Jordan's Water Resources: Challenges for the Future

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Abstract

This paper reviews the status of the water resources in the Hashemite Kingdom of Jordan in the context of the global pattern of increasing demand for water linked to population increase, a growing urban-based population and increasing economic progress. Jordan is currently one of the world's ten water poorest nations, a situation which is being exacerbated by a rapidly growing population. Jordan has a climate ranging from Mediterranean to Arid with approximately 80 per cent of the country receiving less than 100mm of precipitation annually. Evaporation ranges from around 2000mm per year in Zarqa in the north west of the country to over 5000mm per year in Ma'an in the south. Renewable freshwater resources are of the order of 750-850 million cubic meters (MCM) with approximately 65 per cent derived from surface water and 35 per cent from groundwater sources. Current demands for water are of the order of 955 MCM. This shortfall is currently managed by controlling supply, but this is unsustainable. Treated waste water provides a possible additional source of water, but there are concerns and limitations over its use. Jordan must develop a strategy to manage its water resources sustainably, making full use of all available water resources. Some of the problems and possible solutions are discussed.

Introduction

In 1987, The World Commission on Environment and Development (also known as the Brundtland Commission) warned in the final report '*Our Common Future*' that water was being polluted and water supplies were being overused in many parts of the world. Since this time there has been a dramatic increase in water use for food and energy production to meet the demands of a rapidly growing population and to enhance human wellbeing (WWAP, 2006). These demands for water continue to rise and there is increasing evidence of water scarcity in many parts of the world. This scarcity has the potential to adversely affect economic development, environmental quality, sustainable human activities and a limit the possibility of the achievement of a wide range of economic, environmental and societal objectives (UNEP, 2007). In addition, in many countries, particularly in the less developed world, there a rapid growth in the proportion of the population based in urban communities. This growth in urban populations places substantial pressures on water resources and the infrastructure to deliver fresh water to the population and to remove waste water. It is projected that 75 per cent of World population growth to 2015 will take place in cities, predominantly in the developing world (UNDP, 1998), and consequently the need to develop and maintain the infrastructure to deliver water efficiently and of the required quality to both established and new urban dwellers will place tremendous

strain on existing facilities and require major investments in new facilities. In addition to requirements related to water provision there is a rapidly growing requirement to develop and maintain systems to remove wastewater and treat it before its return to the hydrological cycle. The nature and magnitude of these problems are highlighted in the United Nations Development Programme's *Human Development Report* (UNDP, 2006).

Water resources to meet these demands have been declining for a number of years and continue to do so as a result of excessive withdrawal of surface- and groundwater, as well as decreased water run off due to reduced precipitation and increased evaporation attributed to global warming (UNEP, 2007). In many parts of the world (for example West Asia and the Indo-Gangetic Plain in South Asia) human consumption of water exceeds annual replenishment. It is anticipated that by 2025 almost one fifth of the global population will be living in countries or regions with absolute water scarcity and two third of the population will be living under conditions of water stress (UNWater, 2007). Jordan in the Middle East and North Africa region provides an excellent example of a water poor country which has seen rapidly changing demands on water resources in recent years. The case of Jordan highlights the need to manage water resources carefully; this will involve setting clear programmes for identifying priorities for water use.

The Hashemite Kingdom of Jordan

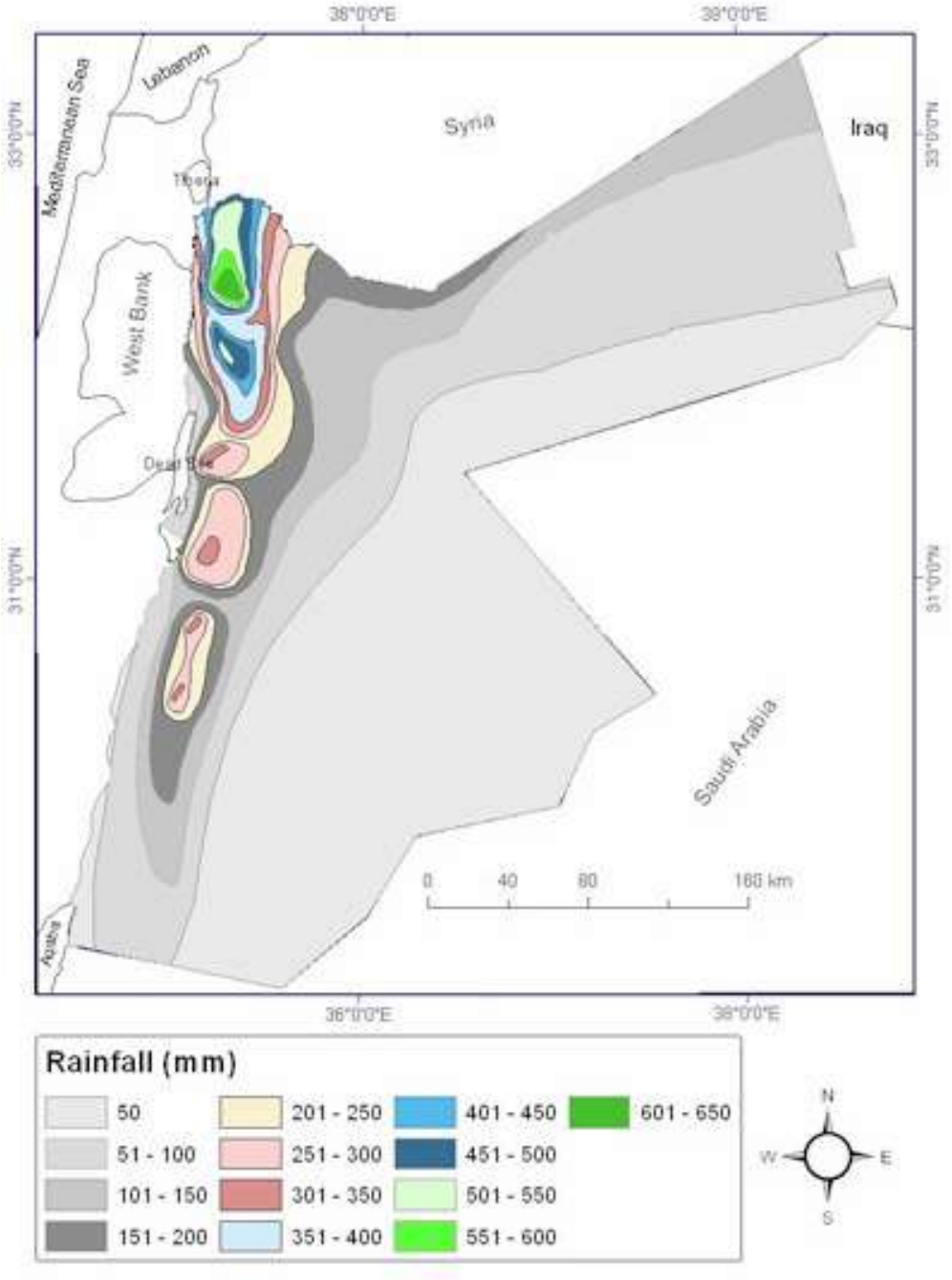
The Hashemite Kingdom of Jordan, lies in the eastern part of the Mediterranean region to the east of Israel, and has a land area of approximately 90 000 km^2 (Figure 1). Topographically it is diverse and the major topographic and geomorphologic features in Jordan control the drainage pattern. The overall drainage system in Jordan consists of two main flow patterns. The first drains water towards the Jordan Rift Valley, through deeply incised wadis and rivers dissecting the Jordan Valley-Dead Sea escarpments, to discharge ultimately into the Dead Sea. The second drains water through shallow streams and washes, which generally flow eastwards from the western highlands towards the internal desert depressions and mudflats.

Figure 1: The general geography of Jordan
(source http://www.lib.utexas.edu/maps/middle_east_and_asia/jordan_rel_2004.jpg)

The climate of Jordan ranges from Mediterranean to arid. The Rift Valley and the highlands belong to the semi-arid to arid climate zone, which is largely affected by moist westerly air masses in winter. In summer, dry easterly and north-easterly desert winds affect the Kingdom. Winds are generally westerly to south-westerly. A Mediterranean climate dominates most of the highlands on both sides of the Jordan River and in the mountain chains east of the Dead Sea and Wadi Araba extending as

far south as Ras El Naqeb. Dry summers with an average maximum annual temperature of 39°C occur between April and October. In the winter months, from November till March, the average minimum annual temperature is 0-1 °C. In winter, the average mean daily temperatures recorded at Amman Airport and Deir Alla were 10°C and 17°C respectively, for the period 1981-1998.

Figure 2: Rainfall distribution in Jordan (Source: Ministry of Environment, 2006)



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

Seasonal, uneven and fluctuating rainfall affects the country between October and May. Eighty per cent of the annual rainfall occurs between December and March. Average annual rainfall in Jordan, as shown in Figure 2, ranges from < 50 mm in the eastern desert to approximately 600 mm over Ajloun heights. Approximately 80 per cent of the country receives less than 100mm per year and less than 5 per cent of the country receives more than 300mm which is considered to be the minimum threshold below which it is not possible to grow wheat in the region. Error! Reference source not found. **1** presents the categories into which Jordan may be classified based on the rainfall distribution .

Table 1: Climatic classification according to rainfall distribution (MWI, 1997)

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

Source: Ministry of Water and Irrigation (MWI)

Rainfall is the only source of water supply in Jordan to recharge the groundwater aquifers. It is scarce and unevenly distributed over the country (Figure 1). The mountainous highlands along the Jordan Valley-Dead Sea-Wadi Araba depression receive the majority of total rainfall volume. Estimates of long-term records (1937/1938-2000/2001) of rainfall distribution over Jordan indicate that the average annual rainfall volume over the country is equivalent to around 8,360 million cubic metres, although probably in excess of 90% may be lost immediately to evaporation and makes little contribution to the overall water budget.

The population of Jordan has risen substantially over the last sixty year, growing from an estimated figure of around 470,000 in the early fifties to 900,000 in 1961 (1961 census) to 2,150,000 in 1979 (1979 census) and to 4.14 million in 1994 (1994 census). The Department of Statistics estimated the total population in 2002 to be 5.3 million, but recent influxes of refugee migrants from Iraq have significantly increased this number. (GTZ, 2004) The present indigenous rate of growth is estimated to be in the region 2.8 per cent; it is estimated that the total population will be around 10 million by ca. 2020 if growth continues at the present rate. Whilst the indigenous growth rate is expected to slow gradually in the coming years, the influx of refugees is markedly enhancing the rate of growth. (Potter, et al., 207b)

Water and its Multiple Uses

Water is a key, indeed an essential element in biological, social and economic systems. Human beings, plants and animals require a minimum level of water supply to be able to survive and their ability to function is often directly related to the extent to which this minimum requirement is exceeded. Within households the livelihoods, both with respect to domestic consumption and in many cases to productive capability, depend upon the provision of adequate water. In the broader context water plays a key role in environmental systems maintaining their productivity. Water cycles through the atmosphere, soil, plants and animals; in its absence biological productivity is reduced and may be curtailed completely. Whilst required to meet this multiplicity of uses, water is often scarce, a situation which creates competition for this vital resource; it is not possible to satisfy all these alternative uses simultaneously. Consequently it will be necessary to prioritise uses, or alternatively if there are water resources of different qualities, it will be necessary to allocate water of different qualities to different uses. In any such allocation a key consideration is whether access to water is on the basis of need or on the basis of which demand sector is able to pay the highest price. Additionally the geographic location of the water often dictates how the water can be used.

The disparity between the water resources of Jordan and its the water demands has been discussed by Molle and Berkhoff (2006). They argue that apparent bias in the allocation of water resources towards agriculture results from the source and quality

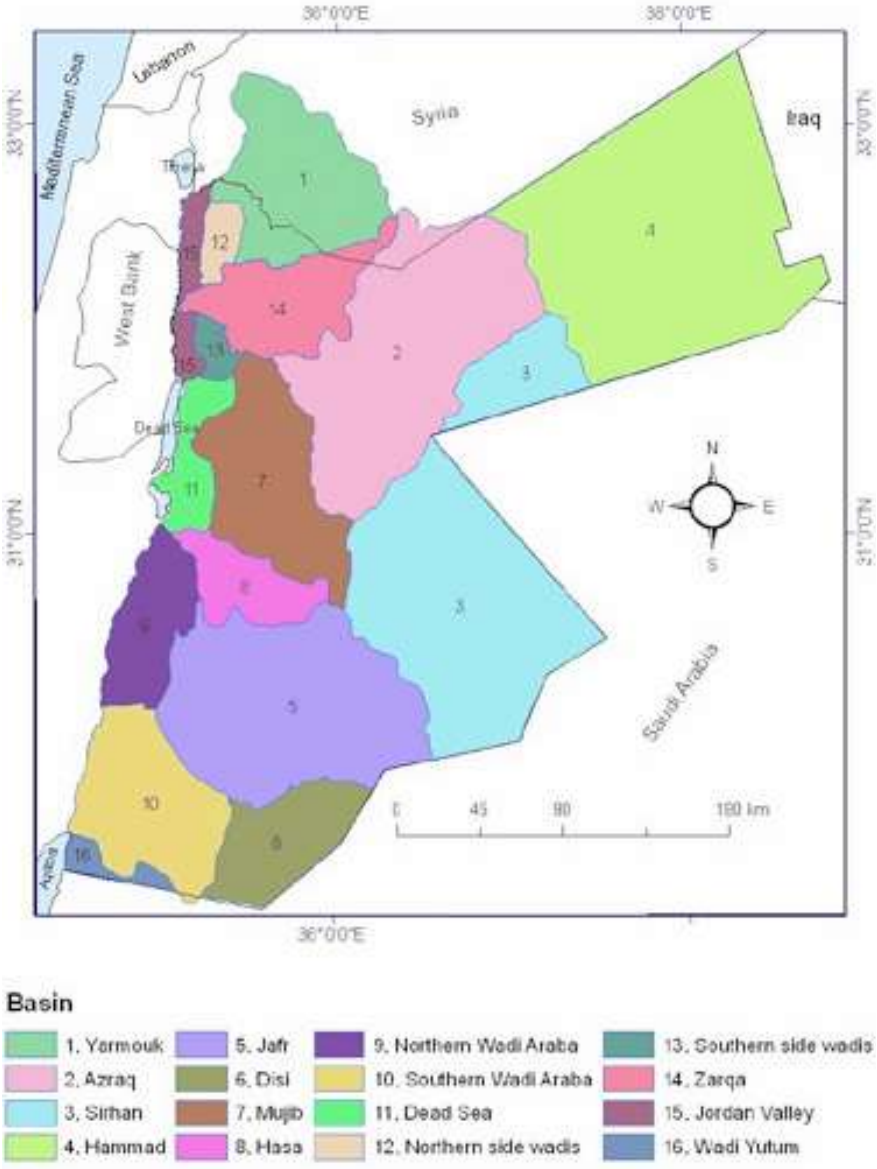
of this water (reclaimed wastewater or periodic flood flows) which makes it unsuitable for supplying to the municipality network. The geographical location of the water in relation to the urban sites of demand also plays a key role in sectorial allocation. Fresh surface water and groundwater that is located far from urban areas is often not exploited for drinking water supply due to the high related pumping and transfer costs. This water is therefore available to be used for irrigation at its source. Whilst water for irrigation will often be essential in the production of food, there is often a tendency to transfer water from agricultural use to municipal, and in some cases industrial uses. These decisions are made on the basis that irrigation is of 'low value' and municipal and industrial uses are 'high value' (Meizen-Dick, 1997). Economists often promote the strategy that water should be allocated to the sector where the highest economic returns can be gained from the water inputs. This causes a tendency to advocate the transfer of water from agriculture where economic returns per cubic metre are low to industry, tourism and municipality uses where economic returns are seen to be higher.

Current Water Resources and Uses

In a global context, Jordan is characterised as a 'water scarce' country. Internationally a 'water scarce country' is one with less than 1000 cubic metres of fresh water per person per year (FAO, 1997;Winpenny, 2000). Jordan is recognised as one of the ten most water deprived countries of the world; currently the *per capita* share of water is estimated to be of the order of 140 cubic metres *per capita* per year which is well below the 1000 cubic metre threshold. On current trends this will fall to less than 90 cubic metres per year by 2025. In contrast the average citizen of the USA has more than 9,000 cubic metres of fresh water available per year (Winpenny, 2000).

Current annual water consumption in Jordan is estimated to be 955 million cubic metres (MCM) whilst the renewable freshwater resources (surface and groundwater) are estimated to be only in the region of 780 to 850 MCM per year, with approximately 65 per cent derived from surface waters and 35 per cent from groundwaters. There is consequently a gap between demand and supply which evidence suggests has been widening rapidly in recent years (Table 3). Table 3 shows recent successes in reducing the total water demand, down from a peak of 994 MCM

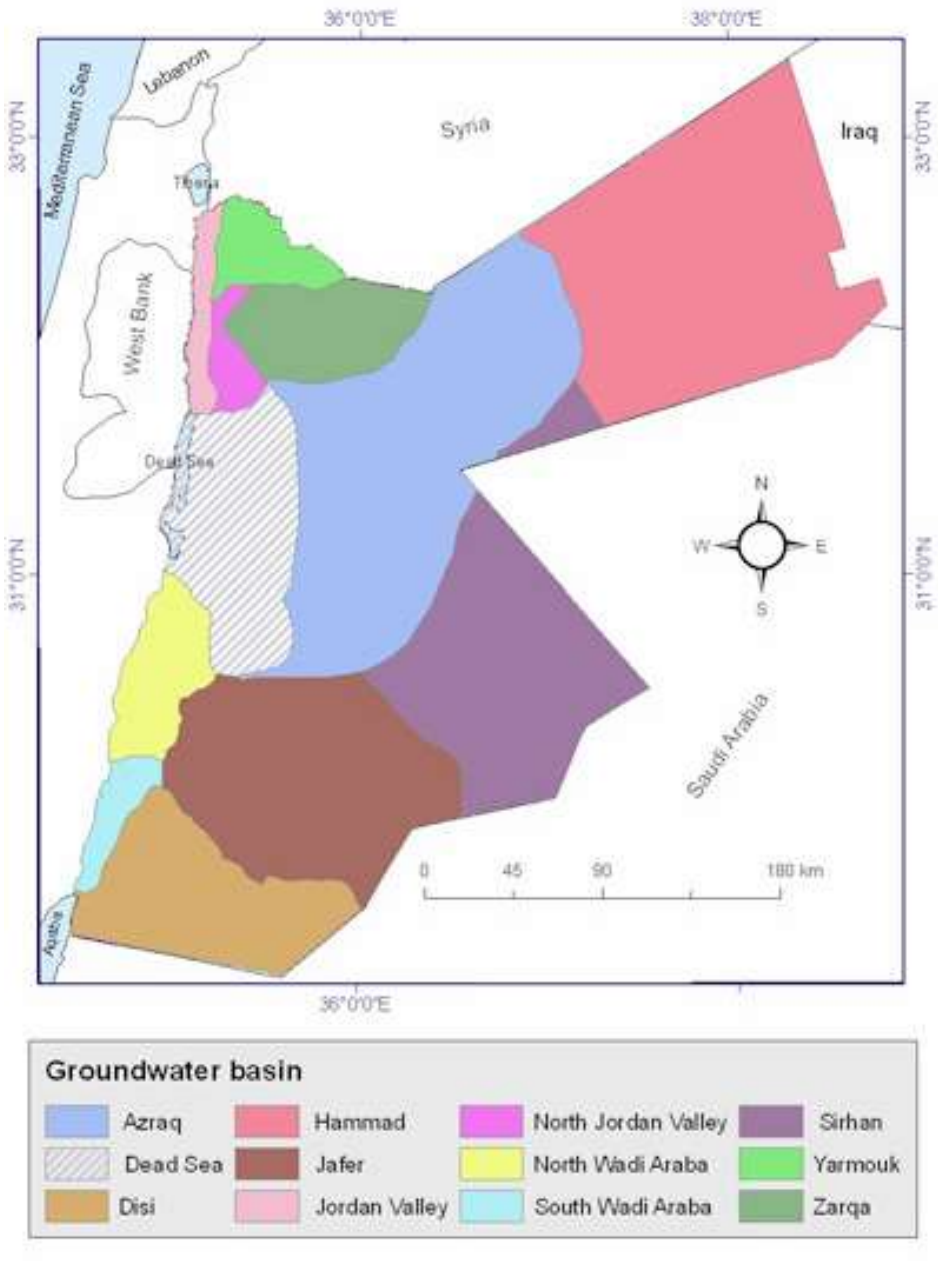
Figure 3: Jordan's Surface water resources (Source: Ministry of Environment, 2006)



in 1993 to 774 MCM in 2001, but current predictions are for the demand to exceed the 1993 peak by almost one third by 2010 (GTZ, 2004), with significant growth in the domestic and industrial uses. Some of these scarce resources are shared with neighbouring countries and as a consequence their management is not solely under national control. Surface water resources are spread across 15 major basins, as shown in Figure 3. Of these the Yarmouk River which forms part of the border with Syria to the north accounts for approximately 40 per cent of the country's surface water resources (Figure 3). In the 1970s the total flow of the Yarmouk River was estimated to be in the region of 400 MCM, but because of developments in the upstream Syrian

part of the catchment, the flow arriving in Jordan in the last 20 years has been substantially reduced and is now estimated at 150 MCM, and in addition, through international treaty agreements, Israel is allowed to access 100 MCM. The Yarmouk River is the main source of water for the King Abdullah canal in the Jordan Valley. The other principal basins include Zarqa, wadis adjacent to the Jordan River, Mujib, Hasi and Wadi Araba.

Figure 4: Jordan's Groundwater Resources (Source: Ministry of Environment, 2006)



Where there is no surface water, groundwater is the only water source. Figure 4 shows that there are 12 groundwater basins, most comprising several inter-related aquifer systems, within the country, approximately 80 per cent of the known reserves are concentrated in the Yarmouk, Amman-Zarqa and Dead Sea Basins. Current exploitation of these groundwater resources is at maximum capacity and in some cases exploitation is well above what is recognised as a safe yield (nationally it is estimated that extraction from groundwater resources is currently 50 per cent above the safe extraction rate). In some cases this over-exploitation has resulted in significant decline in the quality of the groundwater resources, there has also been some contamination of near surface aquifers as a result of the over application of pesticides and fertilisers as part of intensive agricultural practices and through seepage from septic tanks. Table 2 shows the allocation of water resources by source for the three major sectors of agricultural, municipal and industrial use.

Table 2: Sources of water used by sectors in Jordan in 2000 (MCM) (MWI,1997)

	Municipal Sector	**Industrial Sector**	**Agricultural Sector**	**Total**
Source				
Surface water				
- Jordan Valley	38.5	2.5	121.2	162.2
- Springs	14.9	0	38.0	52.9
- Base flow and floods	0	0	56.5	56.5
Groundwater				
- Renewable	176.4	29.6	206.0	412.0
- Non-renewable	9.4	4.6	47.7	61.7
Treated Wastewater	0	0	72.0	72.0
Total	239.2	36.7	541.4	
% of Total	29.3	4.4	66.3	

Source: Ministry of Water and Irrigation (MWI)

Recent trends have seen a rapid increase in the water consumption for municipal use, from around 20 per cent in 1992 to in excess of 29 per cent in 2000. This has resulted from both the higher number of people in the urban areas and the greater water demand resulting from raised standards of living. Increases are expected to continue as urban populations rise and people demand more water to meet their needs. In 2000 approximately 94 per cent of the water used for industry was from groundwater, with approximately 12.5 per cent from non-renewable sources. With the planned economic expansion of the industrial sector this demand is likely to increase in the coming years. Thus it is necessary to seek access to further reliable sustainable water resources.

Table 3: Jordan water use (MCM) by sector according to the Ministry of Water and Irrigation

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

[@] Estimated by Ministry of Water and Irrigation
Source: Ministry of Water and Irrigation (MWI)

The demand for water has been growing rapidly in recent years and the current estimated demand is in excess of the total water currently available (Table 3). There are few non-utilised conventional freshwater resources capable of development, although following the successful completion of the Unit Dam on the Yarmouk River

in the north there are a number of proposals to construct dams in the eastern desert to promote groundwater recharge. In part this is a component of a national programme to encourage groundwater recharge but there is anecdotal evidence that the relatively high price paid for groundwater is encouraging some landowners to recharge areas as an income generation process. There is also a proposed scheme to transfer treated wastewater from Irbid to a proposed dam in one of the wadis leading to the Jordan Valley, with subsequent transfer of this water to supplement irrigation water needs for agriculture in the Valley. The pressures on water are marked in Amman the capital where the vast majority of households receive water only on one or two days per week (Potter *et al*., 2007a, 2007b))

Whilst the total supply of water is a critical problem with predicted demand well in excess of sustainable resources, the allocation of fresh water resources is equally problematic. To date approximately two-thirds of the country's water has been used for agricultural crop production (see Tables 2 and 3). It has been reported that occasionally priority has been given to agricultural uses over urban consumers, industrial needs and the growing demand from tourism (GTZ, 2004). Whilst this may seem peculiar given the high value given to domestic and industrial uses, frequently the problem is geographical or perhaps more appropriately as a result of hydraulic disconnectivity, i.e. water is not necessarily found where it can be made available to these high value uses. This is further exacerbated by the apparent 'loss' of approximately half of Amman's water in the distribution network, both through leakages and unaccounted usage. One immediate response to these shortfalls has been increased extraction from groundwater resources, with many groundwater aquifers extracted at more than double their sustainable yield. This over-extraction exacerbates the problems faced in planning for future demands. Jordan's rapid population growth and the increasing importance of the industrial sector, coupled with the limited available water resources, has resulted in water scarcity being identified as one of the major constraints to sustained economic growth and development. Addressing the demands for water and producing an appropriate framework for the sustainable provision of water has become a high national priority.

Water in Jordan and the future

The *Ministry of Water and Irrigation* (MWI) is the Government body with responsibility for monitoring the water sector and managing the supply of freshwater and the wastewater system. The Ministry has recently established a *Water Demand Management Unit* to provide support for the optimisation of water use and the recommendation of enforcement and regulatory measures to prevent water misuse and wastage. The Ministry of Water and Irrigation embraces the two most important bodies dealing with water in Jordan: the *Water Authority of Jordan* with responsibilities for water supply and sewerage management, and the *Jordan Valley Authority*, with responsibilities for the socio-economic development of the Jordan Rift Valley, with particular responsibility for water development and irrigation which is key to continued economic wellbeing in this part of the country.

In 1997 the Government of Jordan, recognising the critical importance of water to the future of the Kingdom, and under the guidance of the World Bank committed the Ministry of Water and Irrigation to the development of an integrated policy of water resource management. *The Water Strategy for Jordan* was given the remit to consider sustainability of water resource management not only in the context of the economic and social development of the country, but also in the broader environmental context (MWI, 1997).

The key features of the strategy are:-

- To protect surface and groundwater resources by careful management of their use.
- To improve the efficiency in the management of both urban water and irrigation water.
- To develop an institutional capacity capable of managing water resources, supported by a legislative framework.
- To involve the private sector in the development of utilities with efficiency of water use and good financial management structures.

- To introduce a socially acceptable tariff system which might vary depending upon both the nature of the water use (e.g. domestic, industrial, irrigation, etc.) or type of water (e.g. surface water, groundwater, reclaimed wastewater).

This strategy statement moved Jordan towards a situation where privatisation of the water sector was a real possibility, as highlighted by the last two points above. The provision in Amman was privatised in 1999. Subsequently a key element of this strategy is the *National Water Master Plan of Jordan* (NWMP) which was developed in 2004 by the Ministry of Water and Irrigation with institutional support from the (GTZ, 2004) following from a national review of water resources in 1997 (MWI, 1997). The NWMP is a dynamic document which exists in electronic form, providing the opportunity for regular updating both to provide a context for changing conditions and for forecasting outcomes in scenario analysis. The NWMP has no specific legal framework within which it operates, but the key role is to ensure "Sustainable use of scarce water resources in line with a continuous improvement in living conditions for the country's population" (GTZ, 2004). The NWMP provides forecasts and scenarios for 2005 through to 2020, but because of its dynamic nature it is capable of being iteratively upgraded, and current practice is to operate a five year rolling planning programme. Following broad guidance from the United Nations on plans to address the optimal use of water resources (UN, 1989), the principal objective of the Plan is to provide a framework for ensuring organised and integrated planning and implementation of a programme for water resource allocation and use which is consistent with the national objectives of Jordan.

The NWMP recognises that within Jordan water resources are administered by a number of governmental authorities and private organisations, although the overall control lies with MWI. The Water Authority of Jordan is responsible for public water supply and sewerage; the Jordan Valley Authority is concerned with the overall development of the Jordan Valley and within that development programme a key component is the management and development of water resources for domestic, irrigation and industrial uses. Within Amman, from 1999 to 2007, water supply and management was the responsibility of the private sector via LEMA (Lyonniase de

Eaux – Montgomery – Arabtech) a venture established specifically for this purpose. Within Aqaba water provision and sewerage management is under a public venture, run in the style of the private sector known as the Aqaba Water Company. Since 2007 a similar approach has been used in Amman.

The NWMP addresses the provision of water under three broad strategies: those concerned with water resources; those concerned with water allocation and those concerned with the control of water quality. Each of these is reviewed below.

i. Water Resource Strategies

Within the broad remit of Water Resource Strategies the NWMP identifies three 'sub-strategies':-

- The sustainable use of natural water resources. In particular there is a need to protect and sustainably manage groundwater resources which constitute more than half of the current water supply. For a number of years extraction rates from the aquifers has often exceeded the sustainable yield which has resulted in decreasing groundwater tables and increasing salinity in several areas. In addition there are plans to extract 'fossil' water from non-renewable resources.
- Defend and protect the rightful share of international waters through bilateral and multilateral contracts, negotiations and agreements.
- Recycle wastewater and allow its use in unrestricted agriculture, groundwater recharge and other non-domestic purposes in accordance with WHO and FAO guidelines (Pescod, 1992; JISM, 2002)

ii. Water Allocation Strategy

The priority under this strategy is the provision of water for domestic use and indicates that this will be the focus for resource investment. Agricultural water provision is clearly identified as of lower priority and the NWMP allocates 'unwanted' water (e.g. treated wastewater) to this sector. If groundwater which is not required for domestic use can be extracted sustainably for agricultural use this may be used in the agricultural sector. An underlying principle in the strategy for allocating

water resources and ensuring that available water resources meet the demands in the key sectors, is the need to reduce demand and wastage coupled with the reallocation of water resources from low priority sectors (principally agriculture) to higher priority sectors (municipal, industry and tourism).

iii. Water Quality Control

An essential component of any water strategy is not only the provision of an adequate volume of water, but also to ensure that this water is of sufficient quality for the projected uses. For example, Ayers and Westcot (1994) provide general guidance on water quality for agriculture. The strategy emphasises the need to enforce existing national health standards for municipal water quality (JISM, 2001) and stresses the importance of an efficient and effective system of wastewater collection and treatment. Whilst ensuring the quality of water being used is an essential element of the overall strategy for water resources, the management of the water resources must also ensure that there is no reduction in the quality of water resources. For example, there is a need to prevent the decline in the quality of groundwater resources through recharge with poor quality water and, particularly in shallow groundwater aquifers, to prevent contamination of the water resources through inappropriate activities at the surface (e.g. over application of fertilisers and pesticides) with consequent leaching to the aquifer.

The Demand for Water

The increasing gap between the demand for water use and the supply of water has resulted in considerable competition between sectors. Within the NWMP the four basic water demands have been emphasised and prioritised:-

1. Domestic/municipal
2. Tourism
3. Industry
4. Agriculture

Domestic/municipal water is given the highest priority. The trend in water provision has been downwards with a daily per capita provision of 103 litres in 1996 falling to 86 in 2001. The short term target is to return to 100 litres/person/day by 2005, with an eventual aim of reaching an internationally accepted minimum standard of 150 litres/person/day by 2015. A significant tool in achieving these targets is the reduction in water loss from poorly maintained infrastructure (physical loss) and unauthorised abstraction, known locally as 'unaccounted for water'. Levels of physical water loss were estimated at 30 per cent of the total water provision in 2004 and it is anticipated that current water loss reduction programmes will reduce this to 15 to 20 per cent of the total. It is recognised that future developments in urban water provision must involve improved water distribution networks and less interrupted supplies to ensure that water is used effectively and sustainably (Potter et al., 2007a)

Tourism is a rapidly growing sector within the national economy, with significant developments in Amman and Aqaba and small concentrated developments on the shores of the Dead Sea at Sweimeh and Zara. The water demands associated with tourism are not simply the demands of humans but also include demands from the need to maintain attractive landscapes. Tourism is principally attracting visitors from outside the national boundaries, both from within the MENA region and beyond. Many tourists will have no perception of the status of Jordan's water supply and will frequently use water in volumes well in excess of local rates. The water demand for tourism is currently estimated at 5 million cubic meters per year and short term projects suggest this will quadruple by 2020. With careful planning and the development of water allocation strategies water of different qualities and different sources should be used to meet these demands. For example good quality treated wastewater is an appropriate source for many landscaping needs, and is being used as such in Aqaba and Dead Sea Resorts..

Traditionally industry in Jordan has focused on extractive industries, such as mining and quarrying (phosphate and potash) and the industrial production of cements, fertilisers and refined petroleum. Of the 32 million cubic metres of water consumed by the industrial sector in 2001, some 86 per cent was associated with these large traditional industrial activities. In recent years the industrial sector increased in

importance within the national economy, with developments planned at Aqaba, Irbid and Amman. Whilst many of these new industries are not characterised as large users of water the development plans suggest that by 2020, industrial needs will be approximately 120 million cubic meters, of which 54 million cubic meters will be required by the traditional heavy industrial users, some 13 million cubic meters by other established industries and 53 million cubic meters by the new industrial users.

Historically, agriculture has been a major activity among the population, either as a principal activity or often in conjunction with other forms of employment. In 2000 agriculture used approximately 66 per cent of water resources (Table 2) although by 2002 the agricultural sector's contribution to GDP was below 4 per cent. Whilst this suggests the reduction in agricultural production will not have significant impacts on the national economy it is clear that the agricultural sector has an important social and economic role. Agriculture provides employment both directly within the agricultural sector and in a vast number of agricultural support services such as fertiliser manufacture, transportation, irrigation supply and maintenance etc. Agriculture also contributes to food security and nutrition within the country and plays a role in generating tax revenue for central and local governments. The possible social impacts of abandoning agriculture would be particularly pronounced in rural areas where a large proportion of the population are active in the agricultural sector. Yet despite the benefits of agricultural production to the economy, the agricultural water demand is considered to be of low priority nationally and the access to surface and groundwater is most likely to be increasingly restricted. To maintain profitable agriculture there is a need for a strategy which focuses on replacement resources such as reclaimed wastewater, brackish water, water harvesting and the desalination of groundwater. The provision of resources must be coupled with maximised efficiency of water use. This requires careful water scheduling by farmers and correspondingly appropriate scheduling and provision by state water providers. .

Whilst there have been substantial improvements in the provision of drinking water to the population, with in excess of 98 per cent of the population having access, there are still major problems concerning the reliability and adequacy of the water supply, with many households receiving water only two days per week.

As stated above, not all Jordan's water resources are directly under national control. The Peace Treaty of 1994 guarantees Jordan rights to 215 million cubic meters of water annually through new dams, diversion structures and pipelines and also a desalination/purification plant. Currently less than 30 per cent of this water is received. The water supply from the Yarmouk River which has its headwaters in Syria is also currently subject to complex bilateral discussions. The recent completion of the Unity Dam on the Yarmouk will allow greater control of the flow of this river.

Other Sources of Water

As stated previously, economically developable renewable water resources in Jordan are finite, and even taking the upper estimate of 850 million cubic meters, fall well short of the projected increases in demand which are given in Table 3. In part, the increased demand has to date been met by abstraction from groundwater sources at levels, nationally, in excess of 1.5 times what are considered renewable rates; and locally some rates of extraction are considerably greater than 1.5 times the renewable rates. Such extraction rates are clearly not sustainable and provide only a short term solution to the problem.

Recently, agreement has been reached to extract water from the Disi aquifer on Jordan's border with Saudi Arabia (Figure 3), by connecting the aquifer to Amman with a 325 km pipeline. Additionally non-renewable groundwater resources are being exploited from the Zarqua aquifer (approximately 43 million cubic meters). Even excluding these non-renewable resources the current rates still result in a major shortfall of renewable water resources and other sources must be considered; these include:-

1. Treated wastewater – in 2000 approximately 72 million cubic meters of treated waste water was used in the agricultural sector, although much of this water was not of high quality. With recent investments in water treatment facilities (for example at Al Zarqa and Ramtha) the availability of treated wastewater will increased markedly, and the shift from predominantly primary and secondary treatment to tertiary and better treatment technologies there will

be a marked improvement in water quality. Current estimates from the Ministry of Water and Irrigation are that the amounts of wastewater used for irrigation should reach 232 MCM by 2020 (Mohsen, 2007).

2. Brackish groundwater – Jordan has a number of brackish groundwater resources. Whilst there is some limited extraction for agricultural use, the salinity of these waters places some limitations on crop production. Currently proposals have been made to extract brackish groundwater in the Jordan Valley (50 million cubic meters per year) and treat this at a desalination plant to provide water for municipal and industrial use. The GTZ have worked extensively on brackish water use in the Jordan Valley. Several farms in the JV are irrigated with brackish water and some large farms also operate their own desalination plants privately.
3. Seawater desalination – Technologies to desalinate seawater are being considered to supplement Jordan's water resources, initially at Aqaba, Jordan's outlet to the Red Sea. In addition there are tentative proposals to build a pipeline to transfer water from the Read Sea to the Dead Sea (Beyth, 2007). Part of the aim of this pipeline would be to replenish the decline saline water in the Dead Sea There are also plans for desalination facilities to supplement other fresh water sources.

Whilst not an alternative source of water, it is estimated that addressing the losses of water in the water supply system, the so called 'unaccounted for water', could result in a substantial saving of resources. In 2000 it was estimated that approximately 50 per cent of the municipal water supply across the country was considered to be 'unaccounted', and within the Jordan Valley some 35 per cent of the irrigation water is unaccounted for. While unaccounted does not mean unused it is thought that significant losses from poorly maintained infrastructure could be avoided through pipe and canal improvement to reduce leakage.

Conclusions

Ensuring that Jordan has a supply of water that is both sufficient to meet the nation's needs and is of appropriate quality, is one of the major issues facing the country in the 21st Century. The history of water use in Jordan has been one of poor control and

often wasteful use, with, in recent years, consumption consistently in excess of sustainable supply, and the shortfall being met by over extracting from renewable groundwater supplies or extracting water from non-renewable groundwaters. Following national and international investment there is now a satisfactory monitoring system which provides the data base on the nature and extent of the country's water resources, and how the water is used between different regions and different sectors. This monitoring and the data provided are essential components of any future strategy for water resource management.

With water being such a scarce resource, coupled with the rapid expansion of population, it is essential that planning and prioritisation of water use is undertaken. In the past, agriculture has been a major consumer of Jordan's water resources. The plans for the future indicate that the limited water resources available for agriculture need to be allocated appropriately. Consideration must be given to suitable high value crops, with export potential, appropriate irrigation methods, scheduling and cultivation locations. Within the municipal context a priority is to address the infrastructure to ensure that the losses of water either through poorly maintained delivery systems or through unauthorised accessing of water supplies must be a priority. Given the paramount importance of supplying relatively low cost, high-quality water for human use and some industrial uses, it is imperative that Jordan ensures that the high quality resource is not used wastefully. For example, it is necessary to irrigate gardens and clean road surfaces there is a strong case for using alternative resources such as treated waste-water through grey water reuse systems, and roof top water harvesting. The close management of water is imperative for every water use sector, within the Kingdom to ensure sustainable development.

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