwhile mentioning, that farmers in the southern Jordan Valley operate private desalination plants to treat brackish groundwater for irrigation water production.

A major additional groundwater resource is foreseen to be developed in Disi. From this non-renewable resource about 100 - 125 MCM are planned to be tapped for M&I supplies.
The development of surface water resources requires sufficient reservoir capacities. The planned dam capacity will deliver estimated safe yield of 191 MCM in 2005. Further dams are under construction in order to provide additional reservoir capacities in the range of 60 MCM with an expected safe yield of 272 MCM until 2020.

Desalination of seawater and brackish water is foreseen to contribute up to 55 - 60 MCM to M&I supplies.

In total it is planned to increase net supply to municipal and industrial uses from presently 280 - 290 MCM/year to about 380 MCM/Year in the year 2020.

During the above-mentioned planning period adequate action shall be taken to reduce groundwater abstractions to the safe yield level to protect Highland aquifers from salinisation.

2.4.4 Demand Management

Despite ongoing projects and plans to mobilise additional water resources, options for further resources development are very limited and demand side oriented management is of increasing importance similar to other countries in the region.

2.4.4.1 Demand Management

"Water Demand Management" is an objective oriented approach to influence "Water Demand" by means of macro- and micro-economic measures (market policies, marketing, pricing), quoting and/or rationing, education and public awareness rising.

Water demand management within the framework of integrated water resources management encompasses various functions to increase allocation and water use efficiency. Various projects have been set up to reduce water consumption and to reduce water losses.

2.4.5 Scenario Development and Balancing Analyses

Dynamic population growth, wide spread poverty and very limited natural water resources characterise the conditions for Jordan's future economic development. Notwithstanding these adverse development conditions considerable progress in improving people's living conditions could be achieved through decisive economical reforms and fostering free trade, tourism and information technology.

Within the framework of the NWMP demand development and resources availability have been projected until the year 2020.
2.4.5.1 Water Demands

Population growth is considered the major parameter influencing future water demand development. Although Jordan is striving to reduce population growth, population growth is likely to remain on a high level. Until the Year 2020 Jordan's population will be grown to 7.0 to 9.0 Mio. Taking the said population growth and the expected increasing municipal per-capita demands into consideration, municipal demands will double until the year 2020. It is expected that almost 70 % of the projected municipal demand will occur in the urban centres Greater Amman and Irbid.

Considerable investments from the private and public sector in touristic developments could be noted throughout the last years. This trend is expected to continue in the nearer future increasing.

Table 1: Projected Annual Water Demand per Sector including Physical Losses

<table>
<thead>
<tr>
<th>Sector</th>
<th>Water Demand (including physical losses) [MCM, (%)]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>2005</td>
</tr>
<tr>
<td>Municipal and Tourist Industry</td>
<td>372 (24)</td>
</tr>
<tr>
<td>Industry</td>
<td>59 (4)</td>
</tr>
<tr>
<td>Agriculture</td>
<td>1102 (72)</td>
</tr>
<tr>
<td>Total</td>
<td>1534 (100)</td>
</tr>
</tbody>
</table>

The growth in industrial water demand is expected to be moderate for the existing industries while considerable incremental increases are expected due to major industrial projects planned.

Because of the rapid population growth agricultural water demand is already at present far beyond the natural population support capacity, irrigation water requirements have been formulated as water demand to sustain farmland presently under irrigation.

2.4.5.2 Water Resources

Natural water resources potentials have been assessed on the basis of hydrological data of the Ministry's water information system by applying a computerised rainfall/runoff model. The scenario on natural resources availability is based on the natural resources assessment itself and the assumption, that water development projects such as dams, wells and conveyors will be implemented.

In addition to the renewable groundwater resources, non-renewable groundwater like from the Disi-aquifer is considered for development and conveyance to the urban development centres for municipal supplies. The development of non-renewable water resources contradicts the idea of a sustainable development and is therefore only planned to bridge the cap until sufficient alternative sustainable resources can be made available.
Jordan's surface water resources are indigenous flood flows and resources from international water rights on the Yarmouk River and international water rights on the Jordan River.

Table 2: Resource Availability in Jordan for the Years 2005 - 2020

<table>
<thead>
<tr>
<th>Year</th>
<th>Additional Resources</th>
<th>Baseflow</th>
<th>Groundwater</th>
<th>Dam Safe Yield(^1)</th>
<th>Non-Conventional Water(^2)</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>2005</td>
<td>343.6</td>
<td>157.1</td>
<td>259.1</td>
<td>224.8</td>
<td>34.3</td>
<td>1018.9</td>
</tr>
<tr>
<td>2010</td>
<td>511.2</td>
<td>144.1</td>
<td>259.1</td>
<td>259.9</td>
<td>69.3</td>
<td>1243.7</td>
</tr>
<tr>
<td>2015</td>
<td>453.9</td>
<td>144.1</td>
<td>259.1</td>
<td>274.4</td>
<td>88.6</td>
<td>1220.1</td>
</tr>
<tr>
<td>2020</td>
<td>455.9</td>
<td>132.5</td>
<td>259.1</td>
<td>300.9</td>
<td>101.2</td>
<td>1249.6</td>
</tr>
</tbody>
</table>

\(^1\) including treated wastewater discharged to wadis  
\(^2\) Locally available treated wastewater

Non-conventional water resources such as wastewater and desalinated water are of increasing importance as demands exceed by far the available conventional freshwater resources. Wastewater reuse is foreseen in irrigated agriculture in the Jordan Valley, along the Zarqa River and to a smaller extend in the vicinities of wastewater treatment plants in the highlands. Reuse of treated effluents is planned as well for some industries.

2.4.5.3 Water Balance Analyses

Taking into account the above-mentioned demand and resources assessments, Jordan will face an increasing and precarious water shortage in the foreseeable future.

Dramatic deficits occur in the balancing units covering the urban development centre Greater Amman justifying the development of the non-renewable resources in Disi. It will not be possible to meet the projected water demands with the projected water resources until the target year 2020, unless the measures outlined in Volume 9 Water Balances and Allocation are followed.

Water demands have been balanced taking into account present water transfers in order to investigate whether present water allocations are in line with Jordan's Water Strategy and to which demand centres the valuable additional water resources shall be allocated.

2.4.6 International Co-operation

In addition to the pressure on the country's water resources caused by a high population growth, present groundwater abstractions have to limited to the safe yield level rising the need for a restrictive demand management and the development of alternative resources.
The development of even limited quantities of new 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 the annual water supply of only 400 MCM. In the light of the sustainable financial resources of Jordan it becomes obvious, that the continuous assistance of donors is needed for the foreseeable future.
3  Water Uses and Demands

3.1  Introduction

Jordan is considered to be one of the 10 poorest countries worldwide in water resources, and has a population growth rate of about 2.9% (1998-2002), the 9th highest in the world. The available renewable water resources are dropping drastically to an annual per capita share of 160 m$^3$/cap/a in recent years, compared to 3600 m$^3$/cap/a in 1946. Factors prompting such a decrease include, aside from the most prominent one of steep population growth, sudden influx of refugees due to political instability in the region. Competition between demands on limited fresh water quantities is ever increasing. Currently irrigated agriculture is the largest consumer constituting around 64% of the overall uses compared to only 36 % for municipal, industrial and tourism (MIT) purposes.

The purpose of this volume is to assess the future water demands. Section 1 of this report is dedicated to the examination of the historical development of MIT and irrigation water uses based on which water demand projections are made for the planning horizon considered in the Master Plan; 2005-2020 (Section 2). The projections are based on the results obtained from the demand pre-processing modules currently deployed at the Ministry of Water and Irrigation, National Water Master Planning Directorate that were developed with the assistance of the German Technical Cooperation (GTZ).

3.2  Data & Definitions

3.2.1  Municipal and Tourism Sectors

Municipal consumption (M) in the context of the National Water Master Plan (NWMP) refers to the water consumed in a given historical year by the domestic, commercial and pastoral sectors in addition to the light industries, while touristic water consumption (T) is the amount of water used by hotels and furnished apartments. Both M and T get their water from the public supply network, and appear in the Water Authority of Jordan (WAJ) billing information under pre-defined category numbers.

Data on actual municipal and touristic network water consumption can be readily estimated using the billing and supply data obtained from WAJ for all governorates, except Greater Amman, where Lyonnaise des Eaux - Montgomery Watson - Arabtech Jardaneh (LEMA) is charged with municipal water supply under a management contract. Billing data is available on a quarterly basis for all subscribers connected to the network within a settlement, and hence can be aggregated for each settlement and subsequently for any spatial unit under consideration. WAJ billing data considered for analysis was for the historical years under consideration in this report, 1996-2001.

WAJ billing data are also stored in tables in the Ministry's Water Information System database (WIS). Relevant tables contain accumulated water billed by use type, quarter and settlement.
For the purpose of municipal demand projections, the population projections based on the latest Department of Statistics (DOS) growth figures were considered. According to projections on the population growth conducted by DOS in the year 2003, Jordan's population will have almost doubled in 22 years based on the population in 1998 (Figure 1), despite the considerable decrease in growth rates expected during the same period, due to national strategies to increase awareness in birth control and family planning.

Figure 1: Population projections, 1998-2020

### 3.2.2 Industrial Sector

Of the about 18400 industries in Jordan, only a small percentage is considered as industrial water consumers: Most are small to medium industries and can be classified as dry processes industries. Their water use is part of the municipal consumption. Industrial consumption within the NWMP context refers only to the amount of water consumed by industries, which utilise water produced locally; mainly from deep wells, with the exception of the two major industries in Aqaba; the Thermal Power Station and Jordan Fertilizer Industry Company that are currently receiving their water from the public network.

Three classes of industries can be distinguished with respect to water supply:

1. Industries supplied by public networks. Examples: the Thermal Power Station and Jordan Fertilizer in Aqaba Special Economic Zone (ASEZ).

2. Industries operating their own groundwater supplies (wells). These constitute most of the industries in Jordan.
3. Industries operating Surface Water Supplies. These are limited to two industries, namely the Tomato Paste Factory in Deir Alla, and Potash Co. on the Dead Sea shore, with the latter being supplied from both groundwater and surface water.

Data related to the industries and their respective water consumption is available for each source type in the WIS. Relevant WIS tables contain compiled information on the big industries and the respective surface water and groundwater produced locally, together with the amount of water billed from the only two big industries, which receive their water from the public network supply: the Thermal Power Station and Jordan Fertiliser Industry Company in Aqaba.

3.2.3 Irrigation Sector

Irrigation in Jordan occurs mainly in three distinct areas: The Jordan Rift Valley, the North-eastern Desert and Azraq region, and the Southern Desert in the Disi and Mudawwara areas. The Jordan Valley Authority (JVA) supplies irrigation water in the Jordan Rift Valley (JRV), using surface water from Yarmouk River and the side wadis, in addition to treated wastewater. Groundwater is used to a lesser extent in the Valley mostly by farmers in the Southern part of the Valley. In the uplands, irrigation water is pumped from licensed or unlicensed private wells, tapping both renewable and non-renewable groundwater, and to a lesser extent from surface water.

Water consumption in irrigation is defined as the amount of water actually consumed by crops, being equivalent to determining the Actual Evapotranspiration (ETa) (FAO, 1977). As actual evapotranspiration data is not available, use was made of existing agriculture water supply data available in the Ministry's WIS to assess the historical development of the sector water use in Jordan. Water supply data in the JRV is provided by (JVA), in the uplands it is either recorded by water meters on irrigation wells or estimated based on the well capacity and/or planted area and crop.

In addition to water supplied, the data necessary to compute irrigation water requirements was gathered from individual sources including MWI, JVA, Department of Statistics and Ministry of Agriculture and stored in tables in the WIS database. These data include cropped areas, crop type, irrigation methods, leaching requirements, and meteorological data.

3.3 Methodology

Data stored in the WIS was either exported and processed using spreadsheet software, as in the case of historical use analysis or processed by two customised software programs, the Pre-Processing Module and the Irrigation Module, as in the case of water demand projections. Said modules were developed as part of the National Water Master Plan (NWMP), in order to have structured tools to forecast developments of the municipal, industrial, tourism, losses and irrigation demands, as well as the development of anthropogenic water resources (wastewater and additional resources). Data are read from
written to the central WIS database or, in the optional off-line operation, a copy of the relevant data tables under a local database.

Inputs of the Pre-Processing Module belong to two different groups:

- Demand-related inputs such as population development, per capita demand, types of industries, number of tourist beds etc. and
- Consumption-related like network distribution to various sub-sectors, industrial water use etc.

Outputs of the Pre-Processing Module are monthly water demands per demand centre (settlement). The salinity class of the water is stored as well. The module calculates monthly consumption for historic years and permits particularly the calculation of monthly demands for future scenarios.

Inputs of the Irrigation Module are mainly agricultural statistics and Net Irrigation Requirements (NIR). The agricultural statistics are on the level of irrigation centre and encompass the areas and percentage of irrigation technologies applied for the different crop groups in a reference year. The NIR are calculated for different year types (dry, median, wet) and agro-climatic zones by a separate pre-processing application (NIR_Calculator). Leaching is also considered in the module. The irrigation demand model which is linked to a central Oracle database and GIS databases, predicts irrigation water demand in the future based on information provided for a given reference year. Hence, proceeding with assumptions regarding the future is only possible after the reference year demand computations is completed and evaluated.

Outputs of the Irrigation Module are monthly irrigation water demands per irrigation centre. Thereby, gross irrigation demands, application and distribution losses are distinguished. The module calculates these figures for historic years and permits also the configuration and calculation of future scenarios.

The operation of both the Pre-Processing and Irrigation Modules (user-interface) is completely through graphical controls, starting from the spatial selection of demand centres with a GIS module via visualisation of results (both graphical and tabular) to the saving of results. All user-entries are recorded in log tables, thus permitting their review and modification or their exchange with other users (through an upload to the central database) or their exchange with other users (through an upload to the central database).

### 3.4 Historical Water Consumption

#### 3.4.1 Municipal Sector

Under ideal conditions, actual municipal and touristic water consumption should be equal to water billed. However, in reality the former exceeds billed amounts due to
administrative losses; i.e. water not accounted for due to illegal abstractions, non-operational meters and/or un-metered connections as shown below.

Hence municipal consumption had to be estimated based on the difference between Water Supplied and Water Billed provided by WAJ on a governorate basis. This difference represents all Unaccounted For Water (UFW) resulting from administrative losses and physical network losses:

\[
UFW = \text{Water Supplied} - \text{Water Billed}
\]

whereby

\[
UFW(\%) = \text{Administrative Losses}(\%) + \text{Physical Losses}(\%)
\]

\[
UFW(\%) = (1 - (\text{Water Billed}/\text{Water supplied})) \times 100\%
\]

and

\[
\text{Water Consumption} = \text{Billed Water} + \text{Administrative Losses}
\]

In order to estimate administrative losses and subsequently water consumption, physical losses were assumed to be more than half of the UFW at 30% nation-wide.

Review of historical data shows an average municipal consumption of 163 MCM/a, equivalent to 94 l/c/d (Figure 2). The nationwide decrease from 103 l/c/d in 1996 to 86 l/c/d in the year 2001 clearly indicates the increasing pressure of growing population on limited water supply and resources. Amman has the largest share in total municipal consumption countrywide, amounting to close to 40% (65 MCM/a).
Per capita consumption on a governorate level is highly variable. This reflects partly the significant variations in administrative losses experienced due to the technical and socio-economic particularities found in each governorate. Pastoral and illegal uses seem quite dominant in governorates like Mafraq and Ma'an, and until recently in Madaba governorate, where areas witnessing high losses were annexed to LEMA mandated area in the year 2000. Big consumers in Aqaba such as the city port and some water consuming governorate institutions move the per capita consumption share to the upper end of the nation's consumption scale. Other factors contributing to such discrepancies include variation in standards of living, degree of urbanisation, and local technical conditions, such as the absence or inoperability of water meters.

3.4.2 Tourism Sector

Available historical data provided by WAJ shows that the nation's annual touristic water billed ranges between 1.1 and 1.5 MCM/a during the period 1996-2001. This translates into an estimated touristic consumption (including administrative losses) of 1.6 and 2.2 MCM/a, respectively (Table 1)
Table 1: Historical Touristic Water Consumption; 1996-2001 (MCM/a)

<table>
<thead>
<tr>
<th></th>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Amman</td>
<td>1.45</td>
<td>1.42</td>
<td>1.10</td>
<td>1.28</td>
<td>1.03</td>
<td>0.84</td>
<td>1.19</td>
</tr>
<tr>
<td>Aqaba</td>
<td>0.43</td>
<td>0.49</td>
<td>0.42</td>
<td>0.53</td>
<td>0.75</td>
<td>0.74</td>
<td>0.56</td>
</tr>
<tr>
<td>Irbid</td>
<td>0.04</td>
<td>0.04</td>
<td>0.03</td>
<td>0.09</td>
<td>0.08</td>
<td>0.08</td>
<td>0.06</td>
</tr>
<tr>
<td>Others</td>
<td>0.04</td>
<td>0.04</td>
<td>0.04</td>
<td>0.26</td>
<td>0.20</td>
<td>0.17</td>
<td>0.13</td>
</tr>
<tr>
<td>Total</td>
<td>1.97</td>
<td>1.99</td>
<td>1.59</td>
<td>2.17</td>
<td>2.06</td>
<td>1.83</td>
<td>1.94</td>
</tr>
</tbody>
</table>

Due to the progressive touristic expansion in Aqaba city, the touristic consumption in the governorate of Aqaba has been increasing both in absolute and relative terms, from a total of 0.44 MCM/a; 22% of touristic consumption in 1996, to about 0.74 MCM/a in the year 2001 at about 41%, whilst the share of Amman governorate has been falling from 74% to 46% during the respective years. In absolute terms, one would expect that similar investment in big hotels mostly in the capital city of Amman during the most recent years would result in increased touristic consumption in Amman Governorate. However available records show the contrary.

The highest per capita touristic shares exist in Aqaba and Amman governorates, at an average of about 17 and 2 l/c/d (1996-2001), respectively. The increasing number of hotel beds in Ma'an governorate (mostly in Petra) and the advancement in touristic development along the Dead Sea shore in Balqa governorate account for the most recent increase in per capita share of touristic consumption in these governorates.

Despite the steady increase in the number of bed units during the past years, from 22735 bed units in 1996, to 37385 units in the year 2001, WAJ records show almost steady values for the historical amounts of water billed. This suggests that hotels are increasingly buying water from tankers (who obtain their water from privately owned wells licensed for domestic water sales) in order to maintain a regular supply of water throughout the year. Review of the records of some big hotels in Amman City suggests that water tankers provide about 40-50% of annual consumption. Subsequently one might consider that the touristic water consumption is almost double the estimated actual consumption. Keeping this in mind, the average per capita share nationwide may reach 2.0-2.4 l/c/d.

### 3.4.3 Industrial Sector

Jordan's industrial sector is mainly composed of mining and quarrying and manufacturing, and absorbs about 16% of the labour force in the country. Large-scale industries consist mainly of phosphate and potash mining and the industrial production of
cement, fertilisers and refined petroleum. Large industries contribute the lion share of 86% of the industrial water consumption totalling about 32 MCM in 2001.

The total amount of water used for industries during the years 1989-2001 is shown in Figure 3. A general increase in industrial consumption could be identified during the past decade. The decrease starting 1999 however reflects the cut down in phosphate production in Hassa, and Wadi Al Abyad mines due to increased cost of mining.

Major water consumers in Jordan's industrial sector are limited to nine big industries, located in five governorates and consuming about 86% of the total water used by industries. The biggest single consumer is the Arab Potash Company at the Dead Sea, consuming around 33% (10.6 MCM/a) of the total industrial consumption. About 12% of the total water consumed by industries is fossil groundwater (Disi) supplied to the Thermal Power Station and Fertiliser Co. through the public network in Aqaba (2001). Substitution of Disi water with treated effluent of Aqaba Wastewater Treatment Plant after its upgrade is intended however in the near future, in order to conserve the good quality Disi fossil water for municipal use.

![Figure 3: Industrial Water Consumption in Jordan 1989-2001 (MCM/a)](image)

### 3.4.4 Irrigation Sector

The irrigation share of the total water uses demonstrates significant decrease during the period 1985-2002 (78% in 1985 to 64% in the year 2002). In absolute figures irrigation water use has also been reduced from its peak in 1993 (726 MCM/a) to 511 MCM in the year 2002 (Figure 4). Factors contributing to such decrease may be restrictions on well
drilling, equipping private wells with water meters, and reduction in irrigated areas due to water shortages ensuing from the persistent drought throughout 1998 - 2002. While the latter is believed to have had significant impact on the use of surface water for irrigation, it is unlikely that mere monitoring of groundwater abstractions for irrigation could have reduced irrigation use in the absence of reinforcement measures or agricultural water charges.

The use of surface water for irrigation in Jordan has declined in both absolute and relative terms from 249 MCM (42%) of total irrigation use in 1996, to 157 MCM (31%) in 2002. Groundwater use decreased from 290 MCM in 1996 to 216 MCM in 2002, with a steady relative portion of 48% of total uses. The amount of treated wastewater used in irrigation rose from 59 MCM (10%) in 1996 to 70 MCM in 2002 (16%) nationwide. Due to the progressive replacement of fresh water with treated wastewater originating at the highlands, mostly from Amman-Zarqa urban area, the use of treated wastewater for irrigation in the JRV has been increasing steadily and is currently estimated at some 60 MCM; about 84% of the total effluent reuse nationwide.

![Graph showing total irrigation uses from 1996 to 2002](image)

**Figure 4: Total irrigation Uses 1996-2002 (MCM/a)**

Excessive groundwater abstractions from the different aquifers for all purposes have resulted in the decline of groundwater levels and degradation of water quality of some aquifers in the country. In addition to prohibiting additional well drilling, more measures...
such as abstraction fees and fines for exceeding licensed amounts are needed to remedy the groundwater management situation.

3.5 Future Demand Projections

3.5.1 Municipal Sector

While Jordan is presently suffering from decreasing domestic per capita share reaching 86 l/c/d in 2001, it is expected that such a trend will continue if no additional resources are developed. Jordan is therefore striving not only to maintain domestic consumption at its current levels, but also to boost it to internationally accepted standards, at 150 l/c/d.

Municipal consumption was therefore estimated to increase up to an approximate target of 150 l/c/d (excluding losses and tourism) in the urban areas of Greater Amman and Irbid, and 132 l/c/d in rural areas. Higher municipal per capita demands are particularly expected in Aqaba governorate, (155 l/c/d) where major economic development is foreseeable within the Aqaba Special Economic Zone (ASEZ).

Projects to augment water supply are therefore underway hand in hand with development of water management infrastructure and investments in water loss reduction programs to increase the production of fresh water supply. Water loss reduction programs covering Amman, the Northern Governorates (Irbid, Jarash and Ajloun), Mafraq, Karak, Zarqa and Aqaba are in progress and are expected to reduce the physical losses down to 15-20% of the municipal water supplied by the year 2020 (Figure 5).
Table 2 illustrates the resulting projections of the gross municipal water demand up to the year 2020 considering the latest DOS population growth figures of 2003 (See Figure 1).

Table 2: Gross municipal water demand development per governorate (MCM/a)

<table>
<thead>
<tr>
<th>Governorate</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>AJ</td>
<td>7.56</td>
<td>8.30</td>
<td>9.24</td>
<td>10.55</td>
</tr>
<tr>
<td>AM</td>
<td>147.05</td>
<td>158.17</td>
<td>176.07</td>
<td>195.18</td>
</tr>
<tr>
<td>AQ</td>
<td>9.60</td>
<td>10.46</td>
<td>11.48</td>
<td>13.24</td>
</tr>
<tr>
<td>BA</td>
<td>24.39</td>
<td>28.27</td>
<td>31.58</td>
<td>33.90</td>
</tr>
<tr>
<td>IR</td>
<td>61.21</td>
<td>63.56</td>
<td>70.66</td>
<td>80.36</td>
</tr>
<tr>
<td>JA</td>
<td>9.28</td>
<td>10.19</td>
<td>11.35</td>
<td>12.97</td>
</tr>
<tr>
<td>KA</td>
<td>12.62</td>
<td>14.18</td>
<td>15.39</td>
<td>17.57</td>
</tr>
<tr>
<td>MA</td>
<td>9.03</td>
<td>10.68</td>
<td>11.64</td>
<td>12.52</td>
</tr>
<tr>
<td>MF</td>
<td>14.10</td>
<td>17.20</td>
<td>18.90</td>
<td>21.90</td>
</tr>
<tr>
<td>MN</td>
<td>6.39</td>
<td>8.36</td>
<td>8.58</td>
<td>9.36</td>
</tr>
<tr>
<td>TA</td>
<td>5.12</td>
<td>6.15</td>
<td>6.65</td>
<td>7.16</td>
</tr>
<tr>
<td>ZA</td>
<td>60.55</td>
<td>68.99</td>
<td>72.70</td>
<td>78.69</td>
</tr>
<tr>
<td><strong>Jordan</strong></td>
<td><strong>366.90</strong></td>
<td><strong>404.50</strong></td>
<td><strong>444.24</strong></td>
<td><strong>493.39</strong></td>
</tr>
</tbody>
</table>

About 72% of the total municipal demand (including losses) is expected to occur in the governorates of Amman, Zarqa and Irbid, compared with present consumption share of
67% (2001). On the other hand the share of Aqaba Special Economic Zone is estimated to fall a little short of 3% compared with around 4% in the year 2001.

The presently much lower municipal consumption (including losses) of about 235 MCM/a nationwide (Figure 6) is to be understood as the result of Jordan’s shortage in natural water resources. Besides Aqaba, which has the highest per capita consumption, all settlements are supplied intermittently. Amman city, with a population of 1.8 Million inhabitants in 2002, presently supplies its inhabitants once or twice per week. It is however expected that increasing water supply due to continuous network rehabilitation, and implementation of supply augmentation projects, together with higher standards of living and changes in the way of life will result in a much higher municipal per capita consumption.

Figure 6 shows that realistic judgment of future trends in population growth rates is a prerequisite to reliable municipal demand projections.

![Figure 6: Total Gross Municipal Demand Projections Incl. Losses (MCM/a)](image)

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>2001</td>
<td>232.5</td>
<td>232.5</td>
</tr>
<tr>
<td>2005</td>
<td>366.9</td>
<td>384.2</td>
</tr>
<tr>
<td>2010</td>
<td>404.5</td>
<td>436.4</td>
</tr>
<tr>
<td>2015</td>
<td>444.2</td>
<td>496.0</td>
</tr>
<tr>
<td>2020</td>
<td>493.4</td>
<td>564.3</td>
</tr>
</tbody>
</table>

Figure 6: Total Gross Municipal Demand Projections Incl. Losses (MCM/a)

### 3.5.2 Tourism Sector

The development of the tourist sector is of great importance for Jordan’s national income. In 2002 about 10% of the Gross Domestic Product (GDP) has been contributed from this sector. The expansion of tourism is of high political priority.

The specific water demand of this sector was assessed based on bed units and hotel categories. In order to quantify the specific water demand, typical establishments have been investigated for their water demand. Overall, a bed occupancy rate of 47% was considered. In addition to the regular increase in bed capacity (Table 3), sudden increases
due to large investment projects have to be accounted for. Big investment projects are under construction or planned at the Dead Sea coastal area, in Aqaba, Petra and other attractive places in the country.

Table 3: Projected Annual Increase Rate of Touristic Bed Units (%)

<table>
<thead>
<tr>
<th></th>
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<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Growth Rate</td>
<td>9.1%</td>
<td>4.3%</td>
<td>3.5%</td>
<td>3.0%</td>
<td>3.0%</td>
</tr>
</tbody>
</table>

The main touristic development plan in the country is the Dead Sea East Coast Development Project at Sweimeh and Zara, expected to require about 12 MCM/a of water including landscaping and physical losses in the year 2020. Aqaba is another important touristic region that is going through major developments. The Aqaba Complex is envisaged to have 6000 bed units by the year 2020, requiring more than 1 MCM/a excluding landscape, wherefore it is planned to use recycled water.

Considering the network losses, and the landscape requirements in Sweimeh and Zara, the gross touristic demand during the planning horizon is shown in Table 4 below. Touristic demands can be observed mainly in Balqa, Madaba (both abutting the Dead Sea), Aqaba and Amman, totalling about 19.4 MCM/a by the year 2020; nearly 98% of the total touristic gross demand estimated at 19.9 MCM/a. Table 4 shows those governorates where the touristic demand is higher than 0.5 MCM/a.

Table 4: Gross tourism demand projections (MCM/a)

<table>
<thead>
<tr>
<th>Governorate</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Amman</td>
<td>2.79</td>
<td>3.18</td>
<td>3.60</td>
<td>4.02</td>
</tr>
<tr>
<td>Aqaba</td>
<td>1.27</td>
<td>1.76</td>
<td>2.24</td>
<td>2.92</td>
</tr>
<tr>
<td>Balqa</td>
<td>1.10</td>
<td>2.58</td>
<td>6.27</td>
<td>6.22</td>
</tr>
<tr>
<td>Madaba</td>
<td>0.03</td>
<td>2.15</td>
<td>3.66</td>
<td>6.26</td>
</tr>
<tr>
<td>Others</td>
<td>0.33</td>
<td>0.39</td>
<td>0.41</td>
<td>0.46</td>
</tr>
<tr>
<td>Total</td>
<td><strong>5.53</strong></td>
<td><strong>10.06</strong></td>
<td><strong>16.18</strong></td>
<td><strong>19.87</strong></td>
</tr>
</tbody>
</table>

3.5.3 Industrial Sector

The industrial sector is gaining more importance in Jordan indicated by a high labour productivity of about 150 % compared to the national average and a contribution to the GDP of approximately 17% in 2002.

Similar to the tourist sector, it is necessary to define the specific water demand related to the particular products considering the individual production method. In the light of the fact that only about ten companies represent 86 % of the Jordanian industrial demand, a
A questionnaire was developed within the framework of the NWMP. Historical water use and future development and/or expansion plans have been subject of the questionnaire.

A nationwide average regular growth rate of 4.5% was adopted, as almost all the big industries in the country will witness general increase in demand. In addition to regular growth, sudden increases or decreases due to industrial development projects need to be taken into consideration: The development of a free zone in Aqaba is more likely to be conducive of more industrial growth than elsewhere in Jordan. Due to the diminishing phosphate reserves, phosphate production at Al Hassa and Al Abyad mines will be stopped between 2006 and 2008 and substituted with the increased production at Shediya. Furthermore, projects like the Cyber City Industrial Park in Irbid, the Lajoun Oil Shale Mining Project, potash related industries and the Electrical Power Station in Zarqa are under planning.

To estimate the gross water demand for industries, losses varying between 3% and 20% have been assumed, depending on whether industries are supplied through the public network or locally by surface water or groundwater.

The industrial demand in the year 2020 is expected to reach about 120 MCM/a, of which about 88% is almost contributed equally by the big industries and the new industrial developments (Table 5).

Table 5: Total Gross Industrial Demand and its Share by Industry Type (%)

<table>
<thead>
<tr>
<th>Industry type</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Big Industries</td>
<td>63%</td>
<td>56%</td>
<td>50%</td>
<td>45%</td>
</tr>
<tr>
<td>New Industrial Development Plans</td>
<td>24%</td>
<td>32%</td>
<td>38%</td>
<td>43%</td>
</tr>
<tr>
<td>Remaining Industries</td>
<td>12%</td>
<td>11%</td>
<td>11%</td>
<td>11%</td>
</tr>
<tr>
<td>Total Industrial Demand (MCM)</td>
<td>59</td>
<td>77</td>
<td>100</td>
<td>120</td>
</tr>
</tbody>
</table>

3.5.4 Irrigation Sector

Due to the nature of economic development in Jordan, increasingly led by the service and industrial sectors, the contribution of the agricultural sector to the country's GDP has been sizeably declining during the past two decades; starting from 14.4% in 1971, to 3.2% in 2002. In addition, agricultural output in relative and absolute terms estimated at 213.5 million JD in 1991 has been continuously in decline with the output having decreased almost by half.

Using the Irrigation Module mentioned in Section 1.3, NIR were calculated, for each agro-climatic zone following pre-processing of rainfall and other climatic data for the estimation of evapotranspiration for reference crops using the Penman equation. Finally the total irrigation requirements for each zone were determined. This process resulted in volumes of irrigation demands in the future, based on information provided for a given
reference year (1998). The input variables required for the assessment of future demand are:

- Changes in irrigated areas (assumption: no changes in the uplands, expansion of 2500 ha in JRV including Southern Ghors and Wadi Araba)
- Changes in cropping pattern (assumption: same distribution as in 1998, as this was the last year with average rainfall and a complete dataset)
- Changes in the distribution of irrigation methods (assumption: extension services and subsequent shift to more drip irrigation were assumed past 2005, resulting in a higher irrigation efficiency of about 8% in the JRV and 9% in the uplands)
- Projected gains in distribution efficiency (assumption: reduction of losses due to investment in canal lining and rehabilitation in the uplands of about 3%)
- Projected overall gains of about 9% in the JRV and 5% in the uplands.
- Projected irrigation water salinity class (assumption: adequate amounts of water are available for leaching depending on water salinity class and crop type)
- Climatic conditions (assumption: Three different climatic scenarios, dry, median and wet years)

Formulation of future scenarios was carried out in an iterative manner to examine the impact of changing the above parameters on total demand, or using information on planned development and sector strategies. The total gross irrigation demand in a median year under unstressed conditions was seen to decrease from 1093 MCM in 2005 to 983 MCM in 2020 (s. Table 6). The irrigation water use in the reference year (1998) reflected only 44% of the water demand, which is an indicator for the water stress irrigated agriculture is exposed to in Jordan. Other reasons are incomplete and inaccurate measurements of water usage, overestimates of irrigated areas, lack of comprehensive crop surveys, absence of adequate leaching practices and illegal water uses.

Table 6: Projected Gross Irrigation Water Requirements, median year (MCM/a)
3.6 Outlook

In the year 2001, the country's total water demand was in the range of 1350 MCM/a, of which only 774 MCM/a was supplied due to water shortages. It is expected that this demand will reach 1565 MCM/a by year 2010 (Figures 7 and 8). By 2020 the demand will be around 1616 MCM/a, with the increase in demand being mostly contributed by municipal and industrial uses. Increased population, and urbanisation, in addition to improved standards of living are expected to boost municipal uses from its current level of 83 l/c/d, to 142 l/c/d by the year 2020. The irrigation demand will decrease starting 2005, when demand management measures show results, and sink further after 2010, when the irrigation with fossil groundwater in the Disi area is recommended to stop. Also, the relative amount of irrigation water of the total demand will be decreasing, to about 60% in 2020 from 73% in 1998. It is foreseeable that especially the irrigation demands cannot be met within the planning horizon from 2005-2020. Total renewable water resources will not exceed 1150 MCM/a in 2020.
Figure 7: Total water demand in 1998 and future demand projections (MCM/a)
The challenge for Jordan will be to match the foreseen demands with the available conventional and non-conventional resources. The National Water Master Plan gives the guidelines that originate from the balancing between water demands and resources. In order not to overuse the available resources, especially renewable groundwater, Jordan’s water demands need to be in accordance with what water can be made available at reasonable cost and lowest possible environmental impact.

Embedded in the gross demand projections as outlined above are assumptions related to the effect of demand management:

- Water Loss Reduction programs to reduce the municipal network physical losses. A total saving of 100 MCM in Municipal demand will thus be realised. Actual amounts of savings will depend eventually on amounts of water allocated for this sector. This reduction in physical losses should also contribute to savings in tourism demand estimated at 1.8 MCM in 2020.
Irrigation Savings are showing due to gradual use of more effective irrigation methods; Potential savings in the upland could amount to 31 MCM/a. This should release some pressure off the over-stretched groundwater resources. Savings in lining of canals in the uplands would result in releasing a further 5 to 12 MCM/a by the year 2020. Potential savings in the JRV estimated at about 20 MCM/a should allow expansion of irrigated agriculture in the region by 3274-3834 ha compared with areas irrigated in 1998. Alternatively it should allow transfer of the same amount of fresh water to the urban areas in the uplands.

These and a wealth of other demand management measures are and will be necessary to bring down the present and projected demand to the available resources, in addition to reallocation between sectors.
4 Surface Water Resources

4.1 Climatology and Hydrology

Jordan's climate is the result of both its geographical position in the Eastern Mediterranean region and its relief, which ranges from -416 m at the Dead Sea to 1800 m in the Southern Highlands. Roughly, the following main climatic zones can be distinguished:

- The Jordan Rift Valley with its sub-tropical climate, mild winters and very hot summers. The northern part receives fairly good rainfall during the rainy season (October - May). Average rainfall ranges between 350 mm/a in the north, 200 mm/a around the Dead Sea and less than 50 mm/a in the South towards the Red Sea.

- The Northern and Southern Highlands, with rather cool, rainy winters and warm summers. The most favoured areas around Ajloun receive more than 600 mm/a of rainfall in average years. In winter, snowfall is not uncommon.

- The Eastern (Badia) and Southern Desert, with cool winters and very hot summers. Total rainfall in average years is below 100 mm/a, and maximum temperatures may exceed 50 °C in the summer.

The Annex on Monitoring Networks is giving more details about the spatial distribution of the hydrometeorological stations and the availability of data.

4.1.1 Rainfall and Evaporation

More than 80% of the area of Jordan is indicated as desert receiving rainfall of less than 100 mm/a. The transition from the semi-arid highlands to the desert is gradual. The strong seasonal variation of the key climatic parameters rainfall, temperature and evaporation is shown on climate charts.
Figure 1.1 Climate charts of meteorological stations representative for different climatic zones in Jordan
Rainfall in Jordan is subject of a strong interannual variation. In general it can bee seen that wetter periods (early fifties, seventies and nineties) alternate regularly with dryer periods. Despite the fact that the annual rainfall during the past three years (1999-2001) has been under the long-term average, the general downward trend of annual rainfall cannot be detected according to the long-term observation records. In the early sixties, the situation has been as grave. Therefore, the future potential of the surface water resources has been estimated without considering possible influence of a global climatic change.
4.1.2 Streamflow

The water flowing in Jordanian wadis has three different sources:

- Direct runoff from heavy rainfall
- Baseflow leaking out from groundwater bodies
- Discharges from waste water treatment plants

The division into surface water basins is described in Chapter 2, a quantitative assessment of the flows is given in Chapter 3, and the surface water development through diversions and weirs is described in Chapter 4.

4.1.3 Water Quality

The natural quality of the wadis flowing within Jordan has been good. This is particularly valid for floodflows. Some of the wadi baseflows have higher salinities as they are fed from saline springs. Of the international rivers, Yarmouk has excellent water quality, while Jordan River water is rather saline and hardly useable without treatment.

Today, basically three different sources of pollution of surface water bodies can be distinguished:

- Natural elevated salinity levels originating from saline springs.
- Increased salinity levels due to drainage from agricultural areas.
- General pollution (also organic and bacteriological) from the release of insufficiently treated wastewaters.

More details are given in the Annex on Surface Water Quality.

4.2 Surface Water Basins

The drainage system in Jordan consists of three main flow directions. The first one drains towards the Jordan Rift Valley, discharging ultimately into the Dead Sea. The second group of basins drain the rainfall through the wadis flowing eastwardly from the western highlands towards the eastern desert depressions and mudflats. The third flow pattern is limited to the southern parts of the country, draining partly into the Red Sea and partly into the southern desert areas.
Table 2.1 Surface Water Basins in Jordan

<table>
<thead>
<tr>
<th>No.</th>
<th>Basin/Area</th>
<th>Basin Name</th>
<th>Basin Code</th>
<th>Catchment Area (km²)</th>
<th>Average Annual Rainfall (mm/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Yarmouk</td>
<td>AD</td>
<td>1,426</td>
<td>280</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Amman-Zarqa</td>
<td>AL</td>
<td>3,739</td>
<td>220</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Jordan Valley</td>
<td>AB</td>
<td>780</td>
<td>270</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Jordan Valley Rift Side Wadis</td>
<td>North</td>
<td>AE, AF, AG AH, AJ,AK</td>
<td>946</td>
<td>490</td>
</tr>
<tr>
<td>5</td>
<td>Jordan Valley Rift Side Wadis</td>
<td>South</td>
<td>AM, AN, AP</td>
<td>736</td>
<td>370</td>
</tr>
<tr>
<td>6</td>
<td>Mujib</td>
<td>CD</td>
<td>6,727</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Hasa</td>
<td>CF</td>
<td>2,603</td>
<td>130</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Dead Sea Rift Side Wadis</td>
<td>C</td>
<td>1,508</td>
<td>240</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>North Wadi Araba</td>
<td>D</td>
<td>2,953</td>
<td>180</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Azraq</td>
<td>F</td>
<td>12,400</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>11</td>
<td>Hammad</td>
<td>H</td>
<td>18,047</td>
<td>85</td>
<td></td>
</tr>
<tr>
<td>12</td>
<td>Sirhan</td>
<td>J</td>
<td>15,733</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>13</td>
<td>Jafer</td>
<td>G</td>
<td>12,363</td>
<td>45</td>
<td></td>
</tr>
<tr>
<td>14</td>
<td>South Wadi Araba</td>
<td>E</td>
<td>3,742</td>
<td>75</td>
<td></td>
</tr>
<tr>
<td>15</td>
<td>Southern Desert</td>
<td>K</td>
<td>6,296</td>
<td>15</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Total</td>
<td></td>
<td>90,000</td>
<td>100</td>
<td></td>
</tr>
</tbody>
</table>

Source: Rainfall-Runoff Model, Years 1937/38 – 2002/03

Note: Areas are within the Jordanian Territory
4.3 Surface Water Potential

The assessment of surface water resources in Jordan has to distinguish between baseflows and floodflows. Baseflows are much easier to manage than floodflows. In Jordan, they occur only on a few, well known wadi sections. Most catchments, particularly the eastern and southern basins, do not show any baseflow at all. On the other hand, floodflow can occur anywhere, even in the desert. The rarer the occurrence of floodflows, the more difficult is their economic utilisation.

4.3.1 Base Flow

Baseflow is defined as outflow from groundwater bodies into stream courses. After the Azrael springs have dried out, the occurrence of baseflow in Jordan is restricted to wadis
draining into the Jordan Rift Valley along the eastern escarpment. Baseflow in these
wadis is perennial, i.e. even during the dry season the wadis keep flowing.

The baseflow measured at the gauging stations is affected by upstream impacts like
extraction for irrigation along wadis and return flows from wastewater treatment plants.
Upstream abstractions for irrigation are estimated to be in the magnitude of 60 MCM/a,
while for year 2005 wastewater inflows are estimated to be in the order of 87 MCM/a.

With about 210 to 220 MCM/a, natural baseflow contributes considerably to irrigation
and industrial water supplies. Only 197 MCM/a are considered to originate from
renewable groundwater, the remainder of the baseflow is of fossil source. For the optimal
use of base and floodflow, reservoirs have been built or are in various stages of planning.
The Annex on Groundwater Safe Yield is giving details on data sources and calculation
methods for the estimation of baseflows.

Additionally, significant baseflow volumes in the order of 100 MCM/a for an average
year are contributed from the Yarmouk River. During the last decades, the runoff in the
lower Yarmouk River was subject of significant reduction; the Annex on Yarmouk River
Resources discusses the development in detail and quantifies the volumes Jordan can
expect from this international river.

**4.3.2 Flood Flow**

Floodflow is difficult to measure in Jordan; for most catchments the data are not suitable
to serve as a reliable planning source. Therefore, a rainfall-runoff model has been
developed that is producing data out of the rather long series of rainfall observations
(1937/38 until 2002/03).

A detailed description of the model, the input data used and processed and the various
data outputs are given in the electronic help document which is part of digital water
master plan and which consists both as set of interlinked HTML files and as compiled
help file.

The model is using a modified Curve-Number Method and its surface characteristics are
hydrological soil type, land use and climatic zone. The model is country-wide and is
raster-based; each cell is 2 x 2 km large. The model processes daily rainfall figures; the
model results are stored as monthly and annual grid files for rainfall, storm runoff and
deep infiltration. Volumes for any basin or sub-basin can be extracted from these files.
However, the country-wide approach results in the over- or under estimation for some
individual catchment.

Runoff volumes have been calculated on daily basis and are stored as monthly and annual
values; for the 15 main basins in Jordan the data are summarized. The comparison of
median and average annual volumes obtained from the same data set shows the extreme
skewness of the data. This very strong variation of floodflows is an indication that
particularly in the arid catchments the floodflow potential remains a potential which can never be developed to the full extend.

Table 3.1 Annual Flow Volumes in MCM/year for Main Basins

<table>
<thead>
<tr>
<th>Basin</th>
<th>Code</th>
<th>Dry Year</th>
<th>Median</th>
<th>Wet Year</th>
<th>Average</th>
<th>Average</th>
</tr>
</thead>
<tbody>
<tr>
<td>North Rift Valley Side Wadis</td>
<td>A1</td>
<td>5.1</td>
<td>13.5</td>
<td>28.8</td>
<td>18.0</td>
<td>39.5</td>
</tr>
<tr>
<td>South Rift Valley Side Wadis</td>
<td>A2</td>
<td>7.7</td>
<td>17.5</td>
<td>40.6</td>
<td>25.1</td>
<td>32.9</td>
</tr>
<tr>
<td>Jordan Valley (Jordan)</td>
<td>AB</td>
<td>1.6</td>
<td>4.4</td>
<td>12.1</td>
<td>8.3</td>
<td>-</td>
</tr>
<tr>
<td>Yarmouk (Jordan)</td>
<td>AD</td>
<td>5.3</td>
<td>15.7</td>
<td>40.8</td>
<td>22.4</td>
<td>15.0</td>
</tr>
<tr>
<td>Amman Zarqa (Jordan)</td>
<td>AL</td>
<td>13.6</td>
<td>36.4</td>
<td>68.5</td>
<td>47.5</td>
<td>36.5</td>
</tr>
<tr>
<td>Dead Sea Rift Side Wadis (3)</td>
<td>C</td>
<td>6.6</td>
<td>15.1</td>
<td>34.0</td>
<td>21.7</td>
<td>21.4</td>
</tr>
<tr>
<td>W. Mujib</td>
<td>CD</td>
<td>10.6</td>
<td>30.7</td>
<td>115.2</td>
<td>70.9</td>
<td>31.0</td>
</tr>
<tr>
<td>W. Hasa</td>
<td>CF</td>
<td>2.1</td>
<td>5.4</td>
<td>15.3</td>
<td>13.1</td>
<td>29.4</td>
</tr>
<tr>
<td>W. Araba North</td>
<td>D</td>
<td>7.6</td>
<td>16.2</td>
<td>53.6</td>
<td>34.2</td>
<td>11.6</td>
</tr>
<tr>
<td>Wadi Araba South</td>
<td>E</td>
<td>0.0</td>
<td>1.2</td>
<td>11.3</td>
<td>7.8</td>
<td>0.1</td>
</tr>
<tr>
<td>Azraqa (Jordan)</td>
<td>F</td>
<td>0.4</td>
<td>9.3</td>
<td>44.3</td>
<td>40.9</td>
<td>0.0</td>
</tr>
<tr>
<td>Jafer</td>
<td>G</td>
<td>1.3</td>
<td>3.9</td>
<td>14.7</td>
<td>12.5</td>
<td>0.6</td>
</tr>
<tr>
<td>W.Hammad</td>
<td>H</td>
<td>0.0</td>
<td>1.3</td>
<td>30.4</td>
<td>24.3</td>
<td>0.0</td>
</tr>
<tr>
<td>W.Sarhan</td>
<td>J</td>
<td>0.0</td>
<td>0.1</td>
<td>13.4</td>
<td>17.5</td>
<td>0.0</td>
</tr>
<tr>
<td>Qa Disi &amp; Southern Desert</td>
<td>K</td>
<td>0.0</td>
<td>0.0</td>
<td>0.3</td>
<td>1.0</td>
<td>0.0</td>
</tr>
<tr>
<td><strong>Jordan</strong></td>
<td></td>
<td><strong>120.5</strong></td>
<td><strong>235.9</strong></td>
<td><strong>524.6</strong></td>
<td><strong>365.1</strong></td>
<td><strong>218.0</strong></td>
</tr>
</tbody>
</table>

1) Source: Floodflow data from rainfall-runoff model, years 1937/38 – 2002/03. Dry Year = 20% percentile, Wet Year = 80% percentile of the floodflow results, not of the rainfall data.

2) Baseflow data: Average 1989 – 1999, including upstream abstractions for irrigation but excluding waste water inflows and spring water diversions to municipal networks.

3) Excluding W. Mujib and W. Hasa

### 4.4 Surface Water Development

In Jordan, the following main forms of surface water development can be distinguished:

1. Traditional diversion of baseflows, either with temporary weirs or more recently with portable pumps;

2. Modern diversion of baseflows and smaller floods, through fixed weirs;

3. Storage of all inflows of a wadi in reservoirs regulated with outlet structures and spillways;
4. Retention of floods in so-called "desert-dams";

5. Water harvesting to reduce erosion and increase grazing conditions and groundwater recharge. It is not subject of this volume.

In Jordan, direct runoff from heavy rainfall lasts from less than an hour to very few days. This makes the management of this type of resource difficult. Dams are required for storing the floods during the wet winter season and releasing the water gradually during the summer season when the demand is high. Besides these "ordinary" reservoirs, so-called desert dams help to increase groundwater recharge and to provide water for pastoral use.

Figure 4.1 Basins Controlled by Dams

Together with baseflow and treated wastewater entering the dams and under consideration of unavoidable losses, so-called “reservoir safe yields” have been
calculated for various levels of probability. The Annex on Reservoir Safe Yield is giving more details on the reservoir safe yield concept, the methods and the results of calculations. For the year 2005, 202 MCM/a will be reliably available from the "ordinary reservoirs" which are all located in the foothills of the Jordan Rift Valley, both north and south of the Dead Sea.

Figure 4.2 Monthly distribution of reservoir safe yields

It is assumed, that before the year 2010 all reservoirs currently under construction or study will be completed, except for Yabis and Kufrinjah, which will be completed by the year 2020. The reservoir safe yield is further increasing over time due to the increase of treated wastewater inflow.

Table 4.1 Development of Reservoir Safe Yields

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wadi Al Arab</td>
<td>5.1</td>
<td>5.1</td>
<td>5.1</td>
<td>5.1</td>
</tr>
<tr>
<td>Ziqlab</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
<td>7.6</td>
</tr>
<tr>
<td>Yabis</td>
<td>1.1</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Kufranja</td>
<td></td>
<td></td>
<td></td>
<td>3.7</td>
</tr>
<tr>
<td>King Talal Dam</td>
<td>153.6</td>
<td>169.8</td>
<td>185.3</td>
<td>201.4</td>
</tr>
<tr>
<td>Shueib</td>
<td>5.6</td>
<td>6.1</td>
<td>6.4</td>
<td>6.8</td>
</tr>
<tr>
<td>Wala</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
<td>7.0</td>
</tr>
<tr>
<td>Mujib</td>
<td>11.3</td>
<td>11.3</td>
<td>11.3</td>
<td>11.3</td>
</tr>
<tr>
<td></td>
<td>2005</td>
<td>2010</td>
<td>2015</td>
<td>2020</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
<td>------</td>
<td>------</td>
<td>------</td>
</tr>
<tr>
<td>Bin Hammad</td>
<td>5.9</td>
<td>5.9</td>
<td>5.9</td>
<td></td>
</tr>
<tr>
<td>Karak</td>
<td>4.7</td>
<td>4.7</td>
<td>4.7</td>
<td></td>
</tr>
<tr>
<td>Tannour</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
<td>3.1</td>
</tr>
<tr>
<td>Fedan</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
<td></td>
</tr>
<tr>
<td>Wadi Musa</td>
<td>0.4</td>
<td>0.4</td>
<td>0.4</td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>202.4</strong></td>
<td><strong>233.8</strong></td>
<td><strong>249.7</strong></td>
<td><strong>270.9</strong></td>
</tr>
</tbody>
</table>

All figures are annual volumes in MCM, 80% reliability

The present and planned desert dams are estimated to contribute additional 20 MCM/a to the replenishment of the aquifers.

Surface water from international water sources according to the peace treaty concluded in 1994 are not covered in this volume but is instead discussed in the planning framework. The amount of the "Peace Treaty Water" was 33 MCM in 1998 and should rise up to 90 MCM/year in 2020.

In spite of all efforts, the potential to increase the surface water resources is very limited. The same is valid for the sustainable use of groundwater resources. Therefore, demand management will be required for sustainable development.

Table 4.2 Summary of development of surface water resources in Jordan

<table>
<thead>
<tr>
<th></th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Baseflow inflow into reservoirs (contributing to safe yield)</td>
<td>48</td>
<td>63</td>
<td>63</td>
<td>75</td>
</tr>
<tr>
<td>Baseflow use upstream from gauging stations</td>
<td>55</td>
<td>55</td>
<td>55</td>
<td>55</td>
</tr>
<tr>
<td>Baseflow observed downstream from reservoirs</td>
<td>48</td>
<td>48</td>
<td>48</td>
<td>48</td>
</tr>
<tr>
<td>Baseflow in wadis w/o reservoirs</td>
<td>54</td>
<td>39</td>
<td>39</td>
<td>27</td>
</tr>
<tr>
<td>Total baseflow excluding reservoir inflow</td>
<td>157</td>
<td>142</td>
<td>142</td>
<td>130</td>
</tr>
<tr>
<td>Reservoir safe yield (under consideration of floodflow, baseflow and wastewater), 50% reliability</td>
<td>225</td>
<td>260</td>
<td>274</td>
<td>301</td>
</tr>
<tr>
<td>Yarmouk water diversion to KAC</td>
<td>166</td>
<td>167</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td><strong>Total surface water resource</strong></td>
<td><strong>548</strong></td>
<td><strong>569</strong></td>
<td><strong>583</strong></td>
<td><strong>598</strong></td>
</tr>
<tr>
<td>Treated Wastewater not flowing into reservoirs</td>
<td>34</td>
<td>70</td>
<td>89</td>
<td>101</td>
</tr>
</tbody>
</table>

Note: Surface water from Peace Treaty is excluded
4.5 Recommendations

Recommendations outlined in the Report on Surface Water Resources include:

- Improvements of database organisation within MoWI: improve data verification and permit data reading access to the Water Information System (WIS) to all staff of the hydromet section.

- Improvements of inter-institutional data exchange, particularly with the Department of Meteorology, The Jordan Valley Authority (JVA) and the Water Authority of Jordan (WAJ).

- Reorganisation of the monitoring network (rainfall observation network, meteorological network, baseflow stations and water quality stations)

- Review of project economics for reservoir projects

- Water management planning: limit groundwater abstractions to the level of average annual recharge (this will stop the further recession of baseflows) and upgrade wastewater treatment plants to such levels that their effluents are environmentally safe for release into wadis.
5  Groundwater Resources

The volume "Groundwater Resources" is a part of the National Water Master Plan for Jordan. The objective of the report is to provide an up-to-date evaluation of the groundwater situation in Jordan.

5.1  Aquifer Systems in Jordan

Within this chapter a comprehensive description of the hydrogeology of Jordan including the characterization of the aquifer systems, their spatial extent, hydraulic properties, groundwater dynamics and hydrochemical characterization is given.

Two aquifer types can be distinguished in:

- bedrock aquifers, and
- unconsolidated aquifers.

The biggest part of the country consists of bedrock aquifers, which are the main groundwater sources. The main aquifers are:

- the sandstone aquifers like the Ram sandstone aquifer ("Disi-aquifer") and the Kurnub aquifer,
- the carbonate aquifers like A7/B2 and B4/B5 aquifers, and
- the basalt aquifer.

Unconsolidated aquifers, like fluvial deposits in the Jordan Valley, are - compared to the bedrock aquifers - of minor importance.

On a regional scale, the aquifers in Jordan can be grouped into three major aquifer systems. This classification is based on their spatial distribution, lithology and age of the geological units. These aquifer systems are:

- Tertiary-Quaternary Shallow Aquifer Systems: They include B3 aquitard, B4/5 aquifer, Basalt aquifer and alluvial deposits.
### 5.2 Groundwater Budget

A description of the mean annual budget of renewable groundwater in Jordan is given. Groundwater inflows are groundwater recharge from precipitation, transboundary inflow from Syria and return flows from irrigation, leaks from pipes, reservoirs, and wastewater treatment plants. Groundwater outflows are from abstraction by pumping wells, springs and baseflow discharge. The corresponding quantities are presented in the following table.

<table>
<thead>
<tr>
<th>Budget component</th>
<th>Quantity (MCM/year)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Groundwater recharge from precipitation</td>
<td>395</td>
</tr>
<tr>
<td>Trans-boundary groundwater inflow from Syria</td>
<td>68</td>
</tr>
<tr>
<td>Return flows from irrigation, leaks from pipes, reservoirs, wastewater treatment plants</td>
<td>70</td>
</tr>
<tr>
<td><strong>Total inflow</strong></td>
<td><strong>533</strong></td>
</tr>
<tr>
<td>Groundwater abstraction (wells, springs)</td>
<td>440</td>
</tr>
<tr>
<td>Baseflow</td>
<td>197</td>
</tr>
<tr>
<td><strong>Total outflow</strong></td>
<td><strong>637</strong></td>
</tr>
<tr>
<td>Change in storage (inflow - outflow)</td>
<td>-104</td>
</tr>
</tbody>
</table>

At present times the groundwater budget is negative (change in storage is -104 MCM/year) and groundwater management is not sustainable. Thus, as a consequence of the over-exploitation of the groundwater resources, a decline in groundwater levels as well as a decrease in baseflow and spring discharge are observed. Furthermore, this over-exploitation leads to a deterioration of water quality by the increase of salinity.

The sustainable groundwater abstraction rates (safe yields) for the different groundwater basins in Jordan are:

- Jordan Valley (15-20 MCM/year), Jordan Side Valley (28-32 MCM/year), Yarmouk (30-35 MCM/year), Amman-Zarqa (60-70 MCM/year), Azraq (30-45 MCM/year), Hammad (12-16 MCM/year), Dead Sea (40-50 MCM/year), Wadi Araba North (5-7 MCM/year), Wadi Araba South (4-6 MCM/year), Jafir (7-10 MCM/year), Sarhan (4-6 MCM/year), Southern Desert (2-3 MCM/year).

Besides renewable groundwater resources Jordan possesses limited resources of fossil, non-renewable groundwater in the Disi area from the Ram aquifer and Jafir area from A7/B2 aquifer. The yield of this resource is estimated to be about 125 MCM/year for the Ram aquifer and 18 MCM/year for Jafir area for the next 50 years.

Brackish groundwater is one of the resources for further development. Recent explorations have shown that non-renewable brackish groundwater resources of deep
sandstone type (Kurnub, Zarqa Group) possess an approximate potential of around 77 MCM/year.

5.3 Groundwater Models

The development and use of groundwater models has been practiced in Jordan since the mid 1970's. At present time most of the models are flow models, which are mainly used to simulate groundwater management scenarios.

A brief overview of existing models in Jordan is given by the evaluation of previous groundwater models.

In the framework of the National Water Master Plan a transient, multi-layered groundwater flow model for the entire country of Jordan was developed. The model is implemented at the Ministry of Water and Irrigation.

5.4 Groundwater Monitoring

In this chapter the groundwater monitoring activities in Jordan with respect to quality and quantity are described. Monitoring groundwater levels and groundwater quality is an integral component of the water resources protection strategy. By regularly monitoring it is possible to identify impacts on the aquifers and make decisions based on this information to avoid groundwater problems.

Beside the description of the existing activities recommendations for improving the groundwater monitoring programme are given. For the future the amendment of the groundwater monitoring strategy according to groundwater management policy of MWI (1998) is recommended.

5.5 Groundwater Resources Planning and Development

The basic strategy and policies for the water sector in Jordan are compiled and published in Jordan's Water Strategy and Policies (MWI, 1998). One of the main objectives for the future is the reduction of groundwater abstraction to the level of safe yield to guarantee a sustainable use of the scarce groundwater resources in Jordan. The quantity of Jordan's economically developable renewable groundwater is approximately 275 MCM/year. The reduction of groundwater abstraction is assessed as being achievable by the year 2020. If this goal is not achieved, irreparable damages of groundwater will occur, leading to a further reduction of the usable groundwater resources.

A comparison of groundwater abstraction rates with the safe yield in different basins in Jordan shows, that a reduction in groundwater abstraction must be done mainly in Amman-Zarqa, Dead Sea, Azraq, Yarmouk, Jordan Valley and Jafr basins.
A reduction scheme for the MWI is developed. It states, that the use of renewable groundwater for municipal and mainly irrigation water use will be reduced until 2020 in order to reach the safe yield. From a practical point of view the reduction of the abstraction must be done stepwise. A proposed reduction schemes from 1998-2020 is developed. It relies on the findings of water balances and the results described in Volume Water Balances and Allocation.

It is believed that the legal basis for the groundwater abstraction reduction plan is given by existing laws (Water Authority Law No.18, 1988) and the most recent by-law (Underground Water Control, No.85, 2002) and its amendment (regulation No. 76, 2003), namely Articles 4, 16 and 29 of the said by-law. The by-law contains the legal basis that needs to be enforced accordingly to reduce groundwater abstraction to the safe yield until 2020. The implementation of the groundwater by-law warrants the introduction of supporting institutional and technical measures to improve compliance and monitoring of resources on the one hand. On the other hand the establishment of an appropriate information base on private wells is needed. The database should include information on areas, crops, irrigation methods and requirements, abstractions, and wells data.

As a consequence the reduction of groundwater abstraction leads to a deficit in water supply. To bridge the gap, different options are available (options are ranked by priority):

- Use of known fresh fossil groundwater.
- Use of known brackish groundwater.
- Prospection and development of unused groundwater resources.
- Increase of artificial groundwater recharge.

### 5.6 Groundwater Protection and Quality Conservation

For groundwater protection, the development and implementation of a programme is needed in order to ensure that plans for groundwater protection, management, monitoring and restoration are defined, integrated and managed in a cost-effective manner. However, such a programme needs:

- a strong legal basis, given by laws and by-laws,
- guidelines and legal provisions,
- an administrative structure for implementation and survey, and
- public involvement.

The legal basis of this programme is given by:

- Water Authority Law No. 18 of 1988;
- WAJ's Regulations for the Quality of Industrial Wastewater;
- Jordan's Water Strategy and Policies;
- Standards for Drinking Water No. 286 of 2001;
- Standards for Industrial Wastewater No. 202 of 1991;

It should be noted that from the legal and regulatory point of view, the existing laws in Jordan are strong enough to control the use of groundwater resources and protect groundwater. However, up till now the application of these laws is still unsatisfactory, thus suggesting the need for future strengthening of law enforcement.

To improve groundwater protection several groundwater protections projects were implemented in the past. The main project is the "Groundwater Resources Management" project, which is carried out together with the Federal Institute for Geosciences and Natural Resources (BGR). The objective is to elaborate and implement groundwater protection measures by implementing groundwater protection areas in Jordan and applying concepts for groundwater contamination prevention.

In order to implement the Groundwater Protection Areas in the country, a "Higher Committee for Water Resources Protection" was established, with the aim of preparing national guidelines for the delineation of groundwater protection areas, and to propose corresponding by-laws. The establishment of groundwater protection zones is initiated in the public interest and will be coordinated by the Ministry of Water and Irrigation under the Water Authority Law (1988) with its subsequent amendments as well as on the By-Law of the Water Authority of Jordan (2002).

5.7 Recommendations

The main problems in groundwater resources management in Jordan are related to sustainability. Presently more groundwater is abstracted than recharged and protection of this limited resource must be improved. Hence the following is highly recommended:

I. On Groundwater Monitoring

1. Historical data review to identify site-specific groundwater quality issues.

2. Assessment and/or review of analytical requirements to develop an appropriate sampling plan (including parameters, spatial and temporal sampling frequency).

3. Assessment and/or review of monitoring well locations to ensure that an effective monitoring well network is in place. Implement if necessary refinement for the network depending on the importance of the aquifer and its vulnerability. This is recommended for B5/B4 and A7/B2 aquifers in the east and south-eastern part of the country.

4. Implementation of quality assurance / quality control programme, which ensures that data obtained from the monitoring programme, is valid.

5. Review of observation well maintenance.
6. Defined procedures for data exchange and storage between MWI (WIS) and WAJ laboratory database.

II. On Groundwater Development and Planning

1. Groundwater abstraction should be reduced to safe yield values recommended in Chapter two and five of this report. To this effect the following is warranted:

   • MWI should annually provide groundwater volumes to be extracted per basin based on the safe yield and most recent abstraction data, which should be communicated to the Board of Directors of WAJ.

     Quotas have to be revised and lowered in order to reflect the abstraction reduction scheme.

   • Rising of water prices if current levels do not show desired effect.
   • An internal regulation should be introduced for the execution of well closures by WAJ.
   • For unlicensed wells, a regulation to penalise abstraction exceeding the granted limits similar to the regulation for legal wells set in Article 38 is needed.

2. Introduction of supporting institutional and technical measures to improve compliance and monitoring of groundwater resources.

3. Establishment of an appropriate information base on private wells to support the implementation of the groundwater by-law, including information on areas, crops, irrigation methods and requirements, abstractions, and wells data.

4. Strengthening of irrigation advisory services in order to help farmers cope with groundwater abstraction reduction.

5. The reduction of groundwater abstraction leads to a deficit in water supply. To bridge this gap, limited use of fossil groundwater and brackish groundwater can be made.

6. The prospection and development of unused groundwater resources and artificial groundwater recharge can be used temporarily to bridge the gap until sufficient alternative sustainable resources can be made available.

III. On Groundwater Protection

1. The existing laws in Jordan are strong enough to control the use of and protect groundwater resources. However, the application of these laws is still unsatisfactory, thus suggesting the need for future strengthening of law enforcement through adequate penalty system.
2. The guidelines for the implementation of groundwater protection areas for all public water supplies are being prepared in Jordan. Implementation of these areas requires not only legal, but also technical and institutional support. Technical support includes carrying out relevant hydrogeological studies, inventory of possible sources of contamination for a groundwater protection area, and groundwater vulnerability assessment.

3. Surveillance and monitoring of compliance with defined restrictions is also required.

4. Measures to ensure compliance are also needed. These could include warnings, payment of fines and necessary actions to remedy the groundwater and soil.
6 Non-conventional water resources

6.1 Introduction

Jordan suffers from scarce resources of water supply to meet the demand for various sectors. There is a serious competition between municipal, industrial and tourist uses as well as irrigational demand for the same water resources. The growth in water demand in Jordan has led to the exhaustion of surface water and to the over-extraction of groundwater.

The fact that most of conventional water resources in Jordan have been developed led the country to seek non-conventional water resources development. Non-conventional water resources may be defined as water resources that are not readily available and suitable for direct beneficial use including

- wastewater reuse,
- water desalination,
- importation of water, and
- weather modification (cloud seeding).

6.2 Wastewater Reuse

Wastewater treatment involves reducing, removing, and disposing of water contaminants. It aims to process and dispose municipal and industrial liquid wastes in a manner that reduces the pollution, particularly, of the aquatic environment and make usable treated effluent for restricted reuse.

6.2.1 Description of the Technology

The technical systems required for wastewater reuse consist of a suitable wastewater treatment, a conveyance network and possibly storage reservoirs. In general, wastewater reuse is possible for non-potable urban use, agricultural use and industrial reuse as well as even potable water reuse. By far the most common form of reuse is for crop irrigation.

Due to increasing water demands, wastewater reuse is becoming more popular throughout the world, particularly in arid and semiarid regions. The main advantages of wastewater reuse are:

1. It provides an additional source of low cost water.
2. It can reduce the environmental and health related hazards if planned properly.
3. It can help increase crop yields because of supplemental irrigation and the nutrients (in particular nitrogen, phosphorus) within the wastewater.
### 6.2.2 Institutional Background in Jordan

The *Ministry of Water and Irrigation (MOWI)* is the responsible body in Jordan for the water sector. The *Water Authority of Jordan (WAJ)* is responsible as a national government agency for the provision of water and wastewater services including the development and management of sewerage systems, treatment plants. The *Ministry of Agriculture (MOA)* is responsible for agricultural irrigation and irrigation water quality (see also Wastewater Related Institutions).

Concerning the Water Policy of Jordan the Ministry of Water and Irrigation prepared a Water Strategy for Jordan formulating a series of policies. The *Policy Paper No. 2 "Irrigation Water Policy"* details the long-term objectives on water related issues of resource development. The *Policy Paper No. 4 "Management of Wastewater"* focuses on the management of wastewater as a water resource and including its development, management, wastewater collection and treatment as well as its reuse of wastewater.

As far as wastewater collection, treatment, disposal and reuse are concerned; most important Related Standards and Regulations are the following:

- Treated Domestic Wastewater (see Annex Jordanian Standard JS 893/2002).
- WAJ's regulation for the quality for the industrial wastewater to be connected to the sewerage system.

### 6.2.3 Present Wastewater Treatment in Jordan

In 2002, wastewater was treated in 19 treatment plants located in the urban centres of Jordan. Most of the plants rely on treatment by wastewater stabilization ponds consisting of mechanical treatment, anaerobic, facultative and maturation ponds. About 80% of the wastewater is treated by these systems, while activated sludge/Extended Aeration and trickling filter processes are applied at about 10%. About 89 MCM of wastewater per year is treated in available facilities (2002). Almost 66,000 tons of BOD₅ are annually discharged to the existing plants (see Table 2.1). Annex Existing Wastewater Treatment Plants presents some additional information on the existing wastewater treatment in Jordan.

Table 2.1: Wastewater treatment (2002)
It has to be mentioned that about 40% of the installed treatment capacity belongs to As Samra treatment plant with about 68,000 m³/d treating wastewater of Greater Amman. The present discharge to this plant, however, is more than 260% of its design capacity.

6.2.4  Present Wastewater Reuse Practice in Jordan

Treated wastewater reused for agricultural irrigation purposes of 71 MCM/year would be 14% of the total irrigation water use (some 511 MCM/year in 2002). Restricted irrigation by the treatment plant's effluent is applied in the direct neighbourhood of the plants and downstream of them without any dilution with freshwater. Unrestricted irrigation takes place, in particular, in the Jordan Valley by treated effluent in particular of As Samra treatment plant after mixing with freshwater (generally one portion of wastewater to three portions of fresh water). The total treated wastewater quantity for restricted irrigation is estimated to about 10 MCM/year and for unrestricted irrigation at 59 MCM/year (see Table 2.2).

Restricted irrigation is done for about 7,800 dunums and unrestricted irrigation for about 91,000 dunums. While restricted irrigation is limited to fodders, cereals, forests and fruit trees, comprises unrestricted irrigation various vegetables, additionally.

Table 2.2: Quantities of reused treated wastewater (2002)
Total irrigation water (incl. treated sewage) | MCM/year | 444
Total wastewater for irrigation | MCM/year | 71
Portion of total irrigation water | % | 16
Wastewater for restricted irrigation | MCM/year | 10
Wastewater for unrestricted irrigation | MCM/year | 59
Via King Talal Reservoir  | MCM/year | 57
Via Wadi Shua'ab Reservoir  | MCM/year | 1.9
Via Kafrein Reservoir | MCM/year | 0.5

1) Inside, near to or downstream of the treatment plants’ area
2) Deducted by 8% losses during transmission and storage (irrigation the Jordan Valley)
3) Treated effluent of As Samra, Baqa and Jerash Treatment Plants
4) Treated effluent of Salt and Fuhis Treatment Plants
5) Treated effluent of Wadi Essir Treatment Plant

### 6.2.5 Alternative Treatment Technologies

The following mechanical and biological processes of wastewater treatment do certainly not reflect the variety of all possible processes, but they are most frequently or could be potentially applied in Jordan:

- Primary treatment,
- Activated sludge (medium load),
- Extended aeration,
- Trickling filter (high load),
- Stabilization pond system,
- Constructed wetland.

Similar thing can be said for the following tertiary treatment processes. Due to the proposed reuse of treated effluent of treatment plants for irrigation, a certain tertiary/advanced treatment has to be provided, such as:

- maturation ponds
- sand filtration
- membrane filtration

Annex Alternative Treatment Technologies summarizes some basic criteria for the selection of alternative treatment technologies including tentative cost figures.

### 6.2.6 Future Development in Jordan

In 2002, 19 treatment plants were in operation including the plants of Wadi Hassan and Wadi Mousa (completed 2001/02). Planned Development of Wastewater Treatment
foresees in addition the construction of 17 new plants is proposed during a period of 10 to 12 years. After completion of all planned measures the total number of treatment plants will increase to 36. In several of the newly planned treatment plants sand filtration is proposed as tertiary treatment instead of maturation ponds.

Based on the existing studies and reports on the planning of related sewerage systems as prepared by the various Consultants, wastewater quantities were estimated up to the target year (of the present study) 2020.

As far as the wastewater collection and treatment is concerned, future development is generally based on the Consultants' studies available for each sewerage system and wastewater treatment plant except for the water demand estimations, which are based on the results of the net demand projections for municipal, industrial and tourist purposes (See Volume Water Uses and Demands). Estimations of wastewater collected have taken into account connection rates to the sewer network, losses of/inflow in the sewerage system and return flow factor following the Consultants' assumptions after adjustments are made to suit the requirements of processing by the Wastewater Module. Effluent quantities of the plants were estimated based on inflow and on a reduction caused by losses due to evaporation and/or infiltration in the underground within the treatment plants. Table 2.3 shows the total wastewater inflow and effluent of the treatment plants taking into account the assumptions presented above.

Table 2.3: Future development of wastewater treatment

<table>
<thead>
<tr>
<th></th>
<th>Unit</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wastewater inflow to treatment plants 1)</td>
<td>MCM/year</td>
<td>134</td>
<td>191</td>
<td>227</td>
<td>262</td>
</tr>
<tr>
<td>Wastewater effluent of treatment plants</td>
<td>MCM/year</td>
<td>126</td>
<td>179</td>
<td>213</td>
<td>245</td>
</tr>
</tbody>
</table>

1) Including touristic and industrial inflows

With regard to Future Reuse of Treated Wastewater in most of the new planned treatment plants local reuse systems were selected in particular for the small treatment plants of low effluent quantities. However, most of the effluent quantity will be conducted to irrigation systems more or less far from the treatment plants site due to the fact that the treated wastewater of the big plants (e.g. As Samra, Zarqa, Irbid) is not reused close to the treatment facilities.

6.2.7 Investment Implementation Schedule and Cost

Based on the prioritization of the planned projects an implementation schedule of project measures (new constructions and rehabilitation/extension for existing projects) was elaborated up to 2020. Most of the new project will be even realized until 2010. Assumed implementation periods are based on the proposals made in the Consultants' Study Reports. The biggest treatment plants serving Greater Amman are supposed to be completed in 2006 (As Samra) and 2009 (Wadi Zarqa). In general the treatment plants are planned for a design capacity reached within 10 to 15 years after their completion. This requires an extension of the plants after this time period. Investment costs up to
2010 taking into account new constructions and rehabilitation/extension for existing projects were estimated.

### 6.2.8 Reported Costs

During the period 1997/2002 the running cost for Wastewater Treatment increased annually by 10%. Cost for operation and maintenance are significantly lower for the treatment by wastewater stabilization ponds in comparison to the conventional treatment systems (extended aeration, trickling filters, activated sludge etc.).

Average costs for 2000/2002 were found to be (costs for operation and maintenance only):

- 0.244 JD/m³ for extended aeration process
- 0.124 JD/m³ for activated sludge process
- 0.190 JD/m³ for trickling filter process
- 0.052 JD/m³ for pond system process

Staff and electric power costs have a share of 46 and 28% respectively, dominating the cost for operation and maintenance.

Preliminary capital, operation and maintenance costs (price basis 2000) were estimated for local reuse facilities for irrigation (Reuse of Treated Effluent). Investment cost estimates of each project consider all required facilities between the wastewater treatment plants and the potential irrigation areas. This means that they comprise pumping facilities too (if required), but they do not include distribution facilities downstream of the storage reservoir or the transmission pipe. It is assumed that the users of the irrigation system will finance that distribution network. Average costs for operation and maintenance (period 1999/2000) were found to be:

- pumped systems: 0.01 - 0.03 JD/m³
- gravity systems: 0.006 - 0.017 JD/m³

### 6.3 Desalination of Brackish and Seawater

#### 6.3.1 Description of Technologies

Desalination process essentially entails the separation of nearly salt-free water from sea or brackish water, with the salt originally in the feed water concentrated in a reject brine stream. Both thermal and membrane separation methods are in common use.

There is universal agreement today that desalination is a proven and reliable alternative for the development of new water sources. These processes include distillation by Multistage Flash (MSF) and Multiple Effect Evaporation (MEE), the membrane processes of Reverse Osmosis (RO) and Electro-Dialysis (ED) as well as solar
desalination (SD). Because of the rapid rise in energy prices, development of the RO process for seawater and brackish water was accelerated and MSF has lost its place to RO as the most widely used process.

The Thermal Desalination or evaporation process (MSF and MEE), utilizes the very basic principle of impurity separation by phase average. When water is boiled, water vapour and other volatile matters are released to the atmosphere above the boiling liquid, while the dissolved solids remain in the liquid. Distilled water is then obtained, when the water vapour is condensed.

Reverse Osmosis (RO) is a pressure driven process that separated two solutions with differing concentrations across a semi-permeable membrane (for more details see Membrane Technology). The rate at which the fresh water crosses the membrane is proportional to the pressure differential across the membrane that exceeds the natural osmotic pressure differential. As fresh water permeates across the membrane, the fed water becomes more and more concentrated.

Electrodialysis (ED) is a membrane separation process that uses voltage as the driving force instead of pressure. The product water does not pass through the membrane, but instead, the ionic salts are attracted to a cathode and anode according to their polarity, and pass through an ion selective membrane. The ions are drawn out of the space between membranes leaving behind purified water.

6.3.2 Review on Renewable Energy Desalination Technologies

Electricity from photovoltaics (PV) can be used in desalination applications to drive electromechanical devices such as pumps or in direct current devices. Electrical power may be produced by a number of PV modules. Reverse osmosis (RO) and electrodialysis (ED) appear to be the most suitable choices for coupling with PV systems, as they require electricity in some form.

An increasingly popular option is wind energy conversion devices combined with various desalination units including RO, ED or vapour compression systems. For all of these options, energy comes from a single wind turbine or a wind farm. Although non-electrical power options are possible, the most widespread method for capturing and converting wind energy is by means of a wind turbine generator.

In a solar still solar energy is used directly for heating or evaporating water. The solar distillation of brackish water or seawater is based on the same principle as all other thermal desalination processes. Solar stills may constitute a reasonable solution in certain locations, particularly remote arid or semi-arid regions, where the application of complex desalination technologies may be economically or technically infeasible.
6.3.3 Proposal According to the Middle East Regional Study

A pre-feasibility study on seawater desalination was carried out in the frame of the "Middle East Regional Study on Water Supply and Demand Development". The proposals commonly made for Jordan, Palestine and Israel are presented in the following.

Reverse Osmosis Desalination Plants

One option of the above mentioned study foresees the construction of reverse osmosis desalination plants at various sites along the Mediterranean Sea and at the Red Sea. The total plant capacity is 150,000 m³/d (quoted module capacity: 5,000 - 10,000 m³/d).

Intersea Desalination Scheme (Med-Dead Project)

The Med-Dead-Project foresees a connection between the Mediterranean and the Dead Sea. The basic idea of this option is the use of the static head (400 m) between sea water level and Dead Sea for hydropower generation and subsequent use of electric power for the desalination process. The connection would consist of 80 km tunnel, 18 km of a closed pipe and 20 km of an open channel.

Intersea Desalination Scheme (Red-Dead Project)

Comparable to the Med-Dead-Option the Red-Dead Project foresees a connection between the Red and the Dead Sea. The difference of the water level between the Red and Dead Sea of about 400 m would offer good conditions for hydropower generation. Generated electric power will be used for the desalination process. 141 km of tunnel and closed pipe as well as 39 km of an open channel are required to conduct seawater from the Red Sea to the Dead Sea. The intake structure is planned to be at Aqaba. An about 400 km alignment of the transfer pipe will be along Wadi Araba/Arava. A reverse osmosis plant will be located south of the Dead Sea.

6.3.4 Desalination in Jordan

In 2003, 27 desalination plants were available and 7 plants were under construction. Most of the plants are operated privately by farmers to desalinate brackish water for irrigation purposes. Only some plants are operated by WAJ for drinking purposes.

WAJ operates four existing desalination plants and further two are under construction. All these plants are run or will be run by WAJ to treat saline water for drinking water supply. The units are all of a small size compared with plants e.g. in the Gulf Region (some 8,000 m³/d).

In 2003 23 desalination plants for irrigation purposes were under operation, while further three were under construction. The first unit started operation in 1996. All plants are
constructed and run privately by farmers. In all plants reverse osmosis technology is applied. The capacity of the plants are 20 - 80 m³/h (total capacity almost 1,000 m³/h).

Proposed future development for desalination of seawater and brackish groundwater comprises:

- Seawater desalination development: Aqaba seawater desalination
- Brackish groundwater development

**Aqaba seawater desalination plan**

Proposed Aqaba seawater desalination development plan foresees

- 5 MCM/year production from seawater expecting to start operation in 2005,
- 15 MCM/year production (i.e. additional 10 MCM/year) from seawater expected to start operation in 2015.

In 2003 no particular activity with regard to planning or construction is under preparation.

**Main, Zara and Mujib brackish groundwater desalination plan**

This brackish groundwater desalination project foresees the construction of facilities (reverse osmosis technology) of an average capacity of 38 MCM/year (maximum capacity of 45 MCM/year). It will be implemented in the area northeast of the Dead Sea. Raw water will be used from Mujib Dam, Wadi Zara-Ma‘īn. Treated water has to be pumped to Amman by a pumping height of some 1,500 m.

In May 2003 contracts for construction of the desalination plant was evaluated. Start of construction is planned for September 2003.

**6.3.5 Estimated Costs**

All costs quoted are 1996 constant terms omitting taxes and custom duties. Total levelised discounted (5 %) water costs for production and conveyance of desalinated water from the production site to Amman are

- 0.91 US$/m³ for reverse osmosis desalination plants,
- 0.72 US$/m³ for intersea desalination scheme (Med-Dead Project), and
- 1.01 US$/m³ for intersea desalination scheme (Red-Dead Project).

More detailed information on cost estimation are given in Annexes Reverse Osmosis Desalination Plants, Med-Dead Project and Red-Dead Project.
6.4 Importation of Water by Sea

6.4.1 Description of Concept

An alternative to conveying freshwater by pipeline or canal is to transport the freshwater in container vessels by sea. For large-scale applications, transporting the water by tankers is historically the preferred choice. Tanker or bag transport is done by shuttle service between two points.

A recent alternative concept for freshwater transport is to utilize specially-constructed reinforced plastic bags as the container vessels. The filled bags have sufficient buoyancy to float quite low in the sea, and can be towed as barges using tugboats. The speed of travel is significantly slower than can be achieved using tankers.

In the case of tanker transport or the use of plastic barges to ship freshwater, the required associated facilities are basically the same. The freshwater would be diverted through a pipeline to probably an offshore loading facility. At the receiving end, the tanker or bags would be unloaded at a similar offshore facility, and the water pumped through a pipeline to an area of use, an existing distribution system, or a terminal storage facility.

6.4.2 Proposal According to the Middle East Regional Study

In the frame of the "Middle East Regional Study on Water Supply and Demand Development" a pre-feasibility study on import of water by tankers and large vinyl bags was carried out. Proposed system was based on shuttle service operation to haul 200 MCM of freshwater per year from southern Turkey to Mediterranean coast (southern Israel). Water would be taken from an existing reservoir on the Manavgat River located some 12 km inland. The water would flow by gravity to a loading facility located about 2 km offshore through a series of tunnels and pipelines. The water would be discharged into medusa Bags or tankers and transported to an unloading facility about 3 km offshore of Haifa, Israel. Water would then be pumped through a new pipeline from Haifa to Jordan.

6.4.3 Estimated Costs

Following estimated levelised discounted water costs reflect the existing situation in the region, focusing on the Manavgat River in Turkey as source of water:

Cost estimation of water import by tankers (price basis 1996):

- "Used crude oil tanker" solution: 0.83 US$/m³
- "New tanker" solution: 1.12 US$/m³
- Conveyance Haifa - Amman: 0.65 US$/m³
Cost estimation of water import by large vinyl bags (price basis 1996):

- "Large Medusa bag" solution (1.75 mio.m³): 0.55 US$/m³
- "Nordic bag" solution (30,000 m³): 1.90 US$/m³
- Conveyance Haifa - Amman: 0.65 US$/m³

More detailed information on cost estimation is given in Annexes Import by Sea Tanker and Import by Sea Bags.

6.5 Importation of Water by Land

6.5.1 Description of Concept

The transfer of freshwater by pipeline or canal from one to another river basin or drainage area is a well known and practiced in several countries in the world. The import of water would require a long pipeline between the location of available water resources and Jordan. Big pump stations have to be constructed to allow the water transfer.

6.5.2 Proposal According to the Middle East Regional Study

The "Middle East Regional Study on Water Supply and Demand Development" considered in a pre-feasibility level the possibility of water import on land (pipelines).

Import of Water Through Pipeline from Turkey

The capacity of the proposed system considered 150 MCM/year (and as alternative 200 MCM/year). The proposal foresees two separate pipelines for the water supply of Jordan and for the west of Jordan River. The pipeline would be laid from Adana Reservoir of Ceyhan and Seyhan Rivers in Turkey via Aleppo, Hama, Homs and Damascus to Da'al in Syria.

Import of Water Through Pipeline from Iraq

The proposed system foresees a capacity of 150 MCM/year. Again two separate pipelines for the water supply of Jordan and for the west of Jordan River would be constructed. Water would be taken from Haditha Dam at Euphrates River in Iraq. A diversion line is planned east of Amman for water supply of Jordan, while another pipeline will connect this point with the Lower Jordan River to supply Israel, the West Bank and the Gaza Strip.
Import of Water Through Pipeline from Lebanon

This option would require the shortest pipeline. Proposed system of a capacity of 150 MCM/year foresees two separate pipelines. First pipeline connects Khardali Dam of Litani River in Lebanon with Amman (via Hashbani to Da'al in Syria and via Irbid). Second pipeline conducts water from Khardali Dam to Lake Tiberias via Hashbani River. From Lake Tiberias a further diversion line would discharge water to Bet Shean at the Lower Jordan River.

6.5.3 Estimated Costs

Cost for import of water through pipeline from Turkey (price basis 1996) was estimated as:

- for a 150 MCM/year-system:
  - Pipeline from Turkey to Amman: 1.65 US$/m³
  - Pipeline from Turkey to Lower Jordan River: 1.44 US$/m³

- for a 200 MCM/year-system:
  - Pipeline from Turkey to Amman: 1.54 US$/m³
  - Pipeline from Turkey to Lower Jordan River: 1.36 US$/m³

Cost for import of water through pipeline from Iraq:

- Pipeline from Iraq to Amman: 1.13 US$/m³
- Pipeline from Iraq to Lower Jordan River: 0.94 US$/m³

Cost estimation of import of water through pipeline from Lebanon:

- Pipeline from Lebanon to Amman: 0.68 US$/m³
- Pipeline from Lebanon to Lower Jordan River: 0.15 US$/m³

6.6 Cloud Seeding

Atmospheric water in the form of precipitation is one of the sources of fresh water in the world. However, a large amount of water present in clouds (70-90%) never gets transformed into precipitation. This has prompted scientists and engineers to explore the possibility of augmenting water supplies by means of "cloud seeding", (CS).
6.6.1 Description of Technology

Clouds form when atmospheric water vapour rises and cools by expansion with lower pressure at higher altitudes. As a result, condensing on very small atmospheric aerosols, known as Cloud Condensation Nuclei (CCN), takes place. Research shows that very small water droplets form around the CCN. The main objective of rainfall enhancement (cloud seeding) is to introduce ice nuclei particles for the formation of ice crystals in clouds.

Seeding Agents, including dry ice (CO₂), silver iodide (AgI), and lead iodide (PbI) are quite effective in promoting the freeing of super-cooled water droplets. Because of its attractiveness due to its ice nucleating capabilities, as well as economic and environmental considerations, silver iodide (AgI) is the chemical compound used by the majority of weather modification programs throughout the world.

Cloud seeding Delivery Systems are generally categorized under "ground" dispensers, and "aerial" dispensers. The choice of delivery systems should be made on the basis of the project design, which should establish the best system for the specific requirements of a given project since each system has inherent advantages/disadvantages.

In Jordan experimentation on cloud seeding were carried out since several years (see Experiences on Cloud Seeding). The operational cloud seeding and research data acquisition systems were installed in a seeding aircraft (a Cessna 340 A), which was put in operation during the rain season of 1990/91. In the frame of the experimental program cumuliform clouds during transition seasons were treated with ejectable flares that are fired from a rack mounted on the undercarriage of the aircraft. Static seeding, on the other hand, add small concentrations of ice nuclei to clouds that suffer a shortage of natural ones. This is the cloud type that produces most of rainfall in winter months.

6.6.2 Tentative Costs

The following costs have to be considered as tentatively because comprehensive cost evaluation is available for none of the projects. Estimated costs for the Jordanian Program are (according to Tahboub 1992):

1. Capital Costs: Planes, radar, computer, etc.: ~0.64 million US$/season
2. Recurrent costs: Seeding agents (AgI and NaI): ~12.00 US$/h/ground generator
3. Production cost: Average cost of water added 0.032 US$/m³
7 Water and Environment

7.1 Institutional and Legal Issues

In 1997, the Ministry of Water and Irrigation of Jordan formulated a national Water Strategy, which was the foundation to four subsequent water policies, all of which touch on matters of environmental protection in relation to the water sector:

- The Water Utility Policy
- The Groundwater Management Policy
- The Irrigation Water Policy
- The Wastewater Management Policy

All of these policies emphasize the need to study the environmental feasibility of proposed water projects. The policies also focus on public education, requiring awareness campaigns to be carried out in order to educate the public on methods of water resource protection and conservation. They also emphasize the need for continuous research and development, as well as constant review and updating of set standards and specifications.

7.1.1 Legal Issues

The only law pertaining directly to the environment in Jordan is the Law of Protection of the Environment, Temporary Law No. 1, 2003. The law touches upon issues of water but does not define a clear mandate for the MOE in this regard.

There are many other laws and standards that indirectly affect the environment as it pertains to the water sector, such as

- The Water Authority Law, No. 18 of 1988
- The Temporary Public Health Law No.54 of 2002
- The Jordan Valley Development Law, No. 19 of 1988

The legislative sector lacks laws that specifically address watershed or source water protection.

The most relevant specifications relating to water in Jordan are:

- The Jordanian Specifications for Drinking Water No. 286 of 2001
7.1.2 Institutional Background

The primary legislative responsibility for water and irrigation in Jordan belongs to the Ministry of Water and Irrigation (MWI). The Ministry of Environment (MOE) is responsible for protecting natural resources in Jordan. Under the umbrella of MWI, the Water Authority of Jordan has the full responsibility of carrying out water and wastewater projects in Jordan. Its mandate relating to environmental protection includes controlling the licensing of wells and monitoring of water resources. The Jordan Valley Authority (JVA) is responsible for development, management and distribution of water resources along the Jordan Valley, along with environmental protection and improvement and tourism development in the area.

All health matters of Jordan are under the responsibility of Ministry of Health (MOH), which includes monitoring of both wastewater and water systems to ensure compliance with public health standards. The Ministry of Agriculture (MOA) has several responsibilities relating to soil and irrigation water. The MOA has mandated the Royal Society for the Conservation of Nature (RSCN) to protect, conserve and manage wildlife in Jordan. The Department of Antiquities (DOA) at the Ministry of Tourism and Antiquities is entrusted with the protection of archaeological and historical sites in Jordan. Under the umbrella of the Ministry of Municipalities and Rural Affairs (MMRA), municipalities in Jordan are responsible for solid domestic waste collection and disposal. Within the Ministry of Industry and Trade (MOIT), the Jordan Institution for Standards and Metrology (JISM) is the body responsible for setting standards and regulations in Jordan.

7.1.3 Environmental Monitoring System

In its quest for sustainable water development, the MWI has compiled a central database, the Water Information System (WIS), which contains most water-related monitoring information compiled by MWI.

7.1.3.1 Drinking Water Monitoring

In accordance with the Water Authority Law No. 18, 1988 and its amendments, WAJ monitors drinking water in order to ‘ascertain the safety of water and wastewater structures, public and private distribution’. This activity is performed by the Drinking Water Quality Monitoring Department at WAJ laboratories, whereby water quality is
regularly monitored prior to and after treatment. The purpose of this monitoring is Quality Assurance in order to safeguard public health.

As for Quality Control, the Ministry of Health also monitors drinking water. If any deterioration in quality is observed, MOH informs WAJ so that the situation is rectified and precautionary measures are taken.

The Ministry of Environment, through a contract with the Royal Scientific Society and under ‘The National Project for Water Quality Control in Jordan’, also monitors potable water in Jordan. There does not seem to be a law that specifically stipulates the MOE’s responsibility for monitoring potable water. In case of pollution, MOE reports to MWI and follows up the situation.

Assuring the quality of any water resource that has been treated for human consumption is the responsibility of WAJ. Quality control in this case is a public health issue, which falls under the jurisdiction of MOH. MOE’s efforts should therefore concentrate on protecting water quality not in relation to use but as a national resource.

Another important issue to note is water quality in wells and springs utilised in rural areas for drinking purposes. These areas should be identified and properly controlled, with proper cooperation between MWI and MOH.

### 7.1.3.2 Irrigation Water Monitoring

There are currently no national standards for evaluation of irrigation water quality in Jordan. Since most agricultural activities in Jordan are in the Jordan Valley, JVA has become the main monitoring agency for irrigation water quality in the country. JVA therefore monitors surface water quality in the Jordan Valley. The monitoring is done mainly to secure a water quality suitable for irrigation purposes. Recently, the laboratory of JVA merged with that of WAJ so that they are now operating under the same management.

Even though there is no clear legal basis for it, the Ministry of Agriculture also performs some limited irrigation water monitoring activities in certain areas in Jordan. The monitoring is not systematic and restricted to parameters that affect crop production.

MOH’s role in monitoring irrigated water quality is limited to special cases when there are reports of uncontrolled use of wastewater for irrigation of crops.

The current situation leaves MWI/WAJ/JVA as both the operator and entity responsible for quality assurance and control. Another agency should be assigned the task of quality control for irrigation activities. The MOA, whose role is currently unclear, seems the likely candidate to undertake this task.
7.1.3.3 Water Resources Monitoring

Systematic water resources monitoring is mainly done by MWI through its Monitoring Network. Through these activities, MWI aims to accomplish one of its primary responsibilities, which is to conserve and protect water resources in the country.

Therefore, in order to aid MWI in its task, the Ministry of Environment should concentrate its efforts on systematic quality monitoring of surface and groundwater resources and report to MWI of any irregularity that may indicate a pollution incident.

For that purpose, water resources monitoring guidelines may be set, in coordination with MWI, MOE and other relevant entities.

7.1.3.4 Wastewater Monitoring

Wastewater in Jordan can be classified into two categories. One is domestic wastewater, and the other is industrial wastewater discharged from the various industries in Jordan.

Domestic Wastewater

WAJ monitors wastewater at public and private wastewater treatment plants in Jordan, in order to ensure compliance with the standards. The MOH has undertaken the responsibility of quality control at wastewater treatment plants, emphasising mainly on biological parameters.

Domestic wastewater disposed of in septic tanks and cesspools constitute a major environmental problem in Jordan, as monitoring the private tankers that collect them is a difficult task that is handled by the municipalities. Even selection of the disposal site is in many cases decided only by the relevant municipality. Therefore, there needs to be a clear and transparent method for ensuring that this wastewater is being delivered to the appropriate site, which has been selected through consultation with relevant entities, including MWI.

Industrial Wastewater

Wastewater discharged from private industrial sources is sampled by WAJ and MOE, who coordinate together in order to avoid duplication of sampling. WAJ and MOE inform each other in case of violations, warn the violators and in certain circumstances take them to court.

Solid waste disposal is done by municipalities and is under the mandate of the MMRA. Its monitoring is the responsibility of MOE and MOH. Monitoring these sites have ceased since early 2003. It is therefore recommended that more resources be allocated into resuming this monitoring process, such that MWI is kept informed of any detected risks to water resources.
As for hazardous waste, it is currently stored at the site where it was produced. There is a plan to construct a hazardous waste disposal site at Qasr Tuba, east of Swaqa, in 2005.

### 7.2 Environmental Impact Assessment for the Water Sector

Environmental Impact Assessment (EIA) serves as a tool for determining the environmental impacts expected from a proposed development project.

The current Environmental Protection Law stipulates that the MOE’s responsibility is to coordinate with the proper agencies in order to draft instructions for EIA. As MWI has been involved in conducting EIAs for projects under its jurisdiction, it has gained its own experience, which may contribute to a future cooperation with MOE.

Until this day, Jordan does not have a national environmental impact assessment methodology. The current strategy is that the donor agency financing the project determines the EIA methodology to be applied.

Even though all of the above-described procedures have been developed through years of practice and are sufficiently effective, environmental impact assessment should be tailored according to the needs of the country. The MOE Jordan should develop a national EIA strategy and procedure, through intense consultations with all concerned entities.

### 7.3 Environment Protection and Water Development Projects

Even though water-related development projects directly usually produce a positive impact on the environment, they also indirect produce negative environmental impacts.

#### 7.3.1 Non-Conventional Water Resource Development

The most common source of non-conventional water in Jordan is treatment of domestic and industrial wastewater. Other sources of non-conventional water in Jordan include desalination of brackish water.

Even though these projects may differ drastically in terms of their processes, there are several components that raise similar environmental concerns, mainly during construction of the required facilities. The most important of these are:

- Disturbance of archaeological and cultural heritage sites
- Permanent loss of land and resettlement
• General disturbances relating to traffic, noise and dust
• Employment opportunities for unskilled labourers
• Production of construction debris
• Increased cost on the population due to improvement of the services provided
• Residents’ concerns regarding the location of the planned facility

7.3.1.1 Wastewater Treatment and Reuse

Exposure to wastewater is a major cause for the outbreak of water-borne diseases within communities. Therefore, sewer services are essential for providing the basic health needs and ensuring a sanitary environment.

The presence of heavy metals in wastewater, a problem usually associated with industrial discharges, is cause for alarm as these substances are not reduced by conventional treatment methods.

The government of Jordan has successfully endeavoured to minimise the negative health impacts associated with water and wastewater through improved drinking water quality, sanitation and sewer coverage, as well as to rising public awareness.

Domestic Wastewater Treatment and Reuse

Currently, there are nineteen domestic wastewater treatment plants that are operational in urban areas in Jordan. Some of these plants have been overloaded and are not able to meet the standards specified by the government.

Planned and deliberate use of treated wastewater (Direct reuse) is still limited in Jordan. However, effluents from WWTPs normally discharging to seasonal surface water are reused in diluted form for restricted or unrestricted irrigation (Indirect Reuse).

The major environmental issues of concern regarding wastewater treatment facilities in Jordan are listed below.

Occupational Safety and Health

The workers at a mechanical wastewater treatment plant will mostly be exposed to safety hazards and risk of injury. When a wastewater treatment plant is composed of ponds, a major health hazard is exposure of the workers to the treated and raw wastewater.

Reuse of the treated wastewater in agriculture is another health hazard to the farmers working the land. Farmers should therefore never be exposed to effluent not compliant with Jordanian and WHO standards.
Awareness and education of the workers and farmers is the most effective way of dealing with this issue.

**Odour**

Another important public health issue associated with wastewater treatment and reuse is the problem of odour. The most common source of hydrogen sulphide is usually anaerobic processes associated with natural systems for wastewater treatment. As-Samra WWTP is considered a nuisance due to the persistent odour emanating continuously from the plant site.

In order to avoid problems associated with odour, when planning construction of a new WWTP, odour parameters should be studied and analysed in order to locate the plant at the most appropriate site.

**Groundwater Contamination**

The risk of percolation to groundwater in the case of ponds or storage reservoirs, from irrigation sites and from discharge into a wadi cannot be disregarded. Of the most critical parameters are the TDS, NO3 and dissolved ions. Constant monitoring of the nearby aquifers should be done.

**Surface Water Contamination**

Discharge of treated wastewater from the WWTP presents a threat to surface water quality. Overflow of the treated wastewater due to over application during irrigation can be another source of surface water contamination. If the discharged effluent has a high phosphate content, then eutrophication of the water body is a possibility.

**Soil Condition**

Irrigation using the treated effluent of a wastewater treatment plant may lead to increased salinization of the soil. It may also cause accumulation of chloride, organic compounds and other chemicals. However, the increase in vegetative cover of the land will serve to reduce the risk of soil erosion. According to a study conducted on five wastewater treatment plants in Jordan, salt accumulation in the soil was not found to be significant.

**Flora and Fauna**

When a planned project site is located near a sensitive area of flora and fauna, construction activities may disturb breeding and migratory patterns of birds, displace many animals and may lead to the uprooting of the natural vegetation onsite.

Wadi discharge of treated wastewater serves to enhance the habitat in the wadi and attract wet habitat wildlife and fauna.
Another impact on wildlife is due to eutrophication of the surface water body, which will render it useless for both the flora and fauna inhabiting or utilising it.

**Impacts of Sludge Disposal**

Sludge is a by-product of wastewater treatment and its disposal has always been a problematic issue. In Jordan, sludge is currently sun dried, as treatment, and then buried in a selected site nearby. The major issue relating to burial of sludge is groundwater pollution due to percolation.

**Industrial Wastewater**

As for disposal of industrial wastewater in Jordan, there are currently three methods applied. The most common is via a connection to the public sewer network, another is by recycling or irrigation and the last is by transportation through tankers and ultimate disposal in specified sites. Of these methods, the most problematic environmentally is the one where tankers are utilised.

According to WAJ, the highest violations are in the food industry, such that the pollutants are organic and therefore biodegradable. This means that connecting to the network will be enough to solve the problem.

Industries are generally concentrated in one area in the country, namely Zarqa city. This geographic distribution makes it convenient for the construction of one industrial wastewater treatment which has the capacity to treat most of the industrial discharges in the area.

**Desalination of Brackish and Seawater**

There are currently 22 private desalination plants in the Jordan Valley as well as 4 public ones. The private plants are relatively small and the brine resulting from the desalination process is disposed of via plastic pipes to the nearest wadi or into the drainage systems constructed by JVA and leading to Jordan River.

Several positive environmental impacts regarding the use of desalinated water were identified and these include improvement of physical and chemical characteristics of the soil, and decreased pressure on freshwater resources for agricultural purposes. One of the major environmental problems relating to desalination is disposal of the brine water produced by the treatment process, which could have a negative impact on soil and vegetation cover in the wadis, groundwater resources in the surrounding areas and the Jordan River. So far, the impact of brine disposal in Jordan has not been studied.

MWI has been studying the economic feasibility of desalination for the past few years and has proposed several desalination projects on a national level. Two of these projects are discussed below.
7.3.1.2 Future Plans for Non-Conventional Water Use in Jordan

Since Jordan is a country suffering from severe water shortages, finding alternative water resources has become a priority for the MWI. Apart from wastewater treatment and reuse, MWI has been studying the possibility of desalination on a much larger, national scale.

Nationwide Wastewater Treatment and Reuse Projects

The MWI/WAJ has been vigorously striving to upgrade, rehabilitate or expand all the wastewater treatment plants that have become outdated or overloaded, and that are causing environmental problems as well as introducing new ones where needed.

Of the existing plants, the most environmentally damaging is the waste stabilisation ponds at Khirbet As-Samra, which serves Greater Amman and Zarqa city. Design of a new, more efficient treatment plant to replace the exiting one at Khirbet As-Samra has already been done. This project is expected to reap far-reaching environmental benefits in the area. It will provide a huge amount of high-quality effluent for agricultural reuse and will greatly improve the condition of the Zarqa River.

Red Sea - Dead Sea Canal and Desalination Plant

The level of the Dead Sea basin has witnessed extensive water development activities in the past few decades that have lead to its decline. A further drop in the Dead Sea level will result in an increased drainage of groundwater into the Dead Sea. This decline has also led to a reduction in landscape values in the surrounding areas and to losses affecting the two companies that extract minerals from the sea.

The Red Sea-Dead Sea Canal Project is aimed at the provision of potable water for the Jordan Rift Valley and its surroundings using the process of reverse osmosis (RO) desalination. The desalination plant will be operated utilising the hydropower generated from the difference in water level between the Red Sea and Dead Sea. Further investigation identified another potential objective, which is to increase the level of the Dead Sea, or at least to halt its decline. The canal will have a length of 200 km with a planned maximum capacity of about 850 MCM/a of freshwater, two thirds of which are foreseen to be used in Jordan while one third to be supplied to Israel and the Palestinian Territory.

Positive impacts of the project are as follows:

- Restoration of Dead Sea levels to its natural, pre-1960s levels
- Refilling of the groundwater aquifers along the coastline
- Contribution to the Peace Process in the region, through enhancing cooperation between all the parties involved
• Increasing employment opportunities during project construction and within the tourism sector

• Providing more secure socio-economic conditions for the nearby residents

Negative impacts include:

• Threatening the stability of evaporation pond dikes of the potash companies

• Disposal of chemicals from desalination process in to Dead Sea

• Decrease the efficiency of the mineral recovery processes

• Limit the future expansion of the two plants northwards

• High energy requirement in order to transfer the water from the Dead Sea area to the recipient areas in Amman

7.3.2 Groundwater Development

Groundwater resources in Jordan constitute more than half of the water presently supplied in the country. For many years, water has been pumped from aquifers at a rate that exceeds the sustainable yield resulting in decreasing groundwater tables and increasing salinity in several areas while plans are presently underway to extract water from non-renewable groundwater sources, such as the Ram (“Disi”) fossil water. Land use planning in Jordan rarely takes into account the risk of contamination of groundwater resources and activities are carried out without regard to the vulnerability of aquifers to pollution. It is therefore imperative that measures are taken by the government, in order to protect these precious water resources

Highland Aquifers

Half of the water pumped from the Amman-Zarqa Basin in north-eastern highlands is used for agricultural purposes. The current rate of pumping exceeds the safe yield. Over abstraction had led to deterioration in the water quality of the aquifers due to salinization and to declined groundwater tables. Reducing agricultural abstractions should be targeted in order to safeguard M&I supplies.

The Azraq Oasis

Abstraction of groundwater from the Azraq basin is done in order to supply Amman and Zarqa cities with their domestic water needs and for irrigation purposes within the surrounding area. Groundwater extraction from this aquifer system exceeds 50 MCM/a, while the average annual direct recharge rate is about 20 MCM/a.
The site of the oasis is considered a nature reserve of international importance. Studies show that the reserve contained water birds and more than 20 species occurring in internationally important numbers, as well as the Azraq Killifish, a species not present anywhere else in the world. Despite government efforts to rehabilitate the wetland, the over-extraction of the groundwater below has led to the wetland drying out as well as to salinization of the aquifer.

In order to protect the Azraq Oasis, it is recommended that the level of water exploitation be reduced and to construct storage reservoirs that will aid groundwater recharge.

**Disi-Mudawwara Groundwater Extraction**

The Disi-Mudawwara Groundwater extraction project is proposed to pump 100 - 125 MCM/a of water from the Ram Aquifer in the south of Jordan, in order to supply it to Greater Amman. The anticipated environmental consequences of exploiting this water resource are as follows:

- Depletion of fossil water
- Eventual salinization of the aquifer
- Loss of jobs for many labourers in the agricultural sector in the Disi area
- Disrupting construction activity in the well field area, located in Rum Desert

As the Ram groundwater is non-renewable fossil water, which should be used primarily for domestic use and for the direct benefit of human health and sanitation. Constant monitoring of water quality in the wells is also of utmost priority, in order to confirm that the proposed rate of extraction is suitable.

**7.3.2.1 Groundwater Protection**

Apart from degradation of quality from salinization consequent to over-draft, groundwater is susceptible to contamination from various other sources such as effluents from wastewater treatment plants, industries, residential compounds without sewer connection, waste disposal sites and septic tanks of private residences not connected to the sewer system. In several areas groundwater degradation has been observed.

Land use planning, in line with the requirements of groundwater protection, offers the most effective and in principle the less cost intensive tool to protect groundwater. The mapping of groundwater vulnerability and associated hazards and setting up the proper database required for groundwater protection has been under preparation for several years by MWI. Once the relevant information for all the areas of Jordan have been compiled, the resulting maps will provide an effective tool for national land use planning, taking into consideration the groundwater resources available in the country. Nevertheless, this
should not replace the site-specific studies required for approving a project posing high risk for groundwater.

**Wadi Dhuleil**

Ever since irrigation started in the area of Wadi Dhuleil, Eastern Jordan, water quality in the aquifer has been deteriorating with an increased salinity and nitrate content due to over-abstraction of the groundwater, poor irrigation practice and the discharge from As-Samra WWTP into Wadi Dhuleil. In order to prevent salinization of the groundwater, it is important that the farmers reduce abstractions to sustainable groundwater yields and are informed about the proper methods and timing of leaching they should apply.

**Jordan Valley**

Fertilizers used in the Jordan Valley have an especially high concentration of nitrates, thereby leading to contamination of the shallow water aquifer. It is therefore of utmost priority to develop commercial reporting procedures for quantities of fertilizers that are sold or used in the Valley. Awareness campaigns to inform the farmers of the proper handling techniques are also recommended.

Another groundwater problem in the Jordan Valley relates to over-abstraction by the farmers from private wells. Salinization of the aquifers is the ultimate result of these activities. Monitoring and control of well abstraction by WAJ is the only current available option.

### 7.3.3 Water Storage Systems

Building of water storage systems, such as dams, reservoirs and ponds, is common practice in areas along the Jordan Rift Valley to utilise surface water resources. The cumulative effect of building dams along the Jordan River tributaries is the decrease in flow into the Jordan River from and eventually the Dead Sea.

In terms of socio-economic impacts, water storage projects may result in:

- An increase in cultivated agricultural and in some cases fish farming (Yabis Dam)
- Reduction of flood risk (Mujib and Wala Dams)
- Resettlement of people who reside in the area or destruction of agricultural lands (Kufranja Dam), natural habitats and historical or archaeological sites
- Decreased agricultural land and vegetative cover downstream of the dam
- Promoting tourism in the surrounding area
Health impacts associated with water storage projects include:

- Occupational safety and health risks
- Increased breeding opportunities for insects

The main natural resource impacts relating to water storage projects:

- Surface water pollution due to sediment swirl up or spilling of liquids (Wala and Yabis Dams)
- Loss of topsoil, mixing of horizons within the excavation area and soil erosion
- Destruction of plants and wildlife inhabiting the area to be inundated
- Enhancement of the natural habitat in an area if proper measures are implemented
- Cooperation between the riparians as they will have to collaborate to reach an agreement

7.3.4 Water Transfer/Conveyance

Water conveyance projects include construction of pumping stations, reservoirs and transfer pipelines. The main purpose of these projects in Jordan is to transfer water from the various areas in the country to the Greater Amman region.

In terms of socio-economic impacts, water conveyance systems may result in:

- Power, road, water or wastewater services cuts
- Destruction of structures along the route
- Destruction of archaeological and historical sites

Health impacts associated with water conveyance systems include:

- Accident risks mostly relating to the construction workers

The main natural resource impacts relating to water conveyance systems:

- Soil disturbances, which may lead to soil erosion
- Increased seismic risk
- Disturbance of natural flora and fauna
Disi-Mudawwara to Amman Water Conveyance Project

The groundwater extracted from the Ram Aquifer will be transferred via a pipeline from the Disi area in the South to the city of Amman, 325 km north. The conveyor itself will be buried, as several related structures are constructed along its route.

The most likely effects during construction of the Disi pipeline will be the disruption of traffic flow in several areas, demolition of walls and some businesses, and removal of power lines.

Excavation works in the sand dunes of the Disi desert will have a direct negative impact on rodents, reptiles and birds of the area some of which are globally endangered species.

Other negative impacts include interference with tourism areas along the route, such as those between Madaba Bridge and Abu Alanda.

Red Sea – Dead Sea Canal

The proposed pipeline passes for around 15km below Dana Nature Reserve. Even though the construction activities may not directly affect the surface of the reserve, the vibrations that will be produced can be detrimental on the precious flora and fauna in the area, including 25 endangered species. It is therefore essential that the impact on biological diversity be addressed seriously and comprehensively.

Even though the Red Sea-Dead Sea Canal will be impervious, there remains a risk of groundwater pollution at Wadi Araba from accidental leakages, as a result of a serious seismic event.

Another identified environmental concern is the probable impact on the precious coral reefs of the Red Sea in Aqaba, due to construction of the intake structures there. Construction of this canal will increase income and employment opportunities.

Due to the novelty of this project, it is recommended that in addition to the mitigation measures identified and considered, an effective monitoring scheme is employed.

7.4 Recommendations

Recommendations that will aid in the environmental planning process in water development activities in the country are as follows:

- Development of technical guidelines for the delineation of watersheds as well as the legal framework for the establishment of protection zones
- Formulation of a committee within MOE for the purpose of regulating land use activities
• Preparation of national guidelines for EIA procedures by MOE with approval of MWI to assure integrated environmental planning in Jordan

• Early environmental impact assessment during project planning

• Consultation with MOE on EIAs prepared by MWI

• Preparation of an environmental resource location map by the MOE, in cooperation with other entities to aid in EIA process

• Centralising the environmental departments at MWI/WAJ/JVA

• Development of a general Water Law

• Studying the cumulative impacts of water sector development projects

• Separation of monitoring and quality assurance responsibilities

• Systematic monitoring of wells and springs in rural areas

• MOA to monitor irrigation water

• Development of national guidelines for evaluation of water quality for irrigation

• MOE to conduct systematic water resources monitoring, in coordination with MWI

• Setting guidelines for water resource monitoring

• Controlling tankers for wastewater disposal

• Monitoring of solid waste disposal sites by MOE

• Implementation of MWI’s water strategy pertaining to reduction of groundwater resources to sustainable levels, with domestic water use as a priority
8 Water Sector Economics

The scarcity of water resources has been a shaping factor for the structure of the Jordanian economy. It has limited the development of sectors with high specific water consumption (especially agriculture) and oriented the economy towards the service sector where the water consumption per unit of value added is very low. There is however no evidence of a negative impact on economic growth resulting from scarce water resources. On the contrary, water scarcity has favoured and promoted modern sectors with high growth potential, as for example the information and telecommunication sector.

Nevertheless, the growing demand for water due to the rapid population growth and the related economic development puts increasing pressure on the institutions involved in water management to improve their efficiency so as to satisfy the basic needs of the different user groups and to avoid negative impacts on the national economy.

From the public finance point of view the water sector (from the operational point of view: including the two public operators WAJ and JVA as well as private water supply schemes) constitutes a fiscal and debt burden for the government. The annual subsidies to WAJ and JVA amount to about 60 million JD, three quarters of which are "swallowed" by WAJ. Out of this amount, 15 million JD are interest payments on external loans contracted for investments in hydraulic infrastructure. In addition, there are indirect energy subsidies given to farmers reaching a sum of 4 million JD annually. Only 50% of the total cost (O&M cost + depreciation + interest payments) of water sector operations are covered from tariffs and related fees.

Whereas WAJ has reached O&M cost coverage both in the field of water supply and wastewater collection/treatment, the picture for JVA shows a deteriorating situation with a continuous decline of the O&M cost coverage ratio from 34% in 1997 to 21% in 2000.

It should be noted in this context that the water quantity billed by WAJ is roughly only half of the quantity produced due to technical and financial losses. This means that WAJ loses half of its potential income – around 50 million JD - to the virtual "Unaccounted for Water consumer".

Irrigation water provided by JVA is sold at a tariff of 11 – 12 Fils per m³. However, private farmers in the highlands who pump their water from wells can support water cost of 50 Fils per m³. This indicates that there is room for adjustment of the water tariffs at JVA. Furthermore, agricultural surveys suggest that the low JVA tariff leads to waste of water as it is not an important component in the cost structure of agricultural production in the Jordan Valley.

The figures of JVA have to be interpreted with some caution due to the fact that JVA is a governmental institution for social and economic development in the Jordan Valley assuming a number of functions apart from water resources development and water distribution. Financial figures do not always allow a clear distinction between the
different activities. Nevertheless, the broad financial tendencies expressed above remain valid.

The investment planning and implementation process is the driving force for the development of the water sector. At present, only the physical dimension of this process is addressed in a more or less coherent sector approach based on a long-term framework of demand and supply forecasts. But the financial dimension of investment planning lacks the needed integration on the sectoral and national level. The Ministry of Water and Irrigation is not in a position to fully assume its responsibility for the preparation of a sectoral annual investment budget that respects on the one hand national financial orientations and ceilings set by the Ministry of Finance and Ministry of Planning and that on the other hand has a binding character for the implementing institutions. Due to the project-based financing schemes offered by foreign donors there is always a possibility to escape from budget constraints when an external credit is offered for a certain projects. These deficits in the investment planning process result in sub-optimal investment programs leading to financial losses both within the sector and on the national level with higher budget deficits and debt service payments.

There is an urgent need to establish an integrated investment and budget planning process in the water sector coordinated by the Ministry of Water and Irrigation. Project selection has to be based on a framework of economic, financial, environmental and social criteria.

An integrated investment and budget planning process requires a powerful "projects database" that provides the needed data for the preparation of projects as well as the preparation of annual, medium-term and long-term investment programs. The establishment of an integrated information management in the water sector with a comprehensive project information system (PIS) is therefore a key element in the organisational modernisation of water sector institutions.

With the view of strengthening the organisational capacity of the Ministry it is strongly recommended to consider merging the present Water Master Plan Directorate and the Planning and Finance Directorate into one directorate. This new directorate would be the coordinator of the project and investment planning process of the water sector. To this end it has to be invested with the necessary authority to assure its coherence with the long-term planning framework as outlined in the Master Plan.

In order to address organisational and IT-issues in a comprehensive and coherent way it is suggested to merge the three MIS Directorates of the water sector into one Information Management Directorate (IMD) which would be responsible for the establishment and operation of the IT-infrastructure and the establishment of the corresponding work organisation.

As the government is committed to a path of deficit (and debt) reduction, the water sector has to contribute its share to this policy. According to the agreement with IMF and World bank it is planned to reduce the budget deficit by about 30 percentage points by 2006, which is also the goal to reach for the water sector.
There are three main areas of action for deficit reduction in the water sector:

- improving the efficiency of operations of WAJ and JVA through technical and organisational measures including privatisation,
- increasing water tariffs,
- strengthening the investment planning process in the water sector.

Tariffs adjustments will of course take into account the concerns of socially vulnerable groups and the economic impact on farmers income.

It is the long-term objective to reach full cost recovery of water production and distribution by the year 2020. It is estimated that 30% of the "cost recovery gap" can be closed by operation efficiency improvements and 30% through an improved integrated investment planning process.

A rapid appraisal of selected projects in different categories led to the following results:

The DISI water supply and desalination projects provide water at a dynamic cost of more than 500 Fils per m³, the Zai-Dabouq-Conveyor at 300 Fils per m³ whereas water gains from network rehabilitations cost only between 26 and 250 Fils per m³ depending on the specific technical situation of the network in question. This clearly indicates that network rehabilitation should be given highest priority. Additional water gains through savings from rehabilitation projects reduce the pressure on the water balance and reduce the need for other more expensive projects. At least such project can be delayed for several years which is a benefit for the economy, for the water sector and also for the water users in terms of more moderate tariffs.

The cost of 120 Fils per m³ for Wehdah dam water – as an example for surface water utilization - shows that surface water is a very advantageous source. It will have a positive financial impact on the average cost of water produced in Jordan.

The dynamic cost figures also show the high cost of wastewater treatment (including the wastewater collection). But these investments are part of the environmental imperatives. They are not in competition with other water supply projects. On the contrary, the supply aspect of wastewater and sanitation projects has to be seen as a "windfall profit" of an environmental necessity.

The above considerations clearly show that the area of network rehabilitations should be given the second priority, after the environmental imperatives, in the investment planning process.

Approximately 40% of the financial deficit of the water sector would have to be covered through higher tariffs. It has to be noted in this context that there will be an upward tendency in the average unit cost of water production and distribution due to the environmental imperatives and the more expensive new investments.
9 Water Balances and Allocation

Using the NWMP Planning Tools, resources and demands have been calculated and stored in a commonly accessible database for various projection years (2005 to 2020). These figures are brought together with the balancing modules to calculate water balances on regional and national scale.

For the balancing and allocation, two different scenarios are distinguished. Scenario 1 is the original demand scenario as described in Volume 3, Water Uses and Demands. Scenario 1 includes already measures for the reduction of water losses in municipal and agricultural water distribution systems. As these water saving measures are neutralized by increased demands, water allocations are proposed. Scenario 2 is such an allocation scenario, aiming to gradually reduce water deficits by the year 2020.

9.1 Resources and Demands

Local water sources are renewable groundwater, baseflow and treated wastewater. Floodflows are not directly usable but have to be stored in reservoirs. The water available from these reservoirs at different levels of reliability has been determined with by reservoir safe yield calculations which consider also inflows from baseflows and treated wastewater. The reservoir yields depend both on the inter-annual variation of floods and the demand hydrograph. Typically, main inflows to reservoirs occur during the winter months, while demands are highest during summer months.

Table 1: Development of Resources and Demands in MCM/a, Scenario 1

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Groundwater</td>
<td>259</td>
<td>259</td>
<td>259</td>
<td>259</td>
</tr>
<tr>
<td>Surface Water (baseflows and reservoir safe yields)</td>
<td>382</td>
<td>404</td>
<td>419</td>
<td>433</td>
</tr>
<tr>
<td>Treated wastewater, not flowing into reservoirs</td>
<td>34</td>
<td>69</td>
<td>89</td>
<td>101</td>
</tr>
<tr>
<td>Additional Resources</td>
<td>344</td>
<td>511</td>
<td>454</td>
<td>456</td>
</tr>
<tr>
<td><strong>Total Resources</strong></td>
<td>1019</td>
<td>1244</td>
<td>1220</td>
<td>1250</td>
</tr>
<tr>
<td>Municipal, Industrial, Tourist demands</td>
<td>433</td>
<td>493</td>
<td>561</td>
<td>634</td>
</tr>
<tr>
<td>Agriculture incl. reuse schemes</td>
<td>1114</td>
<td>1120</td>
<td>1101</td>
<td>1052</td>
</tr>
<tr>
<td><strong>Total Demands</strong></td>
<td>1546</td>
<td>1612</td>
<td>1661</td>
<td>1686</td>
</tr>
<tr>
<td>Groundwater return flows from losses</td>
<td>66</td>
<td>63</td>
<td>62</td>
<td>63</td>
</tr>
<tr>
<td><strong>Deficit in MCM/a</strong></td>
<td>-461</td>
<td>-306</td>
<td>-379</td>
<td>-373</td>
</tr>
<tr>
<td><strong>Deficit in %</strong></td>
<td>-45%</td>
<td>-25%</td>
<td>-31%</td>
<td>-30%</td>
</tr>
</tbody>
</table>

The so-called additional resources are becoming the largest component of water resources. These additional resources include surface water from shared water bodies (Yarmouk River and Peace Treaty water), non-conventional resources (from desalination) and groundwater from non-rechargeable aquifers. The mobilisation of these resources is achieved through ambitious water development projects.
### Table 2: Development of Additional Resources in MCM/a, Scenario 1

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Desalinised sea water</td>
<td>0</td>
<td>0</td>
<td>5</td>
<td>5</td>
<td>5</td>
</tr>
<tr>
<td>Desalinated groundwater</td>
<td>0</td>
<td>10</td>
<td>39</td>
<td>47</td>
<td>47</td>
</tr>
<tr>
<td>Fossil fresh groundwater</td>
<td>70</td>
<td>83</td>
<td>190</td>
<td>124</td>
<td>126</td>
</tr>
<tr>
<td>Peace Treaty Water</td>
<td>50</td>
<td>85</td>
<td>110</td>
<td>110</td>
<td>110</td>
</tr>
<tr>
<td>Yarmouk River Water</td>
<td>166</td>
<td>166</td>
<td>167</td>
<td>167</td>
<td>167</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>285</strong></td>
<td><strong>344</strong></td>
<td><strong>511</strong></td>
<td><strong>454</strong></td>
<td><strong>456</strong></td>
</tr>
</tbody>
</table>

On the demand side one distinguishes between municipal, industrial and tourist demands (MIT) as well as irrigation demands. Losses from municipal distribution networks are considered as part of MIT-demand.

For the approved demand projections (Scenario 1) demands are exceeding the resources by more than 30%. Only in Year 2010, after the completion of several large water development projects, the deficit is less serious. From 2015 onwards, the gap would be widening again. This situation is in contradiction with Jordan’s water strategy which is demanding a sustainable use of its groundwater resources.

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**Figure 1:** Development of national water balance for demand Scenario 1

### 9.2 Transfers

On regional scale, water deficits may be even more serious, while other areas are showing a water surplus. In order to visualize these regional differences, so-called
balancing units were created. For the Masterplan, three alternative balancing layers are considered, administrative, socio-economic and hydrological. For each balancing layer, the areas in the valley are distinguished from the upland areas.

The transfer between surplus and deficit areas is managed by large-scale transfer systems. These conveyance systems consist of pipelines, open channels like the King Abdullah Canal or even wadi sections conveying the release from reservoirs. During the following years, new transfer systems will be constructed and existing ones rehabilitated. In addition to the costs for construction and maintenance, there occur high operational costs for pumping.

The NWMP Planning Tools permit to calculate transfer performance between balancing units. In spite of the complexity of the transfer network, a detailed tracking of water from input to output points is possible. Information on the source type and use type for each transfer is given in the Annex on Transfer Systems.

Table 3: Planned Transfers in MCM/a for Scenario 2

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>AILOUN</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>10</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>AMMAN</td>
<td>0</td>
<td>1</td>
<td>5</td>
<td>5</td>
<td>94</td>
<td>140</td>
<td>153</td>
<td>158</td>
</tr>
<tr>
<td>AL AQABA (V)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>18</td>
<td>17</td>
<td>11</td>
<td>11</td>
</tr>
<tr>
<td>AL AQABA</td>
<td>18</td>
<td>17</td>
<td>11</td>
<td>11</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>AL BALQA</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>8</td>
<td>7</td>
<td>16</td>
<td>12</td>
</tr>
<tr>
<td>AL BALQA (V)</td>
<td>10</td>
<td>8</td>
<td>18</td>
<td>18</td>
<td>200</td>
<td>213</td>
<td>243</td>
<td>238</td>
</tr>
<tr>
<td>IRBID</td>
<td>0</td>
<td>160</td>
<td>163</td>
<td>155</td>
<td>16</td>
<td>16</td>
<td>21</td>
<td>20</td>
</tr>
<tr>
<td>IRBID (V)</td>
<td>144</td>
<td>44</td>
<td>87</td>
<td>79</td>
<td>6</td>
<td>63</td>
<td>74</td>
<td>82</td>
</tr>
<tr>
<td>JARASH</td>
<td>151</td>
<td>163</td>
<td>177</td>
<td>191</td>
<td>1</td>
<td>1</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>AL KARAK</td>
<td>8</td>
<td>21</td>
<td>21</td>
<td>21</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MADABA</td>
<td></td>
<td>13</td>
<td>13</td>
<td>12</td>
<td>13</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MADABA</td>
<td>13</td>
<td>20</td>
<td>21</td>
<td>22</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AL MAFRAQ</td>
<td>23</td>
<td>18</td>
<td>16</td>
<td>14</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>MA‘AN</td>
<td>0</td>
<td>66</td>
<td>84</td>
<td>86</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MADABA (V)</td>
<td>14</td>
<td>39</td>
<td>36</td>
<td>38</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>1</td>
</tr>
<tr>
<td>AZ ZARQA</td>
<td>6</td>
<td>1</td>
<td>1</td>
<td>1</td>
<td>14</td>
<td>60</td>
<td>75</td>
<td>72</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td><strong>396</strong></td>
<td><strong>567</strong></td>
<td><strong>648</strong></td>
<td><strong>650</strong></td>
<td><strong>371</strong></td>
<td><strong>534</strong></td>
<td><strong>609</strong></td>
<td><strong>612</strong></td>
</tr>
</tbody>
</table>

9.3 Allocations

While water saving measures have already been considered in demand Scenario 1, the following additional allocation measures are proposed for Scenario 2, aiming towards a sustainable water management by year 2020:

- A slower growth of per capita allocation
A redistribution of allocations for agriculture, with allocation for 2005 according to irrigation water use in year 2002 and subsequent approach to groundwater safe yield by year 2020. While this cause a reduction in several highland regions, an increase in several lowland regions was possible due to increased reservoir safe yield.

Transfers adjusted to that allocation pattern.

Table 4: Proposed Allocations in MCM/a for Scenario 2

<table>
<thead>
<tr>
<th>Year</th>
<th>2005</th>
<th>2010</th>
<th>2015</th>
<th>2020</th>
</tr>
</thead>
<tbody>
<tr>
<td>Renewable Groundwater</td>
<td>259</td>
<td>259</td>
<td>259</td>
<td>259</td>
</tr>
<tr>
<td>Surface Water (baseflows and reservoir safe yields)</td>
<td>370</td>
<td>387</td>
<td>400</td>
<td>410</td>
</tr>
<tr>
<td>Treated wastewater, not flowing into reservoirs</td>
<td>30</td>
<td>60</td>
<td>77</td>
<td>87</td>
</tr>
<tr>
<td>Additional Resources</td>
<td>347</td>
<td>475</td>
<td>471</td>
<td>496</td>
</tr>
<tr>
<td>Transfer resources</td>
<td>387</td>
<td>526</td>
<td>607</td>
<td>608</td>
</tr>
<tr>
<td><strong>Total Resources</strong></td>
<td>1393</td>
<td>1708</td>
<td>1814</td>
<td>1860</td>
</tr>
<tr>
<td>Municipal, Industrial, Tourist demands</td>
<td>392</td>
<td>439</td>
<td>500</td>
<td>561</td>
</tr>
<tr>
<td>Agriculture</td>
<td>676</td>
<td>703</td>
<td>668</td>
<td>656</td>
</tr>
<tr>
<td>Transfer demands</td>
<td>404</td>
<td>513</td>
<td>632</td>
<td>632</td>
</tr>
<tr>
<td><strong>Total Demands</strong></td>
<td>1472</td>
<td>1654</td>
<td>1800</td>
<td>1849</td>
</tr>
<tr>
<td>Groundwater return flows from losses</td>
<td>57</td>
<td>55</td>
<td>60</td>
<td>55</td>
</tr>
<tr>
<td><strong>Absolute Water balance</strong></td>
<td>-22</td>
<td>108</td>
<td>74</td>
<td>67</td>
</tr>
</tbody>
</table>

By these allocations, the deficit has not only been removed on national scale. Also on regional level, a neutral balance has been achieved for most balancing regions (s. Figure 2).
9.4 Major water management projects to achieve the goals

In order to achieve the water allocation goals, the following technical measures are required:

To achieve the goals of Scenario 1:

- Rehabilitation of municipal distribution networks
- Upgrading of field applications techniques (changing from surface to drip irrigation)
• General demand management methods (c.f. Chapter 4 of the Volume on Water Uses and Demands)
• Extension and improved operation of existing wastewater treatment plants (180 MCM/a total capacity) to make their effluents safe to use for irrigation
• Construction of new wastewater treatment plants (110 MCM/a capacity, c.f. Chapter 2, Table 2.4 of the Volume on Non-conventional Water Resources)
• Development of new wastewater reuse schemes in the vicinity of wastewater treatment plants
• Completion of Al Wehda dam on Yarmouk River
• Implementation of outstanding Peace Treaty Projects "Peace Treaty Desalinated Water from Lower Jordan River", "Peace Treaty Unknown resources".
• Implementation of the following dam projects Kerak, Fedan, Bin Hamad (until 2008) and Kufrinja, Yabis (until 2015).
• Completion and/or new development of projects for desalination of brackish water: Sweimeh (30 MCM/a capacity, with connection to Zara springs and Hisban well field) and Abu Zighan (18 MCM/a capacity
• Development of a seawater desalination plant of 5 MCM/a capacity at Aqaba
• Development of well fields on fossil aquifers: Disi (100 MCM/a by year 2010), Lajun deep wells (by 2005).
• Construction of a 300 km long pipeline with 100 MCM/a capacity from Disi well fields to Amman.
• Construction of a pipeline from Sweimeh at the Dead Sea to Muntazah (33 km long, 1300 m altitude difference).
• Construction of transfer lines for treated wastewater (capacity 20 MCM/a) from wastewater treatment plants near Irbid to irrigation areas in the Northern Jordan Valley.
• Construction of a pipeline for treated wastewater (28 km long) from Aqaba WWTP to Aqaba fertilizer factory.

Additional measures to achieve the goals of Scenario 2:

• Extension of the planned seawater desalination plant at Aqaba from 5 to 15 MCM/a capacity by 2020.
• Construction of a new pipeline (14 km long, 50 MCM/a capacity) from Abu Alanda in East Amman to Zarqa.
• Construction of a new treatment plant and pipeline (22 km long, 600 m difference in altitude, 40 MCM/a capacity) from Wehdah Dam to Zubdat pump station near Irbid.
• Construction of a branch (32 km long, 10 MCM/a capacity) from Disi - Amman pipeline to Ma’an
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