Policies and strategic options for water management in the Islamic countries

Proceedings of the Symposium organized by the Regional Centre on Urban Water Management (RCUWM-Tehran)

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Preface

The December 2003 International Workshop on 'Policies and Strategic Options for Water Management in the Islamic Countries', held in Tehran, Iran, was co-organized by RCUWM–Tehran, under the auspices of UNESCO, and the Islamic Development Bank (IDB).

RCUWM–Tehran responds to the challenges of urban water management and to the need and call, through several important international events, for a significant change of attitude by the international community from merely verbal appeals to concrete action. Indeed, based on the recommendations of the Ministerial Conference (Hague, March 2000), of the Marseille Statement (June 2001) and of the Regional Consultation (Tehran, May 2001), the government of I. R. Iran proposed to establish RCUWM–Tehran within the framework of UNESCO's International Hydrological Programme. The centre was formally established under the auspices of UNESCO via the agreement signed on 17 February 2002.

RCUWM–Tehran has since undertaken a vigorous initial programme of activities and considers appropriate at this point to adopt a work plan considering a strategic and long-term view. Thanks to the support of international organizations and the government of I. R. Iran, RCUWM–Tehran was able to hold a considerable number of research projects, training workshops, and technical and scientific seminars throughout 2003, its first year of activities, including other successful events such as this workshop.

Run by its Governing Board, which includes twelve member countries (Ministers, governmental and non-governmental organizations), the mission of the centre is to disseminate applicable scientific knowledge and increase capacity-building in all cases and dimensions of urban water management in order to promote sustainable development and enhance human welfare in the region states.

Introduction

Today the role of water as a vital and precious substance, as a stimulating force in socio-economic development and as key factor in water ecosystem conservation is obvious and clear.

While this importance is particularly prominent and tangible in the Islamic countries, which are located in the arid and semi-arid regions of the world and are suffering from intensive water shortage, our water management problems and challenges are not confined to the natural shortage of water resources: inappropriate methods of water management along with incremental deterioration of water quality have been additional stressors.

In the past three decades, research has shown that population growth and accelerated socio-economic development have markedly increased water demand, while the consumptive pattern in the region is facing important challenges. For instance, in many of the Islamic countries, more than 90 percent of supplied water is entirely allocated to the agricultural sector.

Research conducted on water management processes in the Islamic countries show that expansive efforts have been taken solely on the supply side. In many countries, inappropriate water abstraction from groundwater has led to over-consumption and has caused negative consequences, seriously threatening sustainable development. Existing conditions illustrate that mere reliance on supply-side methods is neither a reasonable nor trustworthy solution against regional water management challenges and will not provide water security. In some countries, water resources development through supplying methods has reached or even exceeded the ultimate limits; in countries still capable of supplying water and expanding physical development, the water supplied marginal cost is significantly increasing. Clearly we must come to the conclusion that this trend is not practical and must not be continued. Unfortunately, despite the consequences, the non-structural aspects of water management and demand management are not sufficiently taken into account: water consumption with very low efficiency, disregard for the economic value of water, lack of a proper plan for investment in reusing wastewater, problems related to the operation and maintenance of water projects and intensive water loss in urban water supply networks remain important challenges. We must urgently and with great sensitivity aim at preventing the occurrence of more intensive water crises in the region by both reviewing past behaviour in water management and seeking innovative approaches.

Fortunately, there are signs suggesting that regionally countries have begun to recognize these necessities at political as well as civic and expertise levels. In recent years in many countries, sound approaches packaged as policy reforms are under consideration, ones that emphasize both the demand and supply sides of water management and develop legal frameworks and governance systems. Key issues arising from such considerations include an integrated framework for water resources, as well as information management systems, water quality management, increased water use and allocation efficiency, promoting the role of the private sector in different aspects of water management, pricing policies based on cost recovery methods, prevention of mining groundwater, stockholders cooperation, developing water management structures, food security and virtual water trade, to name but a few.

Undoubtedly, training workshops and seminars can help put such processes into practice and facilitate integrated water resources management in the region. It is our hope that the International Workshop on ‘Policies and Strategic Options of Water Management in Islamic Countries’, held in Tehran, Iran, 15-16 December 2003 – which brought together experts, university professors, decision-makers and governmental and non-governmental organizations from UNESCO, UNESCO-IHE Institute for Water Education, the World Water Assessment Programme, INWRDAM (Inter-Islamic Network on Water Resources Development and Management) as well as from different countries (Bangladesh, Bahrain, Egypt, Iran, Jordan, Malaysia, Oman, Pakistan, Saudi Arabia, Turkey) – was a forward step toward founding principles of integrated water resources management in the Islamic countries, in compliance with the declaration of the Johannesburg Summit towards the 'adoption of comprehensive policies and strategies for integrated water management and active implementation in all countries'.

May the recommendations and approaches suggested in this seminar move us closer to achieving sustainable development for all regional inhabitants, and to strengthening cooperation and seeking practical approaches to solve our common challenges with respect to the cultural, social and economic conditions of the Islamic countries.

Dr. Reza Ardakanian
Director
RCUWM–Tehran

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Unifying Water Concepts: Water, Food and Environmental Security

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I would like to take you on a short trip through the world of the Green Water Sciences and its applications.

Let us begin by looking at some astounding figures: 1.1 billion people around the world do not have access to adequate water supply and 2.4 billion to sanitation facilities. Moreover, in a period of about thirty years, more than 50 per cent of the biodiversity in freshwater ecosystems has disappeared. More than 750 million people are not adequately fed in developing countries; this is also the case for approximately 40 million people in the West and countries in transition. Agriculture and horticulture uses about 67 per cent of the 'blue' water annually available, industry 19 per cent, and 9 per cent goes to urban and domestic use. Still, we are not thrifty with our water usage. For instance, 55 per cent of water used in irrigation processes is lost before it even reaches the crop. Moreover, the switch from a more vegetarian diet to a diet with more meat has also proven disastrous for water consumption: it takes ten times as much water to produce 1 kg of fresh veal (15 m^3) than 1 kg of corn (1.5 m^3). In addition, estimates state that about 15 per cent of total global water consumption is attributed to the 'virtual water trade'. This refers to water that is used to produce a good in agriculture, such as animal feed, being shipped internationally for the international trade of meat and vegetable products. To add perspective, in my country, the Netherlands, a net amount of virtual water equal to one third of the annual discharge of the Nile River is being imported (Van Vierssen & de Zeeuw, 2003; Zehnder, 2003).

Moving beyond figures for a moment, in recent years, much has been done internationally to increase awareness on the issue of water management. This awareness process has been a gradual one, resulting from, among other things, the Stockholm Conference on Human Development (1972), the Dublin Conference on Water and the Environment (1992), the 1st World Water Forum in Marrakech in 1997, followed by a very successful 2nd World Water Forum in The Hague in March 2000. Approximately 15,000 professionals attended the latter forum. In September 2002, the World Summit on Sustainable Development in Johannesburg definitely put water management on the international political agenda, thanks in part to a preliminary memo entitled 'No Water No Future' (HRH the Prince of Orange, 2002). And finally in March 2003, the 3rd World Water Forum in Kyoto assembled more than 20,000 stakeholders; the first World Water Development Report (UN, 2003) presented the first global overview of water problems translated into figures, trends and analyses; and very recently, an editorial of HRH the Prince of Orange was published in the context of the International Year of Freshwater subtitled: 'Water is Everybody's Business' (2003). Indeed, this will be the challenge in decades to come.

In the meantime, we have agreed on these objectives: a significantly higher number of people should have access to safe drinking water and sanitary facilities, with the precondition that there remain enough water for nature. In this respect we have commonly acknowledged that 'there is enough water, but we are not managing it effectively or efficiently enough', the primary reason being, among other things, **the lack of competent institutions**.

In an effort to establish a link between the influential developments in science and society related to this topic, I shall address and illustrate the three following questions based on current developments in water sectors worldwide:

1. The paradigm of changes: large-scale changes in our way of thinking and new insights in how things work
2. Examples of innovative research in the field of water: how Wageningen contributes
3. Institutional preparation: what does a modern multi-national centre of knowledge look like and what requirements must it meet?

The paradigm of changes: new insights

On the phenomenon of change

What do we actually know about it? We usually assume that changes of any kind take place gradually. For example, until recently we assumed that the consequences for water quality in shallow lakes as a response to the increase of phosphate content are linear. We assumed that if the increase were steady, the clarity would in the same steady manner (linearly) decrease due to water becoming more turbid caused by the growth of algae. The predicted effect was that water plants, of crucial importance for biodiversity, would in turn decrease in number due to the diminished clarity. Conversely, we assumed that with steady decreasing phosphate concentrations, water plants would gradually increase again in the biomass. However, nothing seems to be less true. After extensive research, including in many shallow water bodies all over the world, it seems that there is a sudden transition (or a 'catastrophic event') from one condition to the other: either a clear lake with water plants or a turbid lake with only suspended algae. What we see is known as *hysteresis*. In other words: the pollution process is different from the recovery process. This means that with the same phosphate content, two totally opposed situations may occur. We call them 'alternative' in the case of two or 'multiple' in the case of multiple 'stable states'. We may conclude that 1) gradual environmental changes can stealthily undermine the flexibility of ecosystems and systems in general and, even lead to their collapse; and 2) the way back costs a lot of energy (Scheffer et al., 2001; Gunderson & Holling, 2002).

The same phenomena of 'catastrophic events' and 'multiple stable states' have also been identified and documented for coral reefs, savannas, deserts and oceans. However, researchers also discovered, for example, that the formation of large constructions could make societies vulnerable. Based on the reconstruction of building activities in the cities of western American Anasazi Indians, researchers have now confirmed their theory: that larger constructions are not easily abandoned. Even if the circumstances are bad, building activities ensue. This means that societies may actually get caught in a psychological trap, which induces them to cross a rather critical border, which causes natural resources to collapse due to overexploitation, resulting in societies reaching a dramatic end.

From agriculture to ecological services

A second big change occurs in the way we think about agriculture: we are moving from agriculture to ecological services. In Europe, but also elsewhere in the world, we are seeing big changes in the landscape. As a general tendency, huge metropolises are emerging and, partially related to that, depopulation in rural areas. In the Netherlands, we are not yet dealing with large-scale depopulation, but we do see that rural areas are going through drastic transformations. Partly due to European regulations, we are in need of new functions for rural areas because aspects of industrial agriculture are no longer economically feasible. We are also looking for a vital countryside where we will have to find new economic carriers in order to reach sustainable management and production. The same applies to large areas in developing countries where farmers are looking for the same new economic carriers. Niels Röling (2002), a Dutch professor studying such transformations worldwide, thus speaks of 'post-normal agriculture' or 'learning and organizing to make optimal use of ecological services'. In that context, we can easily conceive the conservation and storage of water as the 'blue services' of the future.

Changes to the concept of 'borders'

We are increasingly living in a medial world with the Internet as our superhighway. Knowledge is shared much more quickly than before. Therefore, groups with shared interests and ambitions are coming together more easily than ever before. In the words of Francis Cairncross this is the result of the 'death of distance' (Cairncross, 1997). However, we are running the risk that the world is going to be divided in a rich upper echelon and a poor lower stratum. I do not exclude that we are unconsciously creating small societies as parallel 'multiple stable states'. These could well be the 'gated Internet communities' of the future. It should be our common ambition to keep serving the **whole** society with research, in both the North and the South.

Climate change

We can be sure today that human beings affect climate. The Intergovernmental Panel on Climate Change (IPCC), concludes that the average temperature on earth has increased with an average of $0.6 \pm 0.2\ {}^0$C since the beginning of the twentieth century. Based on these calculations, a further temperature increase of about 1.4 ^{0}C to maximum 5.8 ^{0}C is expected in the twenty-first century. For the northern hemisphere, rainfall levels have increased by 5 per cent to 10 per cent over the past century. This tendency seems to persist. We know quite well what these figures imply for instance in the Netherlands. With a subsiding landmass, a rising sea level and more water discharge, we are living with a serious problem. In my country, the scientific community is closely involved in finding possible solutions, and in the process, we should conjecture to what extent our water management and our hydraulic engineering works are somewhat similar – as far as social effects are concerned – to the Anasazi example mentioned earlier. Internationally we should try to link up research communities in order to enhance our understanding of the impacts of climate change and to develop effective adaptation strategies.

Examples of innovative research

Worldwide, thousands and maybe even tens of thousands of scientists are directly or indirectly dealing with water problems. Allow me to share some examples of the advancements of science, specifically in fields where research has led to certain applications, such as 1) 'competing claims on natural resources', 2) using water more sparingly in agriculture and 3) Integrated Coastal Zone Management.

Competing claims on water

The first example is of competing claims in integrated water management practices in the inner delta of the Niger River. In the framework of an international water research programme sponsored by the Dutch Government (Partners for Water, Interdepartementaal onderzoeksprogramma), multiple uses of water were studied. The conclusion is that there is a clear connection between the management of dams in the Niger River, the fish production and the catching of fish downstream. On the other hand, the management of these dams seems to be a decisive factor for the number of purple herons in the Netherlands. This is also linked to the available food in the downstream part of the Niger. In this context, the concept of ‘environmental flow requirements’ (Van Vierssen, 2003), which was presented in Johannesburg and Kyoto, is of vital importance. The concept is based on the assumption that to fulfil essential ecological functions, the hydrological system of a river should meet a number of minimum requirements. Sufficient water quantity of equally sufficient quality at certain critical moments in a given year is one of these prior conditions. In this context, the knowledge developed in the field of Ecosystems Value is highly relevant (Costanza, d'Arge, de Groot, et al., 1997). This knowledge is indispensable to make a few economic considerations between different functions within the multiple uses of water.

Efficient use of water

We have known for a long time that human interference with natural landscapes (i.e. transforming them into agrarian systems) may drastically affect the water balance: runoff and evaporation increase while infiltration and transpiration decrease. This in turn affect the fraction of rainwater that determines the levels of crop growth. These effects are expressed in the so-called ‘Green Water Use Efficiency’ (GWUE). Water conservation reduces erosion, improves the properties of the soil and increases the GWUE (Stroosnijder, 2003). In the semi-arid regions of Africa, water conservation can double this GWUE and, therefore, contribute to food security. In this context, mulching, or compartmenting fields by means of stones or natural vegetation (for example with *Andropogon gayanus,* a grass) can be very effective to reduce runoff. Breaking the local soil crust also seems very effective. This is especially the case when it is combined with mulching and when the role of termites is optimally used. The latter are of great importance when organic material and, therefore, nutrients are added to the soil. We may conclude that water conservation should always take place when linked to the active management of nutrients and, that under optimal conditions, it can triple local production output.

Another example of water saving in agriculture is evident in the production of rice. Almost half of the world’s population, majority residing in Asia, depends on the production of rice for food consumption, not to mention for employment opportunities and income generation. Seventy per cent of the available amount of freshwater is currently used for irrigated rice growing in Asia. Cultivation requires the crop to be grown under water, i.e. in water rising 5 cm to 15 cm above ground levels. Two to five thousand litres of water is required to produce 1 kg of rice, compared to other corn crops that require two to five times less water. After an extensive study, Wageningen’s researchers discovered that, with adjustments of the entire rice system, a significant amount of water could be saved – up to tens of percentages – without affecting the yield. Therefore, this investigation is partially a search for other crops and varieties.

One of the tools used by our researchers to find and test such varieties is the research robot. This robot analyses the inundation tolerance or drought tolerance of a large number of crops and their genotypes. It translates growth and stress levels into visualizations by means of moving images. In this manner, the water need of a large number of crops can easily be established.

A completely different approach to water saving is a technique used in a number of semi-arid regions, such as the regions in the Sahel, Mongolia and the Mediterranean. Because of non-durable agricultural practices, these regions are threatened by desertification at the expense of natural vegetation. This, in turn, leads to a reduction of the total moisture capacity of the soil and, eventually, vegetation through evapotranspiration. Consequently, the air temperature increases and less precipitation falls. A negative spiral effect and land degradation is the result. By intervening temporarily and directly in the system by means of planting natural vegetation, this negative spiral can be broken thereby increasing agricultural productivity. The theory of the ‘alternative stable state’ also seems to apply in this case.

Wageningen works together in this field with partners in Japan and Saudi Arabia, in a test project in the southwest of the Arabian Peninsula.

Integrated Coastal Zone Management

One last domain is that of the Integrated Coastal Zone Management. Almost 70 per cent of the world population lives within a distance of 50 km of a seacoast. The reason is that coastal zones are generally and naturally very productive, but at the same time very vulnerable. If we look at many of these areas, we are stunned by the number of competing claims (shipping lanes, pipes, natural resources, recreation, extraction of minerals, wind parks). In many of these densely populated areas, freshwater is becoming a limiting factor for economic growth.

Particularly in some southern countries in the Middle East and the Mediterranean region, the need for freshwater has increased so much that a significant part of drinking and industrial water has to be covered by desalination. In southeast Spain, desalinated seawater is used for a large part of horticulture in greenhouses. In the region of Almeria 27,000 ha are unused, which is nine times as much as one of the world's most productive horticultural areas, the Dutch area called the Westland.

However, there is more to it in a salt environment. Recently, an interesting article caught my attention, entitled 'Intensive Sea farm. Wanted: Vegetarian Salmons'! One third of the fish caught in the world – 30,000,000 tons – is processed to obtain fish flour and fish oil, which is used in fish feed. But after 2010, the world's seas will no longer be able to cope with the growth of fish farms, unless salmons are given more and more vegetable food. In the past few years, a strong increase in the field of aquaculture and fish farming has been observed related to an increased demand for fish and the problems related to over-fishing. The feed of carnivorous farm fish consists largely of fish oil and fish flour and it is expected that the demand for these components will be larger than the supply within the next five to ten years.

Recently, an alternative for fish oil was developed. This important fish feed is made under controlled conditions from algae in a reactor vessel. This is a successful bioconversion, which means that a micro-organism is used to make products with high-quality applications. In the laboratory, the selected alga, *Crypthecodinium cohnii*, seems to be capable of producing the desired fatty acid.

How do we prepare ourselves institutionally?

To begin with, we need to pool our resources worldwide in order to be able to cope with the large problems we are facing worldwide. We need to develop multi-national centres of knowledge. By multi-national, I mean virtual institutions with extensive international partnership relations. I would say that the Regional Centre for Urban Water Management in Tehran could become one of these virtual institutes in the region. But if we want to become successful in international collaboration, we have to also be able to place ourselves in the circumstances of other parts of the world, in other cultures and in settings that are very different from our own. We will only remain attractive if we can **act in knowledge**. This means looking at the world around us. Four components of acting in knowledge are important: **identifying** (or observation), **knowing** (or theory), **wanting** (or emotion and values) and **being able** (or action). Coherence and correspondence (relation to the environment) between these components need to exist. If we want to continue developing ourselves as a centre of knowledge, working in knowledge chains and with this model are of central importance.

I hope to have herewith provided some insight into a number of major developments in the green water research domain. It is also my hope that the RCUWM in Tehran will develop innovative solutions to the many needs of the region in integrated water resources management, including the green components.

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Wageningen UR: www.wur.nl
World Water Council: www.worldwatercouncil.org

Water Demand Management Options in Islamic Countries

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Introduction

Most Islamic countries are situated in regions with similar agro-climatic conditions (arid to semi-arid) and with the most water scarcity in the world. Natural water resources are very limited, fragile, and threatened. Freshwater is derived from rainfall that either recharges groundwater aquifer systems or is impounded in manmade reservoirs – where feasible during winter – to be used throughout the entire year. Huge freshwater bodies like big rivers and lakes are limited; freshwater supplies are unequally distributed, unequally shared, and irregular in time and space, creating water shortages in most of the countries.

The water resources situation in Islamic countries can be summarized as follows:

- Water availability is solely dependant on rainfall
- Water resources are limited
- Water demand is higher than supply and continues to increase
- Most of the existing water resources are committed and overexploited
- Most Islamic countries do not make full use of treated wastewater
- Water distribution systems are old
- Water consumption could be reduced by increased public awareness
- Permanent rivers and flowing springs are very limited, thus water for summer uses must be stored in dams or groundwater aquifers
- Water transportation from areas with excess water to those poor in water is very limited and very expensive when it exists
- The steep morphology combined with lack of vegetation reduces the chances for water harvesting and groundwater recharge
- The existence of water resources at remote areas from urbanization.

In addition, water practices and applications differ greatly between countries, depending on:

- population density
- lifestyle and living standards
- development level
- water availability and economic activity
- demand and management
- legal and institutional frameworks
- culture and education.

The following table (Table 1) shows the volume of renewable freshwater resources available per inhabitant per year. Falkenmark indicators were used to define the beginning of water stress at 1,700 m^3 per capita per year, and the beginning of water scarcity at 1,000 m^3 per capita per year.

Table 1: Renewable freshwater resources available per inhabitant per year

Country	Population (thousand)	Land area (000 km^2)	GPD ($)	Agriculture as % of GDP	Life Expectancy (years)	Freshwater per capita (m^3/year)	% of population with access to improved water services
Algeria	29 950	2 381.7	1 550	11	71	477	94
Egypt	62 655	995.5	1 380	17	67	930	95
Jordan	4 740	88.9	1 630	2	71	148	96
Lebanon	4 271	10.2	3 700	12	70	1 124	100
Morocco	28 238	446.3	1 190	15	67	1 062	82
Syria	15 711	183.8	970		69	2 845	80
Tunisia	9 457	155.4	2 090	13	73	434	
Palestine	2 839		1 780	17	72		
Yemen	17 048	528.0	360	17	56	241	69
Bahrain	666	0.7			73		
Cyprus	760	9.2	11 950		78	1 052	100
Iraq	22 797	437.4			59	1 544	85
Libya	5 419	1 759.5			71	148	72
Oman	2 348	212.5			73	426	39
Saudi Arabia	20 198	2 149.7	6 900	7	72	119	95

Source: *World Bank Atlas, 2001.*

The level of exploitation of available water resources varies from country to country depending on the characteristics of the available resources, demand and the availability of funds. The following table (Table 2) shows the available water resources and their allocation between the different sectors.

Table 2: Freshwater withdrawal by country and sector

Country	Total freshwater withdrawal (km^3/yr)	Domestic Use (%)	Industrial Use (%)	Agricultural Use (%)
Algeria	4.50	25	15	60
Egypt	55.10	6	8	86
Jordan	0.98	22	3	75
Lebanon	1.29	28	4	68
Morocco	11.05	5	3	92
Syria	14.41	4	2	94
Tunisia	3.08	9	3	89
Yemen	2.93	7	1	92
Bahrain	0.24	39	4	56
Cyprus	0.21	7	2	91
Iraq	42.80	3	5	92
Libya	4.60	11	2	87
Oman	1.22	5	2	94
Saudi Arabia	17.02	9	1	90
Sudan	17.80	4	1	94
Iran	70.03	6	2	92
Turkey	31.60	16	11	72
Pakistan	155.60	2	2	97

Source: *World Resources Institute.*

While conventional water availability remains relatively constant, demand is increasing sharply as a result of population growth, increases in living standards, and increases in agricultural and industrial development. The situation has been aggravated recently by drought conditions and worsening pollution, which increase the need for water resources management.

Integrated Water Resources Management (IWRM)

When water has been available, increased demand has insofar been solved using a supply-based policy, which consists of drilling a well, diverting a river, or building a dam. This **water supply management** approach has been found to entail environmental and economical consequences, such as the need to develop additional water resources or to over-exploit water resources to meet the continuous growing demand, and to recover at least a portion of the financial cost, for operation and maintenance expenses from the water users.

The increased scarcity of water resources has forced the change to a demand-based policy, according to which **water demand management** is considered as an acceptable equilibrium between limited water resources and increasing demand. This approach gives the right to water users to have access to needed water without harming water resources. In another words, it is a strategy of influencing demand, so as to achieve efficient and sustainable use of a scarce resource.

However, increased demand in the face of finite supply has again modified policy in terms of both supply and demand, creating the need for Integrated Water Resources Management (IWRM), a comprehensive dual management strategy that considers:

- Water resources
- Population water demand
- Environmental water demand
- Conveyance systems
- Distribution systems
- End-uses
- Country-specific policies and strategies
- Legal, institutional and financial frameworks.

The core objectives of this management would be to avoid creating an unbalance between supply and demand for water, which would have a negative impact on development, while stabilizing pressure on the natural environment at acceptable levels. This implies identifying the acceptable level of pressure on natural water in terms of quantity and quality, and changing economic performance in terms of more jobs per drop, more dollars per drop, more crops per drop, etc.

Actions to be taken

To achieve the objectives of IWRM, water resources and water demand need to be considered in terms of the following: water resources/water demand options, strategic options, financial options, and legal and institutional options.

Water resources/water demand options

Presently, most Islamic countries are water-supply oriented, tending to satisfy the current increase in water demand without applying water demand management. This approach has increased the pressure on conventional water resources and promoted unsustainable exploitation, which has resulted in extensive damming of almost all the rivers and wadis, the overexploitation of almost all renewable groundwater aquifers, the mining of most of the non-renewable groundwater aquifers, and the deteriorating quality of most of the water resources, with no consideration given to long-term economics, environment or wildlife.

A sustainable water resources development needs, on the contrary, to take into consideration the impact of continuous exploitation on the environment and on long-term economics, in conjunction with water demand policy, as follows:

- Applying the principal of **safe yield** for defining the acceptable level of abstraction
- Limiting the non-sustainable exploitation by stabilizing pressure at its present level, or even reducing the pressure; i.e. water supply augmentation
- Augmenting water supply by developing 1) additional surface water and groundwater resources, 2) water harvesting, 3) artificial recharge and 4) non-conventional water resources (treated wastewater; brackish water, with and without desalination; desalination of sea water)
- Protecting water resources from pollution
- Limiting the increase and even lowering demand in all water use, through water saving incentives and efficiency improvement This implies 1) water demand adjustment, 2) introducing water saving devices, 3) reducing water losses in water conveyance and distribution systems, 4) improving water use efficiency, 5) developing recycling techniques, 6) discouraging the wasteful use of water, 7) maximizing water productivity, 8) increasing the reuse of treated wastewater for irrigation, 9) increasing public awareness on water scarcity and value
- Reallocating water resources between sectors depending on priority, efficiency and productivity
- Preparing emergency plans for drought mitigation.

Agriculture is considered a strategic priority for countries, providing food security for nations and balancing export deficits. Projected population growth in the future will require an increase in food production by 3 per cent to 4 per cent per year, which has to come mostly from irrigated agriculture. It is quite well known that irrigation withdraws 70 per cent to 80 per cent of freshwater resources, and the agricultural contribution to the GDP ranges between 2 per cent and 17 per cent only.

Given the limited availability of water, agriculture faces competition from other sectors. Agriculture is expected to reduce its share of water use dramatically, thereby allowing adequate quantities for other uses. Increasing Irrigated Water Efficiency through the adoption of the following policies and measures can mitigate this situation:

- Developing mid- and long-term planning of country's water resources
- Increasing water productivity in terms of crop production, crop selection, crop pattern, and water application
- Saving water for other uses, at system and farm levels, by using on-demand delivery systems, improving distribution network systems, adopting modern irrigation technologies
- Using low-cost sprinkler and drip irrigation
- Using marginal quality water for irrigation by eliminating factors (social and economic) hindering irrigation with treated wastewater, using freshwater and treated wastewater in conjunction and creating a Users Association for participation in decision making
- Developing institutional and marketing environments.

Strategic options

Achieving the objective of IWRM, all the while ensuring social and economic stability, without disruption between water supply and water demand, means recognizing that

- water is a limited resource, with economic and social values, and must be treated as such, while ensuring access to safe water for everyone
- water policies should be compatible with sustainable development, in such a way that water resources management and water demand management are considered simultaneously and in the context of ecosystem supply and demand management
- water resources trade-off and allocation entails implementing structural changes for the different water using sectors
- water policies depend on broad participation of all stakeholders in the water sector, in the decision-making process and in management, which implies decentralized management
- private sector participation in building, operating, and maintenance of the different water facilities is essential. This implies strengthening the role of the government as a regulatory body.

Financial options

Although the aim is to bridge the deficit between supply and demand, to increase the reliability of the water supply and minimize the risk of water shortage, IWRM has financial consequences and more investment is needed in order to:

- develop or to save water resources to meet the increasing demand
- protect degrading water resources
- repair/upgrade/improve existing water projects
- raise public awareness and building capacities.

Usually, governments, communities, and private sectors pay the cost of the water projects, with the biggest share on the shoulders of the government. The fair sharing of the cost between the stakeholders should be decided depending on the socio-economic policies of the government in question. Principles of 'beneficiary and the polluter pays' can be applied, with full recovery of costs for domestic, industrial, and commercial uses, with partial recovery of the irrigation water. Efforts must be made to reduce all subsidies that encourage wasteful use of water and funds diverted towards water demand management policies.

To ensure the implementation of IWRM strategies and policies, measures must be taken to mobilize funding for new investments and make **tariff adjustments**. In view of the significant size of needed investments, efforts have to be made to generate significant additional income from drinking water supply and irrigation services in order to cover at minimum the operation and maintenance costs through tariff increases including periodic adjustment for inflation. Tariff increase mechanisms must be developed, which take into account the socio-economic conditions of the consumers and investors and encourage people towards more efficient water use.

Water is usually a publicly owned, limited resource with a natural monopoly, which needs to be allocated and protected. **Private-sector participation** can be limited to the provision of related infrastructure and services without affecting the ownership and management of basic water resources, which generally remain under public sector control. The importance of involving the private sector in the provision of water supply and sanitation services can be outlined as follows:

- Providing the necessary funds for the needed investment
- Addressing IWRM issues more efficiently

- Influencing private sector and consumer participation in decision-making
- Increasing competition, service expansion, efficiency and quality improvement
- Protecting consumers through increased competition
- Finding incentives to encourage efficient provision of services
- Introducing efficient price-setting mechanisms.

The effectiveness of private-sector participation depends on choosing the appropriate mode of private sector involvement and on the regulatory mechanisms used to influence private-sector decision-making and implementation.

Legal and institutional options

Achieving the objectives of IWRM means realizing that social and cultural changes must be made at the level and in the modes of operation of government, management, consumers, and the private sector.

Reviewing resource allocations to benefit more value-added uses would entail implementing structural changes for the different water using sectors so that the scarceness of resources does not hamper development.

Water demand management as well as sustainable development policies and strategies must lie on the broad participation of all stakeholders in the decision-making process and management. This implies 1) decentralizing management at all levels, 2) imposing an environment conservation condition in all development and trade agreements and 3) delegating public services to the private sector, in such a way as to strengthen the role of the government as a regulatory body, improve and reinforce institutions, transfer management know-how and experience to the appropriate levels.

In conclusion

IWRM can be achieved by adopting the following strategies and policies:

- Recognizing water as a basic right, adequate in quantity and quality
- Treating water as economic and social good
- Improving water facilities
- Introducing water conservation strategies
- Allocating water per sector
- Setting an upper limit for each user
- Giving license for withdrawal
- Metering consumptions
- Pricing water
- Increasing water-use efficiency
- Introducing economic incentives for desirable behaviour
- Reducing unaccounted-for water
- Increasing public awareness on water issues
- Introducing penalties for undesirable behaviours
- Introducing the legal and institutional frameworks to accommodate these policies
- Viewing water demand management as a tool to reduce consumption levels to more reasonable levels (World Bank experience indicates that demand management has reduced domestic consumption to the range of 90 to130 l/capita/day).

Expected results from water demand management include:

- Better balance between water supply and water demand
- Sustainable development for water resources
- Reduced water wastage
- Better allocation
- Lower investment cost
- Lower operation and maintenance costs.

UNESCO-IHE: UNESCO's Commitment to Water Education

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Thank you for this opportunity to participate in this important workshop. There is little doubt that education is the basis for developing and implementing policies and options for water management in this region, as it is in other regions of the world.

In a recent speech the Director-General of UNESCO, Koïchiro Matsuura, underscored this obvious and most fundamental aspect of water education: the absolute need to train more water managers if any of the goals set in recent fora are to be met. Without managers, scientists and engineers, we will not be able to deliver the water that the international community has determined is required for social and economic development. Mr Matsuura asked in rhetorical fashion whether we had the full capacity of needed trained professionals and policy makers, whether our institutions are currently prepared to cope with the job to be done, whether the citizenry is sufficiently aware and motivated to support the required investments, whether we understand the fundamental link between water and poverty in all of its manifestations, and whether water-rich countries understand how intertwined their progress is with that of water-poor nations. His response to all of these questions is: 'no, not yet'. My message, my hope, is to offer a partial solution to some of these problems.

It has been estimated that if the Millennium Development Goals are to be met, the number of water managers would need to be tripled in Africa, doubled in the Middle East and Asia and the Pacific and increased by 50 per cent in Latin America and the Caribbean. While we are currently initiating a research project to validate those figures, some would argue that the precise numbers are not really the important part of the message; what is rather the take-home message is the absolute necessity of reinvigorating our technical-education efforts with regard to water. I strongly agree. We cannot put the cart before the horse. Education is fundamental to move us along the sustainable development continuum.

UNESCO's response

First, it is important to recognize that UNESCO was ahead of the curve on this issue. Its response was initiated several years ago when it fortified the Water Sciences Division and charged it with building effective partnerships aimed at capacity and institutional-building efforts and publicly emphasized the direct relationship between water management, education and development. About three years ago, UNESCO entered into negotiations with the Netherlands aimed at transferring the then International Institute for Infrastructural, Hydraulic and Environmental Engineering to UNESCO, as an integral part of the Organization. This process was concluded earlier this year when the Director-General signed the formal statutes and appointed a thirteen-member board of governors, some of whom are present here today.

UNESCO-IHE Institute for Water Education now belongs to the 190 Member States. It is quite literally your institute. The Director-General made quite clear the role of this new institute in his comments to the UNESCO water family meeting held in Delft in July **2003.** 'My vision is for the UNESCO-IHE Institute for Water Education to become the pre-eminent world centre for tertiary-level education, capacity-building and training in water and environment. I hope that it will become the "hub" for the network of UNESCO-related regional centres still being developed… This coalition of expertise, outreach and professionalism would spearhead a concerted effort by all stakeholders. Together we can make a giant leap forward in both qualitative and quantitative terms, to serve the capacity-building needs underpinning the international water agenda.' In the forty-seven year history of the institute, we have trained 621 Masters of Engineering (MEng.), 140 Masters of Science (MSc.) and 8 Ph.D. graduates in addition to 180 short-course participants from the nations of Central Asia. We have a serous and growing commitment to this region of the world.

Second, our institute has signed a number of Memorandums of Understanding (MoUs) with strategic institutions and universities, each with specific aims. In June 2001 we signed such an agreement with the RCUWM (Regional Centre on Urban Water Management), in which we have a shared responsibility to:

- develop RCUWM into a full-fledged partner of UNESCO-IHE
- conduct the trainers courses
- provide assistance in accrediting the educational programmes offered at the centre
- provide assistance in developing electronic tools to assist in the centre's operation.

In June 2003, we signed a second MoU with the centre to develop a working plan for a regional study on urban water management including twenty-five cities in the Middle East and CIS countries.

Third, in July 2003, as alluded to above, the Director-General convened the first UNESCO water family meeting in Delft. The International Hydrological Programme (IHP), UNESCO water Chairs, its seven regional affiliated – Category 2 – centres, course leaders, networks, and partnerships were brought together to ensure that the entire organization would present a united front in addressing the myriad of issues related to delivering according to the mandates given to us. The second meeting of this group will be held in December 2004.

Fourth, UNESCO has pledged its proactive support towards the UN Decade for Education for Sustainable Development that will run from 2005 to 2014. UNESCO was designated the lead agency for the promotion of the Decade, and was asked to prepare a draft international implementation scheme for the UN system and its partner organizations. The dates of the Decade of course help us focus on the work leading up to 2015, the year in which we must report to all Member States on progress towards realizing the Millennium Development Goals (MDGs).

Fifth, I want to announce that next year UNESCO will launch the IHP Fellowship Scheme to facilitate cooperation between IHE and UNESCO. We will also continue our support to the World Water Assessment Programme (WWAP) and the publication of the second World Water Development Report (WWDR). Lastly, I want to emphasize that we will continue to be active in many international bodies with a focus on water, such as the World Water Council, the Inter-American Water Resources Network and the Global Water Partnership, among many others.

More on the UNESCO Institute for Water Education

You have each received a copy of our application form and fact sheet. I ask that you pass it to someone with an interest in postgraduate education in the water field.

Our fundamental focus as an institution of academic excellence remains unchanged. Our mission is aimed at strengthening and mobilizing postgraduate education for mid-career professionals in integrated water management and to contribute to the water-related capacity-building needs of the developing countries and countries in transition. Our delivery modes for capacity-building, education, research, training and policy advice are being updated thematically and with new technologies to ensure that we remain a cutting-edge institution for education and training, for the establishment and management of water education and water-sector networks, and as a policy forum for UNESCO Member States. In its forty-seven year history, the institute has trained nearly 13,000 people from more than 120 nations, including the nations represented around this table. I venture to say that we have trained more water-related ministers than any other single institution of higher education. We are the only unit of the entire UN system that is authorized to confer an accredited postgraduate degree at the MEng., MSc. and Ph.D. levels.

UNESCO-IHE is repositioning itself in a changing world in order to serve the interests of our target groups: the individuals and organizations that work on water development and management in the developing world. This includes taking full advantage of our 'Category 1 UNESCO Institute' status, updating our medium-term strategy, implementing the new Masters Programmes based on a modular system, preparing for accreditation of these programmes, pursuing our work with the Partnership for Water Education and Research (PoWER) and our involvement in the UNESCO water family meetings, as well as focusing our attention on our relationships with UNESCO-IHP, WWAP and the CSD process.

We are convinced that being named a UNESCO institute bodes well for all UNESCO Member States. We strongly believe that we are assisting the world community in meeting the MDGs, as training of water professionals is an obvious need to address the complex problems being confronted in developing countries. We are confident that as knowledge of our new status grows, other donor countries will take a more proactive interest in supporting the work of the institute. Our new status also presents UNESCO-IHE with an excellent opportunity to work on an international, inter-governmental platform providing direct linkages to the 190 Member States of UNESCO. The first manifestations of this relationship include the selection to serve as a venue for a new UNESCO water family policy forum in late 2004 and the provision of seed funding to support young academics from developing countries to both teach at the institute and learn how to upgrade or improve their own institutions. I also urge each of you to provide direct input through your UNESCO National Committees towards prioritizing support for worthy candidates to study at UNESCO-IHE through the support of the UNESCO Participation Programme.

One significant milestone in our development briefly mentioned earlier is the implementation of the new Masters programmes. With these programmes, we hope to achieve the following objectives:

- better meet the training needs arising from the main issues in the global water and environmental agendas
- complete the process of modularization of our programmes and their specializations
- create opportunities – through this modularization – for increased flexibility in exchange of modules between our programmes and programmes in other universities
- create opportunities to diversify and introduce innovative teaching methods.

The main feature of the new programmes is an integral adoption of the modular structure. Each module has a duration of three weeks as outlined in the fact sheet. Both the MEng and the MSc. programme participants complete twelve modules of course work in their area of specialization. The MEng. participants then undertake a six-week period of individual study on a given research topic. Those participants selected for the MSc. programme begin a six-month intensive research project, leading to a thesis.

Finally, I wish to highlight our concern with the quality and relevance of our educational programmes and with specifically maintaining our accredited status. The institute is fully aware that its good reputation in the developing world is built on standards of academic excellence, the practical relevance of these programmes, and on our ability to confer an accredited postgraduate degree. Our challenge is to maintain quality and relevance in a world in which the priorities and capacity building needs of our clients are changing, in which the capacities of our partner educational institutes are on the increase, and in which donors are modifying their financing modalities and criteria.

These can only be achieved with your commitment towards your institute. Together we can ensure that your training needs are met.

Problem Assessment and Strategic Urban Planning on Urban Water Management in the Middle East and Central Asia: Preliminary Results of UNESCO Study

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Introduction

Urbanization creates many water management problems, some of which receive adequate attention, some of which do not. One of the key commitments stated in the Millennium Development Goals is to halve the proportion of people without access to safe drinking water and basic sanitation by the year 2015, compared to the year 2000. This goal is unlikely to be reached unless there is considerable acceleration in the current global efforts to improve the situation. The lack of proper water management has transformed many rivers located near urban centres into open sewers. Groundwater is also becoming increasingly polluted due to inadequate wastewater treatment. According to the World Commission on Water, less than 10 per cent of wastewater is today properly treated in developing countries. Because water management in urban areas of the developing world is becoming increasingly complex, past and present solutions will gradually become increasingly ineffective answers to future problems. In light of this situation, UNESCO decided to initiate a study on 'Problem assessment and strategic urban planning on urban water management', focusing on the Middle East and Central Asia.

Challenges in the region

The demographic challenge

Most countries in the Middle East and Central Asia are facing a huge demographic challenge. The most populous countries in the Middle East are Turkey, Egypt and Iran, each with approximately 65 million inhabitants. The remaining countries have a combined population of 225 million; the smallest, Bahrain and Qatar, have each only 0.6 million inhabitants. In Central Asia, the most populous countries are Uzbekistan and Kazakhstan with more than 23 and 16 million inhabitants respectively.

Population growth rates are high in the region, usually over 2.0 per cent and sometimes as high as 3 per cent. Between 1965 and 1990, for instance, the Maghreb population increased at a rate of 2.65 per cent a year, from 30 to 59 million people, and today totals more than 70 million. In that same period of time, the Egyptian population grew at a rate of 2.3 per cent, from 29 to 53 million people, and today totals 66 million. In Central Asia, in the same period, population growth rates were even higher: 2.9 per cent in Tajikistan and 2.6 per cent in Uzbekistan. The rate of population increase in the Maghreb region have peaked and are beginning to decline, but growth in absolute numbers will continue to be large. For the years to come, the populations of the region will be disproportionably young, with a notable demographic bulge of teenagers and people in their twenties. In addition, the people in this age cohort will be overwhelmingly urban (United Nations, population division, 2000).

The economic challenge

In the Middle East, there are great disparities between countries, in terms of not only total population, population density or per cent of urban population, but also in terms of incomes per capita (GDP/head) and consequently in terms of human development index (HDI). Some very rich Gulf States can be found in the region, as can some of the poorest countries on earth.

Two industries dominate the economic life of most of these countries: oil and tourism. While this may be something of an over-simplification for there are exceptions to the rule (agriculture remains a key sector of the economy in many countries), oil and tourism, directly or indirectly, remain the main sources of income in the Middle East. Today, oil is the economic mainstay of Iran, Iraq, Libya, and all of the Gulf States, and is an important source of income for Egypt, Syria and Yemen. Many of the region's countries that do not possess oil remain indirectly dependent on it in the form of remittances sent home by people working in the oil states.

Turkey and Lebanon have neither oil of their own in large quantities nor large numbers of their citizens working in the oil sector. Turkey has traditionally relied on agriculture, but manufacturing and services have now come to dominate the economy. Turkey, Tunisia and Morocco benefit more than most from the tourism industry. Tourism is a rapidly growing industry in Jordan, Syria, Yemen, Bahrain, Oman, the United Arab Emirates and Libya.

The urbanization challenge

Based on the state of the world cities report (UN World Water Development Report, 2003), it appears that ten cities in the region have already grown to more than 3 million inhabitants and about thirty others to more than 1 million inhabitants. The largest city is Cairo with about 16 million inhabitants. Greater urbanization challenges are to be found in large cities, due to previously existing challenges, and secondarily in cities with high demographic and/or economic growth.

The study

The study is to be carried out in two phases, as indicated above, focusing on problem assessment and guideline preparation for strategic planning.

Phase 1: Problem Assessment

Quick scan/desk study

A quick scan was carried out to try to identify problem areas in the different cities of the region. The quick scan is based on a desk study/bibliographical research. One problem is that while a lot of information exists on countries, very little exists on cities. Furthermore, little information is available in English.

Questionnaire

Based on the preliminary results of the quick scan and experience, a questionnaire was prepared in order to define at the city level the existing or expected problems in the field of urban water management and identify on-going or planned activities. In total, more than 500 questionnaires were sent out to relevant people and organizations, in English, Arabic and Farsi.

The questionnaire addressed both technical data and non-technical issues, such as demographic data, economic data, present water resources, major water users, water consumption and use, waste production, existing and planned water infrastructure, institutional framework, legal framework (including the taxation system), human resources and financial resources, existing projects and programmes, etc. We are still collecting completed questionnaires and the process is ongoing.

Analysis

An analysis of the various problems in and across different cities will allow us to cluster cities and identify pilot cities for further analysis. The selection of pilot cities will be done based on several criteria: identified cities should represent the diversities of the cities in the region, in terms of population, demographic growth, major economic activity, state of the art of urban water, geography, social and environmental context, institutional framework, etc. If need be, short visits to one or two cities will be carried out, depending on the results of the questionnaire.

Phase 2: an urban planning guideline

Guideline preparation

Based on the results of phase 1, a guideline for urban planning will be drafted taking into account worldwide good practices. The relevance of these practices will be analysed in the context of the studied cities (when possible by cluster). Some previously identified best practices will be collected (using Best Practices Database, GWP toolbox, World Bank gateway, etc.).

Complementary studies

Based on the results of phase 1 and guideline preparation, gaps in knowledge can be identified and several complementary studies can be undertaken.

Preliminary results of the study

We have so far have received data from several cities in the region, notably Samsung (Turkey), Adana (Turkey), Sana'a (Yemen) and Dhamar (Yemen).

Table 1. An overview of the main characteristics

	Samsung	Adana	Sana'a	Dhamar
Population	364 000	1 400 523	1 703 915	114 992
National domestic product per capita per year	1 680	**	455	400
Most important economic activity	Food industry	Agro-industry	Mining	Agro- industry
% served by water supply	95 - 100	100	43	100
Water resource	Surface	Groundwater (35%) Surface (65%)	Groundwater	Groundwater
Main water users	**	Domestic	Domestic	Domestic
% connected to sewer	85 - 99	70	22	50 – 100
Wastewater treatment	No treatment	Under construction	Treatment (60%)	Treatment (100%)
Solid waste	Landfill	**	Open dump	Open dump
Services provided by municipal (all)	-Water supply prod. -Water supply distrib. -Sewerage -Drainage -Solid waste collection	-Water supply prod. -Water supply distrib. -Sewerage -Drainage	- Water supply prod. -Water supply distrib. -Sewerage -Wastewater treatment -Solid waste collection	- Water supply prod. -Water supply distrib. -Sewerage -Wastewater treatment -Solid waste collection
Services not provided by municipal	-Wastewater treatment -Solid waste disposal	**	-Drainage -Solid waste disposal	-Drainage

Some identified issues

In several questionnaires the following points appear:

Technical

- Placing meters for measuring water usage
- Guaranteeing water production and distribution
- Replacing old pipe networks to decrease losses
- Updating present treatment facilities or building new ones.

Non-technical

- Lack of legal framework in the fields of wastewater and solid waste
- Improving administration system
- No public awareness programmes.

Conclusions

At this stage, it is difficult to present any major conclusions. Results of more cities are needed to identify urban water management challenges in the region.

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Management and Mitigation Strategies of Drought and Floods

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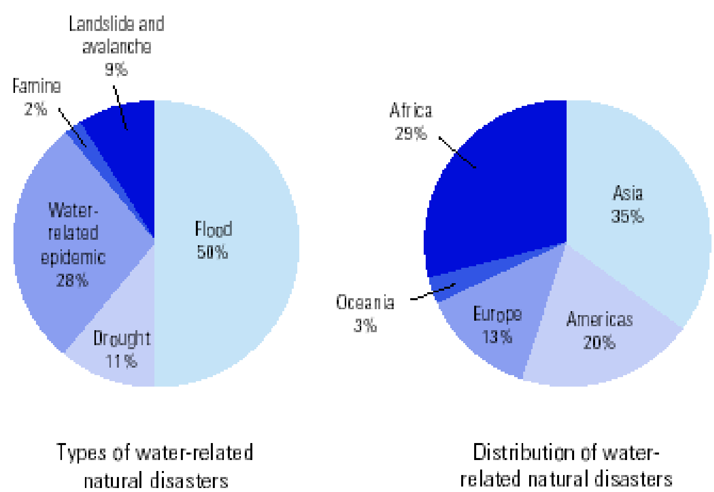
Background

Between 1991 and 2000, as pointed out in the first edition of the United Nations World Water Development Report (WWDR), the number of people affected by natural disasters rose from 147 million per year to 211 million per year. In the same period, more than 665,000 people died in 2,557 natural disasters, of which 90 per cent were water-related. Of these water-related disasters, floods represented about 50 per cent and droughts 11 per cent (Figure 1). Floods caused 15 per cent of deaths and droughts 42 per cent of all deaths from all natural disasters.

Figure 1. Types and distribution of water-related natural disasters, 1990-2001



Source: The United Nations World Water Development Report 2003, chapter 11, figure 11.1, from CRED, 2002.

Recorded economic losses from natural catastrophes have grown from US$30 billion in 1990 to $70 billion in 1999. The true scale of loss, however, is believed to be double or more than the recorded figures.

These figures clearly indicate a tendency for increased flood and drought risks. The Intergovernmental Panel on Climate Change (IPCC), based on the Special Report of Emission Scenarios, has in fact stated that 'projections of future climate indicate a tendency for increased flood and drought risks for many areas under most scenarios' (IPCC, 2002).

Unfortunately, the lower-income countries are the ones worst affected by natural disasters (roughly 97 per cent of all natural disaster deaths occur in developing countries). In addition to the obvious economic losses, both droughts and floods are associated with significant human and socio-economic losses, with the very poor, the elderly, women and children as the most affected members of society.

It is possible to predict the probability of occurrence of floods and to forecast flood events. Mitigation measures include structural means (dams, dikes, etc.) and non-structural means (land-use planning, flood forecasting, response plans, etc.).

For droughts, unlike floods, the onset is slow. In recent years, there have been improvements in seasonal and long-term climate prediction. Mitigation can include: changing land-use practices, irrigation from reservoirs or wells, crop insurance, relief programmes, protecting priority users, etc. Longer-term measures include changing crop types and building reservoirs. For persistent droughts, even population relocation can be considered as a last resort.

Managing floods

Floods were responsible for over 65 per cent of those affected by natural disasters, while famine affected nearly 20 per cent. Between 1973 and 1997, an average of 66 million people per year suffered flood damage, making flooding the most damaging of all natural disasters (Cosgrove and Rijsberman, 2000). According to a study by the United Nations (UN), about 44 per cent of the flood disasters that occurred in the world during the period 1987–1996 affected Asia. These disasters claimed some 228,000 lives, corresponding to 93 per cent of the total number of flood-caused deaths in the world, and resulted in damage of US$136 billion to the Asian economy.

When dealing with floods, two variables need to be taken into consideration. The first one is the ‘hazard potential’, which is expressed as the relationship between the magnitude of the flood and its probability of occurrence. The second variable is ‘vulnerability’, which is a function of land use at a location that has a risk of flooding.

Assessment of the probability of floods requires several years of flow records. However, the changes in world’s climate and therefore in precipitation patterns causes uncertainty as to the persistence of similar flow patterns. This concern does make it difficult to predict future extreme runoff conditions and meet the need for alternative approaches for managing risk under uncertainty.

Traditional solutions

The traditional approach for dealing with both floods and droughts largely involves the implementation of engineering methods. Common techniques include:

- the construction of levees (concrete or earth material) to prevent rising waters from overflowing their natural channels
- the straightening and channelling of stream channels
- the construction of networks of ditches to drain wetlands to relieve flooding
- the construction of dams and reservoirs to prevent rising floodwaters to move further downstream.

Unfortunately, relying solely on engineering approaches does not provide the desired level of protection against floods and droughts. There is a growing recognition that the ecological and environmental effects of structural measures (dams, dikes, levees, etc) also need to be taken into consideration.

Dams and diversions have greatly altered the hydrologic regime of many rivers, resulting in a loss in the connections between the rivers and their associated floodplains. This has a great impact on the regeneration of plant communities that retard and store rising floodwaters and thereby reduce the magnitude of flooding downstream. Furthermore, the channelling and straightening of many meandering stream channels has destroyed the natural potential of those meanders to slow down the storm flow. Furthermore, such structural measures have created a false sense of security, which has encouraged people to settle within the flood prone areas. This has further increased the degree of 'vulnerability'.

In order to minimize the risk stemming from both floods and droughts, urbanization and industrialization demands need to be denied or at least limited in those areas where floods and droughts reoccur frequently.

Non-structural measures

Better practices and planning are the keys to improved management and mitigation of floods. **Farming practices** that provide better infiltration of precipitation into the ground can be introduced, such as tilling on the contour to reduce runoff and maintaining crop cover through the winter and spring snowmelt periods. In addition, the **sustainability of native plant communities** should be carefully watched over in flood or drought prone areas as these species are more adapt to the extreme conditions.

Urban settlements and areas are presently expanding in an unparalleled way and have lead to a remarkable shift of population and social assets into urban areas. For this reason, **flood mitigation measures for cities** have progressed, especially in areas with a high risk of floods such as lowland marshes, alluvial fans and cliffs. In order to minimize the cost of flood damage, zoning ordinances are put into practice to control the total amount of development that is allowed within a watershed. And storm water runoff in cities is aggravated due to impervious cover on the ground associated with streets, parking lots, driveways and walkways. Permeable substrates, such as gravel or perforated pavements, can be used as an alternative to asphalt for walkways and parking lots.

Planning is an important non-structural measure for flood mitigation, covering the entire spectrum of pre-to-post disaster. All parties, including governmental and civil organizations as well as citizens, should be aware of their roles and responsibilities when a disaster hits. The involvement of local authorities and citizens in the planning stage ensures the effectiveness of the contingency plan. A **comprehensive contingency plan** should consider exactly what is needed in terms of supplies and provisions and makes sure that all such necessities are in place when and if a hazard occurs. Existence of well-maintained and operational flood forecast warning and alert systems are a vital segment of emergency plans.

Usually the relief provided during the first seventy-two hours of an event is the most critical in order to limit the losses of lives once the flood has subsided. Spread of water-related diseases might claim further lives in the post-disaster stage. For example, according to the Chinese Government, 90 per cent of the 30,000 deaths from the floods in 1954 were a result of infectious diseases such as dysentery, typhoid and cholera, which struck in the period following the event (Worldwatch Institute, 2001). In contrast, after the 1998 flooding of the Yangtze, no such epidemics were reported. Beyond direct relief, additional post-disaster activities include support in order to quickly restart the local economy and resume basic social services.

In the case of transboundary river basins, cooperation among riparian countries and provision of bilateral or multilateral agreements for flood control and mitigation is necessary for preparedness and operational management of floods. Egypt and Sudan can be seen as an example of this kind cooperation.

Managing droughts

Just like floods, droughts are also associated with significant human and socio-economic losses. From 1991 to 2000 alone, drought has been responsible for over 280,000 deaths and has cost tens of millions of US dollars in damage (Table 1). Since the onset of a drought is slow, there is a greater chance for taking necessary measures to mitigate the impacts.

Table 1. Major drought events and their consequences in the past forty years

Date	Country or continent	Fatalities	Economic losses (US$M)
1965–1967	India	1,500,000	100
1972–1975	Africa	250,000	500
1976	United Kingdom		1,000
1979–1980	Canada		3,000
April–June 1988	United States		13,000
June–July 1988	China	1,440	
1989–1990	Angola	10,000	
Summer 1989	France		1,600
Jan.–Oct. 1990	Greece		1,300
Summer 1990	Yugoslavia		1,000
Jan.–March 1992	Africa		1,000
May–Aug. 1996	United States	130	4,275
Jan.–Aug. 1999	Iran		3,300
Jan.–April 1999	Mauritius		175
June–Aug. 1999	United States	214	1,000

Source: The United Nations World Water Development Report 2003, chapter 11, table 11.1, from Munich Re, 2001.

Drought has a severe impact in poor countries where rainfed agriculture is extensively practiced. It is also often claimed that drought results from a lack of distribution, know-how and human and capital resources in poor regions (Delli Priscolli and Llamas, 2001).

From a management perspective, several questions need to be addressed in order to mitigate the risk of a potential drought more efficiently:

- How frequently can one expect a drought of certain severity to occur?
- What are the vulnerabilities and expected losses?
- What mitigation efforts or options are present and acceptable at what cost?

Finding answers to these questions is essential in order to balance the cost of mitigation efforts with the potential costs of risks. The logical outcome of this process is the identification of measures that will provide an 'acceptable' risk to society for the specific drought at the lowest cost.

Conventional drought mitigation strategies are aimed towards straightening and channelling stream channels, altering land use and agricultural practices, and modifying the severity of the drought by providing irrigation from reservoirs, wells or water imports from areas unaffected by the drought.

Other mitigation measures may include reducing vulnerability to drought by **more careful use of available water.** Since, irrigation accounts for 70 per cent of all water withdrawals, farmers should be encouraged to use **drought-resistant crops** or to utilize **pressurized water systems** through which unnecessary water losses can be minimized. Also, as 48 per cent of the world's population presently lives in towns and cities, switching to **low-flush toilets or alternative septic systems** in residential areas can be a plausible approach for saving water within urban settlements. Most importantly, imposing a higher unit price for excessive water use (increasing block rate) promotes conservation and efficiency. As an example, the luxury consumption of water (i.e. golf courses, swimming pools or extensive lawns) should be taxed accordingly.

The improvement in predictions and establishment of many national and regional institutes (such as WMO's Drought Monitoring Centres in Africa) in recent years aiming for a better prediction of seasonal and long-term climate will also assist effective implementation of contingency plans.

Conclusion

For both floods and droughts, the best solution is that provided by a comprehensive watershed management approach. Such an approach has two main components: hydrological and social.

The hydrological dimension, by assessing the probability of hazard to occur based on long-term hydrological observations, implements structural and non-structural measures to reduce risk. This goal must be complemented by a social goal that aims to reduce the vulnerability of humans to floods and droughts when they occur. The social goal involves controlling and limiting the distribution of human developments in flood and drought prone regions.

At the root of the problem is the exponential increase in global human populations, in which more and more people live on marginal lands where there is a greater risk of both floods and droughts. In order to reduce the economic impact of water-related natural disasters, it is important to assess the risk on a broader economic basis through insurance programmes.

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The Global Water Shortage and Turkey's Water Management

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Water shortage at the global level

Water is essential for human security and one of the engines of sustainable socio-economic development. It is an essential element for the eradication of poverty and hunger.

Water is a precious resource, one that is gradually getting scarcer. More than half of the world population will be living with water shortage within fifty years time, creating a worldwide water crisis, according to report issued by the United Nations Environment Programme. It is highly unlikely, in other words, that there is going to be enough water for everybody unless the necessary steps are taken at regional and global levels.

Population growth, industrialization, urbanization and rising affluence in the twentieth century has resulted in a substantial increase in water consumption. While the world's population has grown threefold, water use has increased sixfold during the same period. The demand on water resources will continue to increase during the next twenty-five years. The problem is further aggravated by the uneven water distribution on earth.

The basic question we should therefore ask ourselves today is what governments and international organizations need to do in order to reverse the situation and avert a water crisis at the global level. How much water will we need to ensure global food security for over eight billion people? How can we ensure the adequate supply of water for irrigation and agriculture? We must also ask ourselves how we can secure a more efficient water management system so that we can meet the most basic of human needs.

Turkey's water potential

With respect to the situation in Turkey, and contrary to the general perception, Turkey cannot be said to be rich in freshwater resources nor is it the richest country in the region in this respect.

Turkey is situated in a semi-arid region, and has only about one fifth of the water available per capita in water rich regions such as North America and Western Europe. Water rich countries are ones that have 10,000 m^3 of water per capita yearly. This is well above the 1,830 m^3 per capita in Turkey.

I should also like to emphasize that Turkey's water is not always in the right place at the right time to meet present and anticipated needs. Certain regions of Turkey such as the Black Sea region have ample but unusable freshwater, while some of the more heavily populated and industrialized regions such as the Marmara and the Aegean regions lack sufficient freshwater.

Turkey's dependence on water for energy

Turkey produces more than 44 thousand GWh of hydroelectric power per year, which corresponds to 36.9 per cent of its total power generation. Turkey's energy consumption is rising at about 5.7 per cent a year on average due to rapid urbanization and industrialization. In 2002, the electricity consumption peaked at 126.9 billion kWh. It is estimated to rise to 265 billion kWh in 2010 and to 528 billion kWh in 2020.

It should also be emphasized that per capita energy consumption in Turkey is only one sixth of that of the EU average and increase in the energy consumption means improving the quality of life of Turkish citizens. Turkey, which neither produces oil nor natural gas, plans to meet the rising energy need in several ways, and hydropower is especially appealing in that it is cheap and clean.

The production of hydropower and its wider use should be encouraged in accordance with the Implementation Plan of the World Submit on Sustainable Development (WSSD) in Johannesburg. As a follow up to the WSSD Summit, the Third World Water Forum and Ministerial Conference gave a prominent place to the issue of renewable energy resources. The importance of hydropower was highlighted in various sessions including the central role of dams and reservoirs in providing a vital source of clean and cheap energy.

The World Bank has also reviewed its energy policy and has placed renewable energy development as one of the key strategic choices. The Bank has adopted a pro-active policy to encourage and provide financial support to renewable energy projects, including hydropower in developing countries.

I believe that developed countries and international organizations, together with financial institutions, should provide more financial support to renewable energy projects. In view of the key role that renewable energy can play in the eradication of poverty, additional steps should be taken at regional and international levels to support and finance multi-purpose water infrastructure.

Turkey's dependence on water for food

Increasing agricultural production by irrigation is one of the most important means for combating poverty and hunger in developing countries. The integrated WEHAB (water, energy, health, agriculture, biodiversity) approach, which was proposed by the UN Secretary General Kofi Annan as a contribution to the WSSD, foresees measures for increasing agricultural productivity, thereby reducing hunger.

In arid and semi-arid regions where precipitation is generally limited to four or five months a year, water resources development projects, especially storage systems and irrigation networks, are indispensable for sustainable socio-economic development. A case in point is the Middle East.

This said, I should like to make a few points with respect to the situation in Turkey. In recent decades, Turkey has made great strides in water resources development for domestic use, irrigation, flood control and power generation. The dams and reservoirs built have enabled Turkey to save water from its brief seasons of rainfall to use throughout the year for various purposes, agriculture in particular. Rainfed agriculture in Turkey is being realized almost to the maximum level. As a result, increasing agricultural productivity has become primarily dependent upon irrigation by using modern techniques.

The Euphrates and the Tigris Rivers

Rivers are one of the main sources of freshwater: 70 per cent of the total easily accessible water is provided by rivers. Moreover, 40 per cent of the world population depends for its freshwater on 214 transboundary rivers flowing through two or more countries. The Danube and Nile, for example, flow respectively through twelve and nine countries.

The Euphrates and the Tigris are two of the most famous rivers in the world. The combined water potential of the two rivers is almost equal to that of the Nile River. Both rise in the high mountains of northeastern Anatolia and flow down through Turkey, Syria, and Iraq and eventually join to form the Shatt-al-Arab 200 km before they flow into the Gulf.

They account for about one third of Turkey's water potential. Both rivers cross the southeastern Anatolia region, which receives less precipitation compared to the other regions of Turkey. This is why Turkey launched projects in the 1960s and 1970s to utilize the rich water potential of these rivers for energy production and agriculture.

Turkey contributes 31 billion m^3 or about 89 per cent of the annual flow of 35 billion m^3 of the Euphrates. The remaining 11 per cent comes from Syria. Iraq does not contribute to the flow.

As to the Tigris, the picture is entirely different: 52 per cent of the total average flow of 49 billion m^3 comes from Turkey. Iraq contributes all the rest. No Syrian waters drain into the Tigris.

The Southeastern Anatolia Project (GAP)

One of the great water success stories is, of course, the Southeast Anatolia Project (GAP), which is a regional integrated sustainable development project based on harnessing the water resources of the Euphrates and the Tigris Rivers and the land resources of 'Upper Mesopotamia', a favourable environment for large scale and intensive agriculture. This area, which used to be the 'food basket' of the region, was named 'fertile crescent'.

GAP has become a well-known example of transition from simple water development to efficient water management. It stands as an outstanding accomplishment in the field of water development and great engineering achievements in irrigation and hydropower.

The project requires US$32 billion of total financing, 16 billion of which has already been invested by Turkey. The project is expected to almost double Turkey's agricultural production. The resulting diversification of and increase in crop production will also create new opportunities for developing agro-industries.

The universal nature and relevance of the GAP has been highlighted by various authorities and experts, notably Dennis Avery, the former head of the Global Food Policy Institute and agricultural economist, who pointed out the importance of the GAP by recognizing that '[we] are on the eve of the greatest farming opportunity in history and it is precisely at this moment that Turkey is creating a new California'. Timothy Reevs, an Australian geneticist, also emphasized the contribution that the GAP may make towards meeting the minimum food requirements at the global level:

> ...The critical question is just how to create 2,600 calories a day for 8.5 billion people? When the future and potential of GAP are examined against that challenge, it is obvious that GAP will be an integral part of the world's response.

Hydropower is cheap and environment friendly and therefore its wider use should be encouraged in accordance with the Implementation Plan of the Johannesburg Summit. Discouraging hydropower and other major development projects to serve narrow interests will result in hindering economic growth.

Turkey's water management in a transboundary context

Turkey's policy regarding the use of transboundary rivers is based on the following principles:

- Water is a basic human need
- Each riparian state of a transboundary river system has the sovereign right to make use of the water in its territory
- Riparian states must make sure that their use of such waters does not produce 'significant harm' to others
- Transboundary waters should be used in an equitable, reasonable and optimum manner
- Equitable use does not mean the equal distribution of waters of a transboundary river among riparian states.

As regards the Euphrates and the Tigris Rivers, I should like to emphasize the following points:

- The two rivers constitute a single basin
- The combined water potential of the Euphrates and the Tigris Rivers is, in view of the Turkish authorities, sufficient to meet the needs of the three riparian states, provided that water is used in an efficient way and the benefit is maximized through new irrigation technologies and the principle of 'more crop per drop' at basin level
- The variable natural hydrological conditions must be taken into account in the allocation of the waters of the Euphrates and the Tigris Rivers
- The principle of sharing the benefits at basin level should be pursued.

With respect to the use of the waters of the Euphrates and the Tigris Rivers, Turkey has consistently abided by these principles and continued to release maximum amount of water from both rivers even during the driest summers thanks to the completed dams and the reservoirs in southeastern Anatolia. For example, 1988 and 1989 were the driest years of the last half-century; the natural flow of the Euphrates was about 50 m^3/s. Turkey however was able to release a monthly average of minimum 500 m^3/s to Syria in conformity with Article 6 of the Protocol signed by Turkey and Syria in 1987, which reads as follows:

> During the filling up period of the Atatürk Dam reservoir and until the final allocation of waters of Euphrates among the three riparian countries, the Turkish side undertakes to release a monthly average of more than 500 cubic meters per second at the Turkish-Syrian border and in cases where the

> monthly flow falls below the level of 500 cubic meters per second, the Turkish side agrees to make up the difference during the following month.

Our motto has always been that water should be a source of cooperation among the three riparian states. Turkey is eager to find ways of reaching a basis for cooperation, which will improve the quality of life of the peoples of the three countries. The point of departure should be to identify the real needs of the riparian states. Turkey designed a 'Three Staged Plan' to this end. The Three Staged Plan is based on the fact that the Euphrates and the Tigris make up one single transboundary river system and the plan envisages the preparation of common inventories of water and land resources for a final allocation of water between the riparian states.

Water transfer to water stressed regions by sea

In view of the expected water shortage in the Middle East in the years to come, Turkey introduced the concept of water transfer by sea to water stressed countries in the region from its national rivers in the Mediterranean region where there is a surplus freshwater.

In order to meet the urgent needs of the Turkish Republic of Northern Cyprus (TRNE), water has been transferred from the Soğuksu River to Northern Cyprus by large water balloons towed by tugboats. As this technique has proved inefficient, projects are being prepared to transfer water to Northern Cyprus by large tankers and/or pipelines in the near future.

Turkey also developed the Manavgat Water Supply Project on the Manavgat River near the city of Antalya with a view to providing freshwater to the Mediterranean coast and countries in the region. The installation of on-shore components for the treatment and storage of water and offshore components for loading water onto tankers were completed in 1997. The water treatment capacity of the Manavgat Water Supply Project is 500,000 m^3 daily.

The Manavgat River has an annual water potential of 3.6 billion m^3. It follows that more water could be drawn from the river by increasing the capacity of the installations, when necessary. Israel has been the only country to date which expressed its political will to purchase treated water from the Manavgat River.

An intergovernmental agreement between Turkey and Israel is expected to be signed soon concerning the purchase by Israel of 50 million m^3 of treated water for a period of twenty years. The water will be sent to Israel by purpose-built tankers. In our view, selling freshwater to Israel will contribute to efforts towards enhancing peace and stability in the Middle East in addition to socio-economic development.

Peace Pipeline Project

Turkey has been developing a Peace Pipeline Project that seeks to provide freshwater to Syria, Jordan, Palestine, Saudi Arabia and other Gulf States from its national rivers, namely the Seyhan and the Ceyhan, which originate from the Taurus Mountains of southern Anatolia and flow to the Mediterranean.

Water is planned to be transferred to the aforementioned countries by two large diameter pipelines namely the Western Pipeline and the Gulf Pipeline. The pre-feasibility study, carried out by Brown and Root, has shown that the project is feasible and applicable.

From our perspective, the project will have multiple benefits. It will supplement the limited water resources of the region, thereby contributing to economic and social development. Moreover, it will promote economic relations among the countries of the region and further enhance peace and stability in the Middle East.

Conclusions

- First and foremost, we view water as a catalyst for cooperation rather than a source of conflict.

- I do believe that economic development and the spreading of prosperity to all people in the region will be the most effective means of creating a climate of peace and good neighbourly relations in the Middle East.

- Transboundary waters should be used in an equitable, reasonable and optimum manner.

- The WEHAB approach is essential for sustainable socio-economic development, namely for reducing poverty and hunger. I was particularly pleased to observe that the UN bodies as well as many international organizations and NGOs have recognized this fact, apparent during the WSSD Summit and the Third Water Forum.

- I welcome the recent change in the strategy of the World Bank, which makes it possible to provide financial support for renewable energy projects, including hydropower.

- The looming water shortage at the global level can only be addressed through a holistic approach and with technical and financial support by the developed countries, by regional and international organizations and by financial institutions.

- In the case of southeastern Turkey, the GAP is not only generating environmentally clean electricity, but is also literally turning near desert areas into fertile farmland. The project is starting an economic revolution in the region, benefiting not just the local population who have some of the lowest incomes in the country but Turkey as a whole. It will also help bring prosperity to a much wider region, riparian states in particular.

- As regards Iraq, Turkey is prepared to contribute to efforts to provide hydroelectric power and other water-related services to the Iraqi people. Given its geographic proximity, know-how and experience, I strongly believe that Turkey can take part in and contribute to the reconstruction works in Iraq, including water and infrastructure as well as institution building.

Water Resources Management in the Sultanate of Oman

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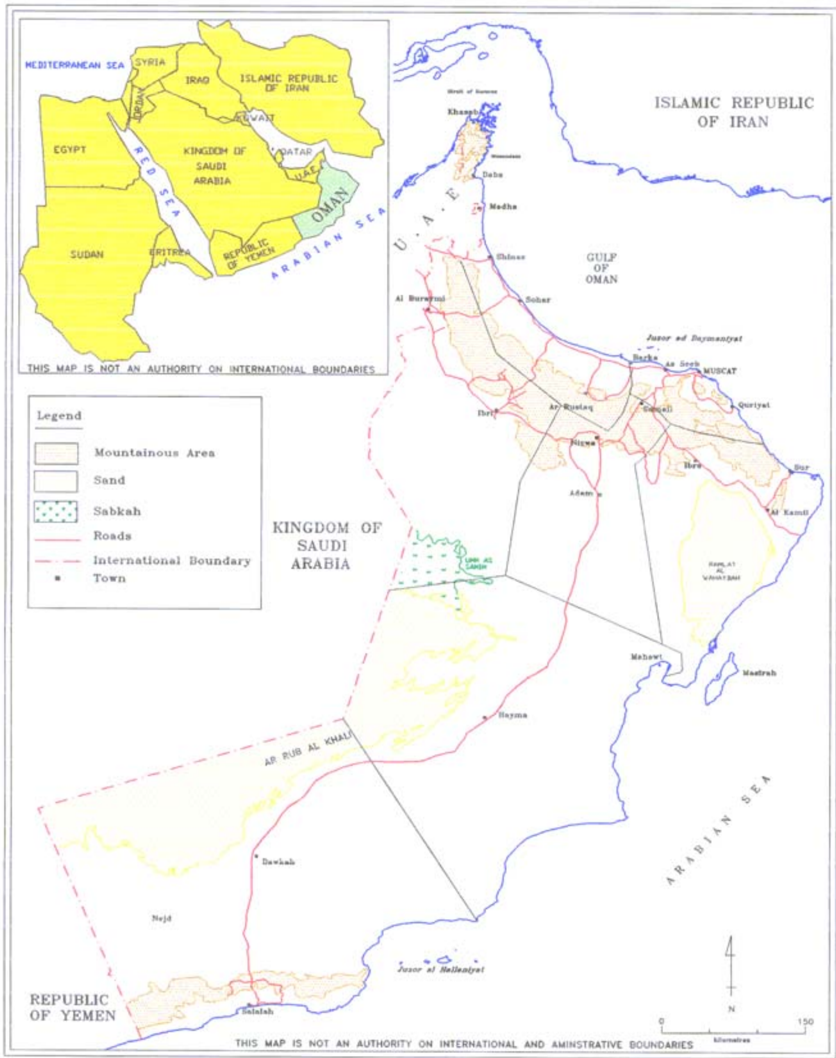
Abstract

In the past thirty years there has been rapid development of the water resources of the Sultanate. The growing economy has brought an increase in urbanization with a demand for high levels of service and quality for water supplies. The accompanying requirement for foodstuffs has led to a major expansion of well-based agriculture, beyond that of the traditional *aflaj* areas, so that water demand in the agricultural sector has tripled and now accounts for 93 per cent of total consumption. Desalination has been developed to augment natural resources for township water supplies and the collection and treatment of wastewater continues to develop. Nationally, indigenous water consumption is 25 per cent higher than the resources currently available from renewable resources, desalination and treated wastewater. In areas where aquifers have limited groundwater storage, domestic and other priority supplies are placed at risk. In coastal areas, over-abstraction has led to saline water intrusion with adverse impact on agricultural production and the environment.

The Sultanate of Oman has made major investments in water resources, development and management in the past thirty years. This has included the establishment of a national monitoring network, execution of national well and *aflaj* inventories and major catchments and aquifer studies accompanied by human-resource development and institutional capacity-building. Water is, and will remain, one of the nation's most valuable resources. Optimization and strategic management of the water sector was seen as a key dimension of the Omani Economic Diversification Strategy at the Vision 2020 Conference in 1995. With the expected increase in water demand by more than 50 per cent over the next twenty years for domestic, industrial, commercial and municipal purposes, effective water management is demanded. To assist in meeting the Vision 2020 strategy and maintaining the country's water security, a National Water Resources Master Plan has been prepared.

Introduction

Oman, situated on the southeast corner of the Arabian Peninsula, is classified as among the driest regions in the world. Rainfall is limited and irregular over much of the country. Mean annual rainfall in the coastal plains and desert areas is relatively low, less than 50 mm, and highly sporadic. In mountain areas, however, rainfall is greater, up to 350 mm, and is relatively frequent, providing a source of natural recharge to a number of aquifers including those in the interior and coastal plains. Nonetheless, two-to three-year droughts are not uncommon. And despite recharge from the mountains, aquifers can become stressed in some areas in the interior and coastal plains.



The natural water resources comprise ‘renewable’ resources, replenished from rainfall and stored in underground aquifers, and ‘non-renewable’ resources that comprise underground fossil water that would mostly not be replenished if abstracted. Total replenishment of the renewable resources is currently estimated to be about 1,300 million m^3/yr with a recovery level of about 70 per cent. Annual replenishment is equivalent, currently about 500 m^3/capita, and approaching a condition of extreme water stress according to international indices.

There has been rapid development of the water resources of the Sultanate in the past thirty years. The growing economy has brought an increase in urbanization with a demand for high levels of service and quality for water supplies. Nationally, indigenous water consumption is 25 per cent higher than the resources currently available from renewable resources, desalination and treated wastewater. In areas where aquifers have limited groundwater storage, domestic and other priority supplies are placed at risk.

It has long been recognized that the successful and sustainable future development of water resources in Oman depends on a thorough understanding of the available resources to meet potential demands. Significant investment has been made over the past thirty years in monitoring, inventory, resource exploration and assessment to establish an appropriate technical foundation for resource development, planning and management.

Water resources assessment in the Sultanate of Oman

Oman, with an area of almost 310,000 km^2, is located in the northern tropical arid zone. Daytime temperatures are high, generally above 30°C and seasonally above 40°C. The mean annual rainfall is low and highly variable, exceeding 350 mm in the mountains of Northern Oman and Dhofar, but reducing to 100 mm in the foothills and to less than 50 mm on the coast and in the desert interior. Potential evapotranspiration varies from 1,660 mm/year on the Salalah plain, with its lower temperatures and seasonal fogs, to 2,200 mm/year in the interior. Despite high evapotranspiration, there is still opportunity for groundwater recharge since rainfall occurs in storms on very few rain days and because the infiltration capacity of coarse alluvium and fissured rock is high. After heavy storms, there is dramatic runoff from the steep and bare hills into the wadis and the surface water flow may last only for a few hours or days.

There are currently over 4,000 monitoring stations for climate, rainfall, wadi flow, *aflaj*, groundwater levels and groundwater quality. The national monitoring network broadly complies with WMO Standards although data collection is rather sparse in the desert regions.

Two large-scale projects were carried out in previous years to establish a complete database for all existing wells and *aflaj.* The National Well Inventory Project, begun in 1992, was initiated with a registration process (167,000 wells) and followed by field inspection that provided a comprehensive data set on water levels, water quality, pump types, water use and irrigated areas. The total number of inventoried active wells was 127,000.

The National *Aflaj* Inventory Project, commenced in 1997, recorded a total of 4,112 *aflaj* of which 3,108 were found operational. Service areas of individual *aflaj* vary significantly but most are less than 2 ha; the largest single system extends over 1,227 ha. The total area serviced by *aflaj* in Oman was found to be 26,500 ha of which 66 per cent was under crop at the time of the field survey.

Surface water assessment and development

Surface water assessments have been undertaken in all major catchments mainly through hydrological studies and data analysis, feasibility studies for recharge dams and local flood studies. Such studies and investigations have created a number of resource development opportunities for both storage and recharge dams.

There are about thirty small concrete storage dams mainly in Jabal Akhdar, to alleviate local domestic water-supply problems. A major storage dam is currently being subjected to feasibility studies at Wadi Dayqah to intercept freshwater flows to the sea and supply water to Quriyat and Muscat.

On the other hand, there are seventeen recharge dams. The dams have generally been designed to store wadi floods for a few days, to allow silt to settle, before allowing controlled release of water downstream to recharge the alluvium. Water balance estimates indicate that, at national scale, wadi flood flows lost to the sea or the desert average about 119 million m^3/yr.

Groundwater assessment and development

A number of regional groundwater exploration projects have been undertaken in Oman and typically comprise exploration and test production well drilling, aquifer tests, and geophysical and topographic surveys. The most significant projects completed to date include Al Massarat, Rimal Ash'Sharqiyah and Najd.

Regional water balances indicate that total groundwater discharge is of the order of 400 million m^3/yr to the sea or inland drainages. While a flow of groundwater to the sea is necessary to maintain a stable sea water interface and, in areas of severe over-pumping, it is necessary to re-establish an environmental flow to the sea, there are areas where the natural groundwater flow still exists and it may be possible to effect reductions in flow losses to the sea by perhaps as much as 50 per cent and still maintain a groundwater balance.

Non-conventional water resources

Desalination

Desalination plants make an important contribution to water supplies where natural water resources are unavailable or inadequate. At the moment, desalination provides about 34 per cent of the potable water supplied nationally. Plants have been installed since the early 1970s, primarily to provide potable water to communities but also to supply industry. They are located both on the coast and in the interior.

Wastewater

The greater part of the water supplied for domestic, industrial and commercial usage returns to the hydro-geological environment as wastewater infiltration. It represents recharge to the aquifer and it is available for reuse at locations further downstream. The principal reuse of wastewater at present is for municipal greening (amenity watering) in Muscat and other towns; it amounts to about 12 million m^3/year.

Collection and treatment systems exist for some 25 per cent of the Muscat municipal population. A treatment plant has been constructed at other main towns and the industrial estates at Rusayl, Sohar and Raysut.

Other

A number of other non-conventional sources of water have been considered in Oman. These include **seawater flushing**, which can be considered as one of the options for the coastal towns. **Treatment and use of oil production water** is another option and active research programmes are being sponsored into methods of treatment and reuse. Trials suggest also that water catch from **fog collection** is possible and further investigations appear warranted. **Cloud seeding** may provide additional precipitation and increase recharge to aquifers or enhance run-off agriculture. However, more testing and investigations are required. **Import of water** from overseas by bulk carrier has also been assessed as a potential resource.

Major schemes and projects

A number of projects and schemes that have impact on resource use are in advanced stages of development or planning. These include:

Augmentation of capital area water supply

Construction of a 200 MW generating plant at Barka together with a desalination plant of 20 million m^3/yr capacity is in progress to meet local demands and augment supply to the Capital area.

Al Massarat water supply scheme

Well fields have been installed and reticulation provided to supply the towns of Ibri, Yanqul and Dank and nearby settlements. It is considered that 115,000 residents will benefit from the first stage of the project that will supply 8 million m^3/year. The project is the first large-scale municipal water supply network, fed solely by groundwater, in the Sultanate of Oman and one of the largest municipal groundwater supply schemes in the GCC countries.

Rimal Ash'Sharqiyah water supply scheme

Well fields have been installed and work has begun on the transmission pipelines to supply the towns of Al Kamil wa Al Wafi, Jaalan Bani Bu Hasan, Jalaan Bani Bu Ali and Al Ashkarah. It is expected that 79,000 residents will benefit from the first stage of the project that will supply 3.3 million m^3/year.

Muscat wastewater

Muscat Municipality plans a scheme to extend its sewage collection and treatment system. The first stage (2006) should generate 70,000 m^3/day of effluent, eventually increasing to an estimated 270,000 m^3/day (100 million m^3/year). This scheme will generate a considerable volume of wastewater that may be considered a potential water resource to be used in the most beneficial manner.

Salalah wastewater

A wastewater treatment plant has been built that will, in the first stage, treat 20,000 m^3/day (7.3 million m^3/year) with two further stages to more than double the initial capacity, in order to treat the effluent to a tertiary level, to chlorinate it and then to recharge it into tube-wells in a line parallel to the coast. The effluent will be injected directly into the saturated zone of a conglomerate and fissured limestone aquifer. It will help to stabilize the seawater interface and a part will be recovered from wells further inland.

Water use and demand

Over the next twenty years, the population of Oman is forecasted to increase by 40 per cent from 2.5 million (1993 Census) to over 3.5 million. There will be a similar increase in the demand for food and domestic water.

Water demand

The demand for water in Oman is broken up into four sectors as follows: domestic (municipal), commercial, industrial, agricultural and environmental.

The present water supply for domestic, commercial and industrial purposes in the Sultanate is estimated as 169 million m^3/yr. Of this supply 114 million m^3/yr is derived from groundwater, although 2 million m^3/yr of it is brackish groundwater that requires treatment by desalination. The remaining 55 million m^3/yr is from seawater desalination.

In the future, the growth of domestic and municipal water demands will depend significantly on the number of towns provided with improved water supply facilities. For planning purposes, this has been assumed to include all towns that will achieve a population exceeding 10,000 during the period 2000-2020.

An estimate of the future water supplies required for domestic, commercial and industrial uses assume that, in all rural and urban areas without a piped supply network, the per capita demand is 80 l/c/d. The demand increases to 192 l/c/d, with an additional allowance of 20 per cent for system leakage (240 l/c/d gross) for towns with a fully reticulated supply. Forecast demands show an increase of 52 per cent (87 million m^3/yr) in total water supply demand during the twenty-year planning period.

The agricultural sector is the dominant water-using sector and accounts for 93 per cent of total consumption, although agricultural returns to water in Oman are generally very low and net benefits contribute only marginally to the national economy (<3 per cent GDP). In total, about two-thirds of agricultural water use is derived from wells and one-third by way of *aflaj*.

Future water requirements for agriculture will depend on the areas irrigated, the cropping patterns adopted by farmers and the efficiency of water use. It is assumed that the demand for water will remain constant at or about the levels determined by the National *Falaj* Inventory.

Water quality issues

The quality of groundwater from *aflaj* and wells located in the upper reaches of catchments throughout northern Oman is generally suitable for domestic and agricultural purposes. The total dissolved solids (TDS) content (≡ EC) sometimes exceeds the highest desirable level for drinking water but is less than the maximum permissible level (according to WHO and Omani drinking water standards).

Groundwater becomes brackish and saline towards the coast on the Batinah plain, where the 6,500 mg/l TDS contour now extends a few kilometres inland. There is a similar deterioration of water quality in the interior with groundwater becoming brackish in the lower reaches of the wadis and even becoming hyper saline towards the *sabkhas* of Umm as Samim. On the Salalah plain there is a lens of fresh groundwater in limestone aquifers in the central region but with brackish water to the east and west, while saline intrusion is developing from the south. In the Najd, groundwater occurs within four distinct limestone formations and the water quality within them varies from potable to brackish. There is also a high incidence of fluoride in many of these waters, frequently exceeding the permissible level for drinking water of 0.8 mg/l (OS 8, 1970/1998).

The results of monitoring demonstrate that in few places the nitrate content of the groundwater exceeds the maximum permissible level for drinking water of 45 mg/l (OS 8, 1970/1998). These high values generally appear within town boundaries or extend as a polluting plume downstream from them.

Water balance

The water balance shows that, in many areas, demand for water exceeds natural replenishment. Where this situation exists, the demand is met by withdrawals from aquifer storage with consequent decline in groundwater levels (and, locally, *Falaj* flows). This situation currently occurs in Al Batinah, Salalah and the inland areas of Adh Dhahirah, Ad Dakhliyah and Ash Shariqiyah. In coastal areas, over-abstraction has led to saline intrusion. This has led to the abandonment of numerous, once-productive farm properties. Nationally, the consumption of indigenous water is 25 per cent more than the resources currently made available from renewable resources, desalination and treated wastewater. The stress, currently imposed by over-abstraction, is exacerbated during periods of drought. In areas where aquifers have limited groundwater storage, domestic and other priority supplies are placed at risk.

Water management

An increased demand has disturbed the earlier equilibrium between naturally available resources and demand. Water-demand projections indicate that if sustainable use of the renewable water resources is to be restored and maintained then new sources of water will have to be found and/or other measures introduced to meet projected growth. Some form of demand management measures, in areas irrigated from wells, is also required.

Regulations and policies

It was very important to set a strategy and establish rules and polices that can help protect and conserve water resources as well as develop the existing water supply. Numerous Royal Decrees have been made in order to control the demands, abstractions, and protection of water resources. The following are the most important:

- Royal Decree 82/88 states that 'the water of the Sultanate of Oman is a national resource to be used according to the restrictions made by the government for organizing its optimum utilization in the interest of the state of comprehensive development plans'
- Royal Decree 29/2000 places a new 'Water Protection Low' emphasis on regulations for wells and *aflaj*, and regulations for desalination units on wells
- Royal Decree 114/2001 organizes the disposal of solid and dangerous wastes, environmental pollutants and untreated sewage wastes without a permit
- Royal Decree 115/2001 refers to organizing the disposal of liquid and solid waste products
- In 2001, a series of Ministerial Decrees refer to the implementation of water supply well-fields protection zones at several regions of the Sultanate.

The key regularity measures include:

- *aflaj* protection
- well permits
- contractor registration regulations
- violations and enforcement.

Well fields were also defined and legislation was passed to regulate activities to protect water resources from pollution. A comprehensive environmental legislation towards protection of water resources from solid waste and wastewater disposals is also in place. A number of initiatives by the government organization have been aimed at encouraging water conservation. This includes irrigation improvement and leakage control in addition to other commercial activities.

National Water Resources Master Plan

The purpose of the Master Plan is to provide a sound basis for the development and management of the country's water resources. It recognizes that water will remain one of the nation's most valuable resources and that it will be of vital importance in the future in order to:

- Preserve and build on the achievements water use has brought to Oman, maintaining and enhancing its contribution to the standard of living, quality of life and health
- Protect and maintain investments made to date in water infrastructure
- Maximize the potential for its future development in support of economic diversification
- Afford maximum protection to the water-based environment
- Provide for water security in times of drought
- Secure the availability of water resources to meet the increasing demands and standards of a modern economy for future generations.

The Plan has been formulated to achieve these objectives and although it has a planning horizon of 2020, it takes into account the need to provide for sustainable development and security of supplies beyond this date.

The Plan, summarily described below, was formulated on a number of principles:

- The development of the country's water resources should be sustainable in the long term, not just technically but also economically, environmentally and socially
- Where resources are already being degraded due to over-consumption or pollution, the water balance of the aquifer should be restored to sustainability by 2020
- Saline intrusion in coastal areas should be halted or largely retarded by 2020
- The non-renewable resources should form a strategic reserve and those of potable quality be allocated only for priority domestic and industrial use. Their development should be planned in distinct stages with adequate intervals for evaluation of the aquifer response to pumping. The long-term strategy should be a flexible and well-managed approach to the use of these resources

- The provision of domestic and industrial water supplies has priority over its use for agriculture except where resources are used in *aflaj* areas where the current supply of water will be maintained

- A reform of irrigated agriculture should be encouraged to increase production from the water made available, to increase financial returns and to minimize 'virtual water imports'.

The Master Plan has suggested some primary actions that are necessary for the best development and management of the country's water resources.

Potable water supply for towns and priority purposes

The Plan provides for the necessary water resources investigations and assessments, including identification and investigation of well fields and the monitoring and protection of water sources.

Increase in recovery and development of indigenous water resources

The Plan includes projects to increase the availability of indigenous water that can lead to reduced dependency of the country on much higher-cost supply alternatives and imports of 'virtual water', where technically and economically feasible. This can be done through reducing surface and sub-surface losses to the sea or to the desert, increasing water availability by treating and reusing wastewater and making limited and strategic use of non-renewable potable and brackish water reserves.

Improvement in aflaj

Aflaj areas are regarded as an important part of the Sultanate's cultural heritage and an important source of water for a large segment of society, particularly in the rural areas. The Plan is committed to maintaining the current allocation of water to them, as well as improving the use of water by the *aflaj* communities.

Establishment of sector water allocations

With the increasing demands on indigenous water resources, the Plan recommends that sector water allocations be set, as early as possible, which formally establish the prioritization of water use. Allocations, on a catchments basis and subject to periodic review, would be made for each of the following sectors:

- Domestic
- Industrial/Commercial/Municipal
- Environmental
- *Aflaj*
- Agriculture (irrigated from wells).

The establishment of allocations of the renewable resources should be seen within the context of the overall water resources availability (renewable and non-renewable natural resources, desalinated water supplies, treated wastewater) and virtual water imports.

Management of agricultural water demand

The current use of water in many areas where wells are used for agricultural purposes is unsustainable and agricultural production is being adversely affected. Conditions will worsen if no action is taken to improve irrigation practices and water management. Some improvement can be made in these areas by adapting cropping patterns and through the introduction of modern irrigation systems. Alone, these measures will not achieve the required reduction in water consumption so that controls on abstraction will be required.

Conclusions and recommendations

The availability of the renewable water resources in Oman is 'scarce' and water-security demands priority attention to, and investment in, integrated water resources management.

Agriculture, a relatively small contributor to the economy, is the heaviest consumer of water. If the demands of an expanding population and the increased standards of service in a modern economy are to be met, the country's water resources will have to be managed in an increasingly advanced technical manner to exploit their maximum development potential.

While the long-term water security of the population has to be ensured, a sound balance has to be struck between the use of indigenous water and imported 'virtual water', within the confines of the economy.

Opportunities to augment resources by conventional and non-conventional means have been identified and are at varying stages of development.

The introduction of appropriate demand management measures in areas irrigated from wells will have to be introduced to overcome locally serious deficits, if Oman is to ensure the future sustainable use of water resources and yet meet the demands for domestic and industrial supplies. Public awareness information campaigns should be augmented as a preliminary action to active conservation control, of domestic, industrial and agricultural water use.

Wastewater from municipal areas represents an important resource that should be incorporated within resource planning. As the coverage of collection and treatment systems expands, effluent of better quality may be used beneficially either for direct use in agriculture or to recharge the aquifer through recharge lagoons.

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The Potential of Greywater Treatment and Reuse in Jordan: Exchange of Know-How between Islamic Countries

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Abstract[1]

Water scarcity in dry areas is a very critical issue for sustainable development. Efficient integrated water resources management (IWRM) methods require the implementation of all possible alternatives of water supply and demand management methods. Water supply in Jordan is limited and lack of new water resources and the competition between different water uses – domestic, industrial and agricultural – is expected to increase in the near future. As freshwater is very limited in Jordan, as it is in most of the Organization of the Islamic Conference (OIC) countries, and insofar as the rural and peri-urban poor are willing to exert time and energy to utilize greywater for increasing production of home gardens to supplement their income, the Inter-Islamic Network on Water Resources Development and Management (INWRDAM) has been developing for the past three years low-cost technologies for greywater treatment and reuse for irrigation at the household level.

Applied research explored has possible improvements to existing sanitation systems and improvements of food security in Jordanian peri-urban areas using greywater for irrigation of home gardens. Greywater recovery and on-site reuse gains importance for two main reasons: 1) it provides households with a considerable amount of irrigation water that can be used to produce supplement food; and 2) it protects shallow groundwater resources from pollution resulting from the infiltration of septic tanks.

This research project is an ambitious programme for the treatment of greywater reuse in home gardens for poverty alleviation. It has strong emphasis on water conservation, pollution prevention, and strengthening the role of the poor in society. The stated main goal of the project is ‘to help the peri-urban poor to preserve precious freshwater, achieve food security, and generate income, while helping to protect the environment’. The main aim of this paper is to highlight the activities and applied research outcomes of greywater treatment and reuse towards strengthening and promoting networking and exchange of know-how related to efficient IWRM between OIC countries.

[1] This paper is merely a description of the teamwork of many experts and consultants of INWRDAM, I among them, under the close supervision and financial support of IDRC. I express my thanks and gratitude to all those who contributed to the implementation of this project, with special thanks to the executive director of INWRDAM, Dr. Murad Jabay Bino, for his continuous support as project leader and major resource person in the design and the implementation of the greywater systems described in this paper. Special thanks go also to Dr. Odeh R. Al-Jayousi for his guidance and useful thoughts that helped in the success of the project and to Mr. Nasser Baroque from IDRC who supported the idea of the project in its early stages and is still supporting the ongoing and upcoming phases of the greywater research projects of INWRDAM.

Introduction

It is of primary importance to define and provide background information on greywater in general and the status of Jordanian water resources in particular.

Greywater[2] is the product water derived from dishwashing[3], sinks, bathing laundry and the like, which does not contain human solid or liquid wastes (referred to as blackwater). There are three major differences between greywater and blackwater: 1) greywater contains less Nitrogen[4] than blackwater; 2) blackwater represents a major source for pathogens bacteria, unlike greywater[5]; and 3) the normal organic content of greywater decomposes at a much faster rate than of blackwater. Greywater effluent from households can be used for two main purposes, indoor and outdoor. An example of indoor greywater use is for toilet flushing that requires special treatment and additional special chemicals. This practice goes beyond the scope of this paper. An example of outdoor greywater use is its reuse for irrigation, which is of interest to us here. This kind of practice can be most efficient in peri-urban areas, where households normally have a piece of land (home garden). If applied correctly, greywater reuse can result in many household benefits, including conservation of domestic water use and consequently a reduced water bill, decrease in quantities of wastewater drained to the septic tank, contribution to the development of home garden agriculture, contribution to household food security and income, etc. There must be adopted criteria in selecting potential beneficiaries and suitable project locations for any greywater reuse in any project. The design of such criteria will depend mainly on the goal of the greywater project. For instance, the most important adopted criteria for this kind of greywater project are: 1) the willingness and ability for the beneficiary to utilize greywater; 2) adequate water consumption in the household; 3) sufficient agricultural land area; 4) appropriate soil quality for agriculture; and 5) sufficient rainfall to contribute in supplementary irrigation.

In some circumstances, it may be better not to consider greywater reuse. Sometimes there might be major constraints for reusing greywater, economic or practical in nature, such as insufficient collection of greywater, lack of sufficient land, difficulty of reaching a house sewer system to separate greywater from blackwater pipes, inappropriate soil and climate for agriculture, lack of sound laws and regulations, inability of family to operate and maintain greywater system, etc.

Jordan covers a land area of 89,342 km^2 extending from its borders with Syria in the north to the tip of the Red Sea in the south and from the Jordan River border in the west to the deserts of the east bordering Iraq and Saudi Arabia.

Water resources in Jordan are characterized by scarcity, variability, and uncertainty. The rainfall period starts in October and ends in May, with a maximum rainfall period between December and February. The annual variations in precipitation are quite high. Average rainfall in the eastern mountain range is from 600 mm to 400 mm/year and in the eastern plateau from 400 mm to 50 mm/year.

Jordan has always had scarce water resources, but high population growth over the last twenty years has pushed its per capita water availability to below 198 m^3/capita/year, far

[2] Greywater here refers mainly to greywater effluent from peri-urban households, which does not contain any additional or special chemicals from industrial activities, other than normal detergents.
[3] Some countries consider kitchen wastewater effluent as blackwater.
[4] Nitrogen requires relatively long retention time in order to be treated in wastewater treatment plants.
[5] Ideally, greywater should not contain pathogens or fecal coliforms. However, some home practices, like washing babies and diapers in the sink, will result in greywater that contains pathogens. This can be dealt with in two ways: 1) through capacity-building and training of women, and 2) limiting greywater use to restricted irrigation, i.e. trees, fodders, industrial trees, etc.

below the benchmark level of 1000 m^3/capita/year often used as an indicator of water scarcity. Below the benchmark level, a country is likely to experience chronic water scarcity on a scale sufficient to impede development and harm human health.

Water management in Jordan had undergone a paradigm shift in terms of how water is valued and managed. Historically, water was viewed as a free good as reflected in the evolution of irrigation water pricing. In the last two decades, however, the concept of food sufficiency has shifted to one of food security. Currently, the Water Strategy for Ministry of Water and Irrigation (MW&I) calls for covering the operation and maintenance (O&M) cost for supplying, treating, and distributing water; water has an economic value. Water conservation and wastewater treatment and reuse are on the priority list for water demand management.

Jordan reuses nearly all wastewater collected by public sewer systems after treatment and mixing with freshwater stored in dams and reservoirs. However, more than 60 per cent of the population is not yet served by sewerage services.

Jordan has a moderately high human development index, higher than the average for developing countries. Nevertheless, 7 per cent of Jordanians earn less than the international poverty line of US$ 1/day. Furthermore, Jordan's high population growth and unprecedented urbanization rate threaten its recent economic gains.

Jordan's economy had experienced decline since the middle of the last decade. The Jordan Dinar (JD[6]) was devalued in 1988 against foreign currencies by 60 per cent and resulted in inflation and a sharp increase in the price of commodities. Although the economic reforms have achieved success and the local currency has been stabilized, these reforms have impacted significant portions of society and unemployment and poverty have increased. Jordan's population growth is 2.7 per cent, and the proportion of its population living in urban areas, already 73 per cent, is expected to reach 80 per cent by 2015 (UNDP Human Development Report, 2000). This trend has greatly threatened the food and water security of the poor, who increasingly find themselves in towns and cities. In 1996 the unemployment rate was 12 per cent and 35 per cent of all families lived below the absolute poverty line. The absolute poverty income limit for households in Jordan is 119 JD/month based on a family size of 6.8 persons (Moh'd Khasawneh et al, 1998).

Centralized sewerage systems, the preferred choice of planners and decision-makers, are inappropriately provided to individual communities and wastewater is transported from several scattered communities to centralized facilities. A World Bank review of sewerage investment in eight capital cities in developing countries found that costs range between US$ 600 and 4,000 per capita (1980 prices) with a total household annual cost of US$ 150-650 (Mara, 1996). Conventional sewerage systems are more costly in small communities. Because of their size and layout, small communities do not enjoy the savings of building large systems. The low population density means that longer sewers are needed to serve each household. The per household cost in the Jordan Valley rural sanitation project was projected at US$ 2,200, four times the average of all urban wastewater projects constructed in Jordan between 1976 and 1996 (Loredo and Thompson, 1998). The high cost of conventional sewers is regarded as one of the major constraints to expanding wastewater services to small communities and is a challenge to implementing the Millennium Development Goals (MDGs) adopted by the UN General Assembly to reduce world poverty by 50 per cent. The World Summit on Sustainable Development (Johannesburg) announced as a target a 50 per cent reduction of the number of people lacking adequate water and sanitation.

[6] One JD is equal to about US $1.4.

Conventional sewerage systems are designed as waste transportation systems in which water is used as a transportation medium. Reliable water supply and consumption of 100 ls per capita per day (lpcd) are basic requirements for the problem-free operation of conventional sewerage systems. Conventional sewerage is not appropriate for small communities in the Middle East region where water supply is intermittent and only limited amounts of water are available. By transporting the wastewater away from the generating community, several reuse opportunities can be lost. Reuse opportunities are often located within the generating community for landscape or for agriculture. Recent research and development in the field of wastewater management suggests that centralized wastewater management is environmentally unsustainable (Hedberg, 1999).

Background of study

Between 2001 and 2003, INWRDAM conducted a greywater treatment and reuse research project in Tafila, Jordan thanks to financial support from the International Development Research Centre in Ottawa, Canada (IDRC). The Tafila project resulted in developing practical and low-cost greywater treatment methods and these were outfitted in twenty-three households, the main Mosque and the girls' secondary school. Outcomes from the Tafila project can be summarized as follows:

- Greywater recovery within a house was maximized and made safe to handle
- Greywater reuse was standardized so that health and environmental impacts of reuse are controlled and minimized. Environment-friendly liquid dishwashing detergent and bathing shampoo detergent were developed and made into viable commercial formulations (patent pending)
- The impact of greywater reuse on soil and plants was monitored and results of over two years of monitoring do not show negative impacts.
- Households (mainly women and girls) were educated and were helped to benefit from urban agriculture practices
- A legal process for regulating greywater recovery was started. The building code for sanitary installations is currently under discussion for adoption of changes proposed by INWRDAM. Greywater quality monitoring was started by the Water Authority of Jordan (WAJ) in order to propose reuse guidelines in Jordan
- Production of olive trees irrigated by greywater was improved
- Household income increased by 10 per cent to 40 per cent due to reuse of greywater in household garden irrigation and conserved freshwater.

Description of greywater systems

INWRDAM has developed and implemented many types of greywater pre-treatment and treatment systems. The first set of research concentrated on pre-treatment (2-barrel systems) and advanced treatment systems (rectangular and circular greywater treatment). The 2-barrel system proved to be cheap, but not so efficient, while the advanced treatment systems were efficient in terms of treatment but not cost effective. INWRDAM therefore concentrated its efforts in two directions: 1) increasing the efficiency of greywater treatment all the while 2) maintaining low-cost systems in terms of materials, installation and O&M costs. The outcome of INWRDAM research resulted in the two following systems: the 4-barrel system and the confined trench (CT) system.

The 4-barrel system

Four plastic barrels constitute the treatment kit. The four barrels are lined up next to one another and are interconnected with 50 mm PVC pipes. The first barrel is a grease, oil and solids separator and thus acts as a pre-treatment or primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease and soap foam, float. This barrel has a 160 l capacity and a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. The second and the third barrels have a 220 l capacity and are filled with gravel 2-3 cm in size.

Once solids and floating material settle in the first barrel, the relatively clear water from the first barrel enters into the bottom of the second barrel. Next, the water from the top of the second barrel enters into the bottom of the third barrel. This water passes through the gravel lumps and from the top of the third barrel is taken into the fourth. Anaerobic treatment is accomplished in the two middle barrels. Anaerobic bacteria gets established on the stone surface so that when the greywater passes through the stones, the bacteria works on breaking down components of the organic material found in the greywater. The last barrel acts as a storage tank for treated greywater. As soon as this barrel is filled, a floating device switches on a small water pump, which then delivers the water through the drip irrigation network. For an average family home, twenty to thirty trees (olives, fruit, etc.) that are planted in the domestic garden can be irrigated.

Within one to two days of resident time in the treatment kit, the influent greywater is expected to undergo a treatment level equivalent to between primary and secondary treatment and meets the World Health Organisation's guidelines for *restricted* irrigation. Figure 1 provides an image of an installed 4-barrel system and Figure 2 shows an engineering drawing of the design of the 4-barrel system.

Figure 1: Installed 4-barrel system

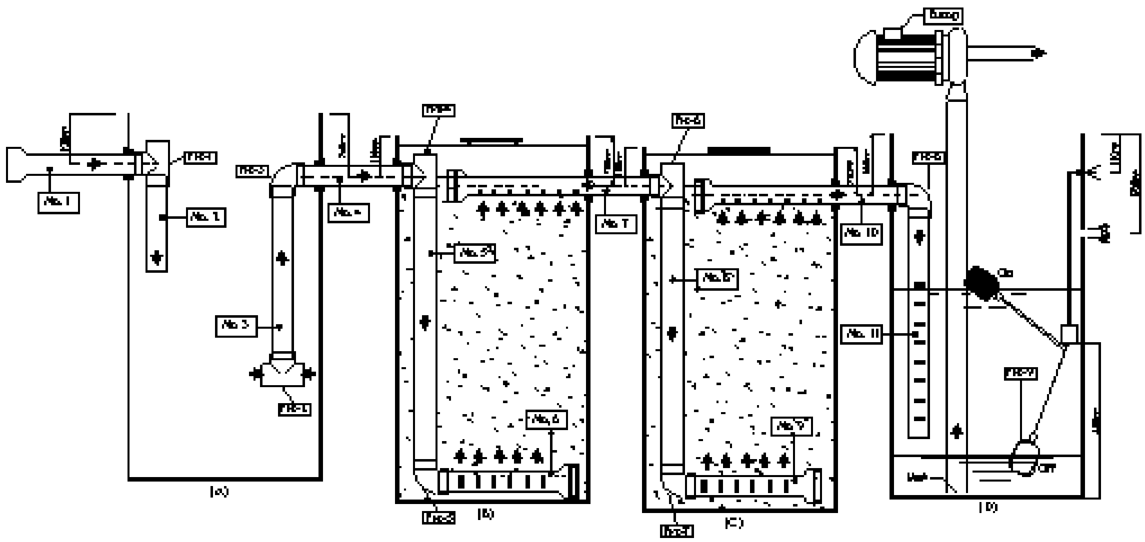

Figure 2: Design of 4-barrel system

The confined trench (CT) system

Two plastic barrels and a dug trench filled with gravel media constitute the confined trench (CT) unit. The first barrel functions as a grease, oil and solids separator and thus acts as a pre-treatment or primary treatment chamber, where the solid matter from the influent greywater settles and the floating components, such as grease and soap foam floats and can be removed regularly. The first barrel has a 160 l capacity and a large cover, which can be tightly closed. When the cover is opened, the chamber can be cleared of both floating and settled material. A trench is dug close to the first barrel with dimensions of approximately 3 meters long, 1 meter wide and 1 meter deep and it is filled with 2-3 cm sized graded gravel. Pre-treated wastewater from the first barrel enters the bottom part of the trench from one side and follows slowly to the other end. The trench is lined with a 400-500 micron thick polyethylene sheet. The sides of the side trench are plastered with a mud layer so that the PE liner sheet is not punctured by sharp stones. A 120 l capacity plastic barrel is perforated and burred in the gravel at the exit end of the trench so that wastewater follows throughout the trench and upwards to fill this barrel. As soon as this barrel is filled, a floating device switches on a small water pump, which then delivers the water through the drip irrigation network. Residence time of greywater in the trench is two to four days under anaerobic conditions. The confined trench unit can serve more than one nearby family sharing the same garden plot and it can deliver more water quantity between pumping cycles. Figure 3 provides an image of an installed CT system.

Figure 3: Installed confined trench greywater system.

Greywater sampling and analysis

The greywater quality parameters are shown in Tables 1, 2 and 3. The above parameters show the degree of effectiveness of the treatment of greywater. The variation in greywater quality was substantial and was affected by the care of family members with respect to upstream prevention of pollution. The regular cleaning of the oil and grease separator barrel resulted in big improvements in treatment and reduction of coliform counts.

Table 1. Effluent quality from 2-barrel system (households No. 1)

Sample type	PH	TSS	O&G	BOD5	ABS
11-6-02	6.4	39	24	154	19
21-7-02	6.7	69	21	186	60
14-8-02	7.8	2	14	23	1
05-9-02	8.3	57	NT[a]	59	2
20-10-02	6.1	94	30	518	NT
13-12-02	8	19	96	12	NT

[a]NT= Not tested

Table 2. Effluent quality from 4-barrel system (households No. 6)

Sample type	pH	TSS	O&G	BOD5	ABS
11-6-02	6.8	183	31	844	110
14-8-02	4.7	165	7	564	95
14-12-02	6.3	76	44	369	NT
17-02-03	7.4	128	40	246	170
29-05-03	8.2	88	NT	225	NT

[a]NT= Not tested

Table 3. Effluent quality from confined trench (households No. 3)

Sample type	pH	TSS	BOD5	COD
07-07-03	7.7	398	467	327
03-08-03	7.2	22	14	87
06-09-03	7.6	48	32	198

The greywater effluent of these units was fit for irrigating olive trees, cactus and many fodder crops. Monitoring of the impact of greywater on soil and plants after two years of application revealed some increase in soil's SAR, but it was below a level that could affect plant yield. All plant growth rates were improved due to regular complementary irrigation and there was no contamination of crops with fecal coliform.

During this project, INWRDAM developed special environmentally friendly liquid dishwashing detergent and bathing shampoo containing potassium or magnesium ions in the place of some sodium ions to control the long-term impact of detergents. The long-term impact of greywater application on soil and plants was also addressed, and available data representing two years of monitoring indicate that no build-up of harmful salinity and harmful chemicals is recorded.

The cost of a 2-barrel kit module that serves a six-person family, and which includes a drip irrigation system for a 2,000 m^2 garden area was about US$ 230, the 4-barrel module costs US$ 370, and the confined trench, which serves up to twelve persons, cost US$ 500, with drip irrigation systems. Cost/benefit studies indicate that household income increases thanks to irrigation with greywater and savings in freshwater bills, reduced septic tank disposal costs and improved crop yield in the range of JD 10 to 30 per month. This means that the cost of greywater units can be recovered on average in less than three years. The life of the greywater units is estimated at more than ten years with minimal running costs.

Greywater networking in OIC countries

During the implementation of this project, IDRC showed an interest in implementing this greywater research project in more countries and requested INWRDAM to start communicating with OIC countries. INWRDAM did so with Egypt, Lebanon, Syria and many others. INWRDAM succeeded in convincing IDRC to support a greywater research project in Lebanon and a pilot research project in Lebanon was financed by IDRC during 2002 with the Middle East Centre for the Transfer of Appropriate Technology (MECTAT). The amount of this support was CAD$ 220,000. INWRDAM is concentrating its efforts to convince IDRC and other donors to support its research in Jordan and to expand its applications to other OIC member countries. It is hoped that interested scientists from OIC countries who read this paper will contact INWRDAM to begin cooperation in an effort to combat food insecurity through helping the poor to harvest water at the household level.

Conclusions and recommendations

If applied correctly, greywater treatment and reuse represents a potential option for combating food insecurity in many OIC countries. Therefore, greywater reuse needs to be seen in terms of its contribution to sustainable water resources management without compromising public health and environmental impacts. INWRDAM is willing to cooperate with all interested researchers, scientists, organizations, institutions, etc. in order to contribute in developing scientific research and distribute the implementation of greywater reuse in their countries. Obviously it is not possible here to discuss all technical, socio-economic and other aspects of this research, but it hoped that this paper will be a benchmark to bring together scientists and researchers in an effort to distribute and develop greywater treatment and reuse in their countries with the goal of helping to alleviate and reduce poverty.

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Water Resources Management and Policies for Egypt

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Introduction

Egypt is unique among the nations of the world due to its extraordinary dependence upon a single water source, the Nile River (Figure 1), which is the longest river in the world. For more than 5,000 years, Egyptians have been managing Nile water for irrigation through a series of hydraulic structures, dams and barrages, from the Aswan High Dam at Lake Nasser in the south to the Zefta and Edfina Barrages at the Mediterranean Sea in the north. Historically, Egypt's rich agricultural land, with the exception of a few scattered oases in the desert, has consisted of the 1,200 km strip of the Nile River Valley and the Nile Delta.

Demands for water in Egypt are growing rapidly in response to an increasing population and the rising standard of living. The increase in population (Figure 2) has led to higher crop intensities and horizontal expansion. The annual share per capita of the country's water resources is approximately 875 m^3, 84 per cent of which represents crop water demand, with consumptive use at nearly 68 per cent.

The national water balance prepared for Egypt indicated that there was an overall deficit of approximately 8 billion m^3. This shortage was compensated for by raising the use efficiency of available water resources through reuse of drainage water and use of groundwater.

While institutional changes in the Ministry of Water Resources and Irrigation (MWRI) are visible, they are still not adequate to address the key water sector challenges facing the country, challenges that can be grouped as follows:

- Deterioration of water quality
- Growing demand-supply gap
- Intensification of inter-sectoral and inter-regional water allocation problems
- Inadequate governmental investments
- Poor cost recovery and operational performance
- Excessive government involvement and bureaucratic control.

These challenges and weaknesses require a strong emphasis on improving the management of water resources based on well-prepared policies and strengthened institutional arrangement. Water policies, in this respect, must be prepared within the context of an integrated framework, which would take into account the interdependencies among sectors and protect aquatic ecosystems, as well as establish improved coordination among institutions, and apply consistent regulations and sound policies. The integrated framework will improve the efficiency of water management through greater reliance on decentralization, user participation and privatization. Still, institutional reform programmes need to continue to be initiated in order to facilitate cross-sectoral action to improve management of water resources. Institutional reforms must rely on legislation that ensures that regulations are coordinated and enforced as necessary components of this reform.

Egypt has no effective rainfall, except in narrow bands along the northern coastal areas where some rainfed agriculture is practiced. Groundwater underlying the Nile Valley and the Delta depends entirely on both deep percolation and seepage of irrigation water diverted from the Nile. Some limited renewable and non-renewable groundwater resources occur in the Nubian sandstone of the western desert (Sahara) and in Sinai. The extent of new land development is a continuous role of MWRI.

Looking to the future, various policies for increasing the usable supply of water or improving the efficiency of its use have been identified. These include:

- Upper Nile development projects
- Improved management of the irrigation system
- Reduced flows to the sea by storage in northern lakes
- Increased exploitation of groundwater
- Expansion of drainage water reuse.

Water supply

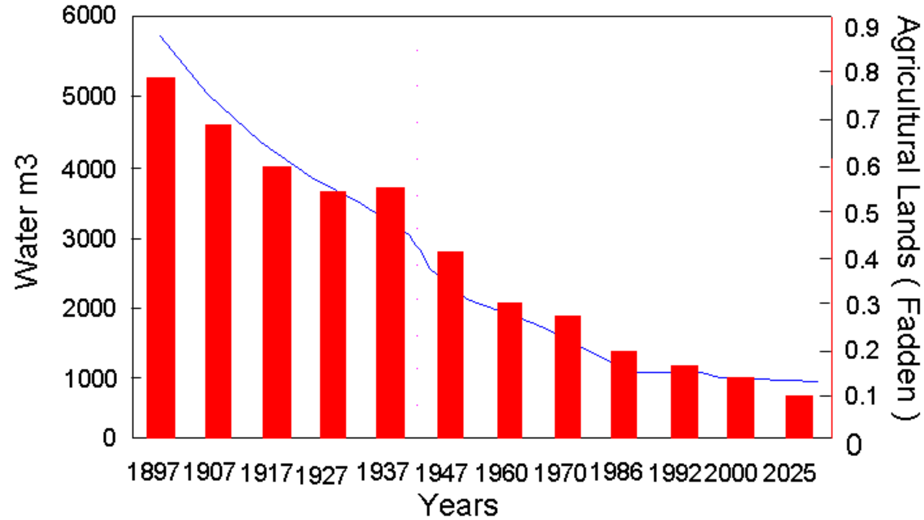
The institutions, sectors and organizations of MWRI (Figure 3) have always focused on developing old and new water supplies to satisfy ever-increasing demands.

High Aswan Dam

Surface water resources are limited to Egypt's share of the Nile River, together with minor amounts of rainfall and flash floods. The average annual natural flow of the Nile estimated at Aswan is about 84 billion m^3, of which 55.5 billion m^3 represents Egypt's share, 18.5 billion m^3 Sudan's share, and the remainder is allowed for evaporation. High Aswan Dam provides storage to guarantee regulated water supplies (Figure 4).

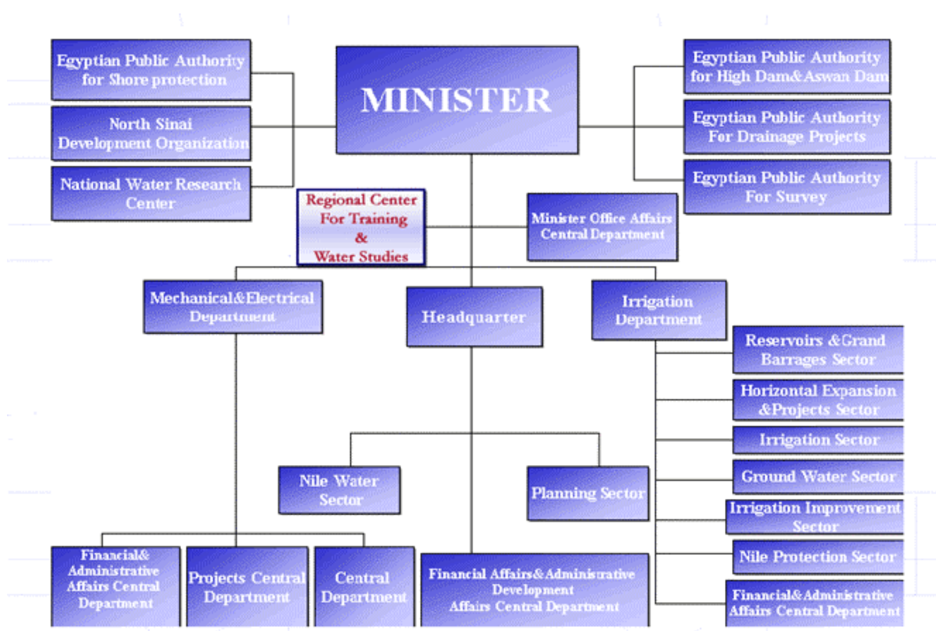
The Upper Nile projects

The 1959 Nile Waters Agreement stipulates that joint projects are to be executed to increase the yield of the river. The expected yield of these projects shall be divided equally between Egypt and Sudan. Three projects in particular are scheduled to be implemented in the near future: the Jonglie Canal, the Bahr El-Ghazal development, and the Sobat-Machar River marshes. The Upper Nile water development projects will add approximately 18 billion m^3/yr to the present flow of the Nile, equally divided between the two countries. This water is procured by minimizing the losses in southern Sudan, and does not affect the supply to the other eight Nile Basin countries. In reality, only Phase I of the Jonglie project, expected to increase Egypt's share of water by 2 billion m^3/yr is expected to be completed before 2025.



Per Capita Share of Water and Agricultural Lands

Figure (2)



Ministry of Water Resources and Irrigation Organization Chart

Figure (3)

Groundwater

Groundwater exists in the Nile Valley and Delta, the western desert, and Sinai. The largest groundwater deposit is the giant Nubian sandstone aquifer underneath the eastern part of the African Sahara, and is shared between Egypt and four other countries. The top of the aquifer varies from near-ground level to over 4,000 m below. It contains over 150,000 billion m^3 of non-renewable water in total, with a salinity mostly less than 1,000 parts per million (ppm). Much smaller aquifers, with relatively high salinity levels, exist in Moghra, Sinai and along the cost.

The aquifer underlying the Nile Valley and Delta has a total capacity of 500 billion m^3, with salinity levels around 800 ppm. The current abstraction level is about 4.4 billion m^3 /yr from the Nile aquifer.

Groundwater in the Nile aquifer cannot be considered a separate source of water. The aquifer is renewable only by seepage losses from the Nile, irrigation canals, and drains, and percolation losses from irrigated lands. This aquifer should be seen as a reservoir underlying the Nile River, with about 7.5 billion m^3/yr rechargeable live storage. The same applies to the other aquifers existing on the fringes of the Nile Valley and Delta, where surface water is the main source of irrigation (Moghra in the western Delta, and Plio-Pleistocene in the valley). In these aquifers, the groundwater potential depends greatly on subsurface drainage. The main water resources in Egypt are shown in Table 1.

Table 1. Water Resources

Types of Water Resources	Water quantity (BCM)		
	1990	2000	2025
Nile water	55.5	55.5	55.5
Reuse of agriculture drainage water	4.6	7	7
Deep groundwater	0.5	2.5	3.8
Treated waste water	0.2	1.5	1.5
Winter closure water	------	1.0	1.5
Water harvesting (rains etc.)	------	-----	1.5
Reducing evaporation losses from High Aswan Dam	------	------	2.5
Sea water desalinization	------	------	1.0
Total	60.8	67.5	74.3

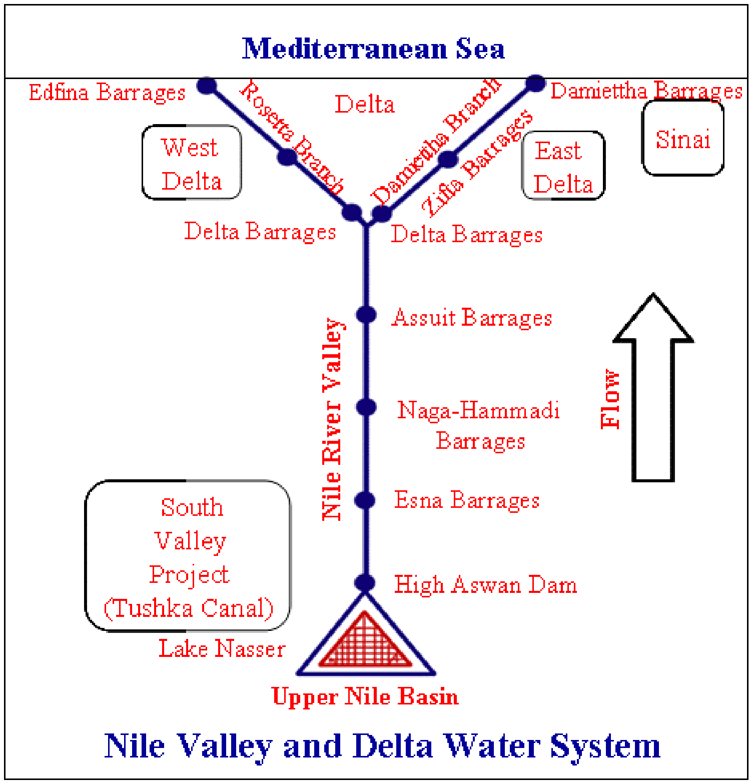


Figure (4)

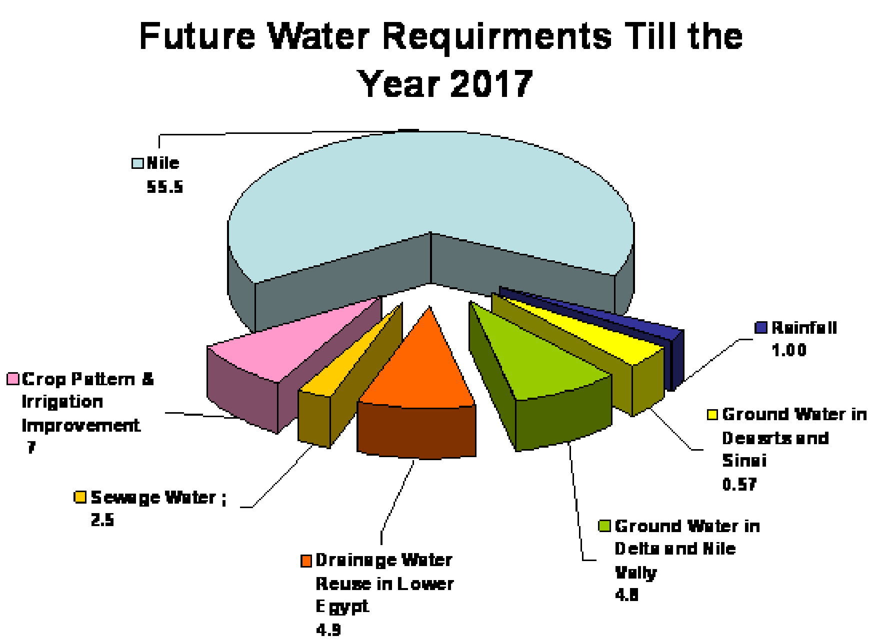


Figure (5)

Water demands

Irrigation agriculture consumes the bulk of the available water supplies. Despite losses of agricultural land to urbanization, the cropped area statistics indicate a very modest increase during the last decade due to an increase in cropping intensity, complying with the national plan to achieve food security. The distribution of crop areas has not changed significantly in the last decade. Present withdrawals for irrigation water are calculated based on the cropping pattern of the year 1995/96 and on the crop water duties. The main regional irrigation demands (including the recently reclaimed lands) are shown in Table 2.

Table 2. Regional irrigation demands

Region	Area (km^2)	Annual water use (billion m^3)
Eastern Delta	7.77	13.35
Middle Delta	6.93	11.60
Western Delta	6.30	10.60
Middle Egypt	5.88	9.90
Upper Egypt	5.04	8.40
Total	31.93	53.85

Agriculture consumes water by evaporation and evapotranspiration. Evaporation losses are conveyance losses from the canals, estimated at about 2.0 billion m^3/yr for the whole country. Evapotranspiration is dependent on the cropping pattern. Cropping patterns are a crucial factor in water resources management, especially under the free-market policy. The prediction of future water requirements depends upon the best estimation of cropping patterns. Figure 5 illustrates the future water requirement for the year 2017.

The combined effect of rapid population growth and an increase in living standards has led to an increase in the demand for food. MWRI, in collaboration with the Ministry of Agriculture and Land Reclamation, has planned an ambitious programme to reclaim approximately 7,170 km^2 by 2010.

Some of the reclaimed areas will be irrigated by mixing the Nile water with drainage water, such as that of the El-Salam Canal, which will cross the Suez Canal to reclaim 2.605 km^2 in Northern Sinai. Others will rely on the conjunctive use of deep groundwater with Nile water. In addition to this programme, there are sub-programmes to reclaim 126,000 ha using groundwater in the western desert and 84,000 ha using sewage water after treatment.

Municipal and Industrial Water Demands

Estimation of the municipal water use depends on population growth rates, the consumption in litre/capita/day, and distribution system losses expressed as conveyance efficiency. Estimation of municipal water use is shown in Figure 6.

Navigation and Hydropower Water Use

From February to September, water released from the High Aswan Dam for irrigation, municipal, and industrial purposes is sufficient to maintain the required navigational draft in the Nile (Table 3).

Table 3. Water Uses

Water uses	Water Requirements (billion m^3)		
	1990[1]	2000[2]	2025[3]
Agriculture	49.7	59.9	69.9
Domestic use	3.1	3.1	5.0
Industry	4.6	6.1	7.0
Navigation	3.0	0.3	----
Total	60.4	69.4	81.9

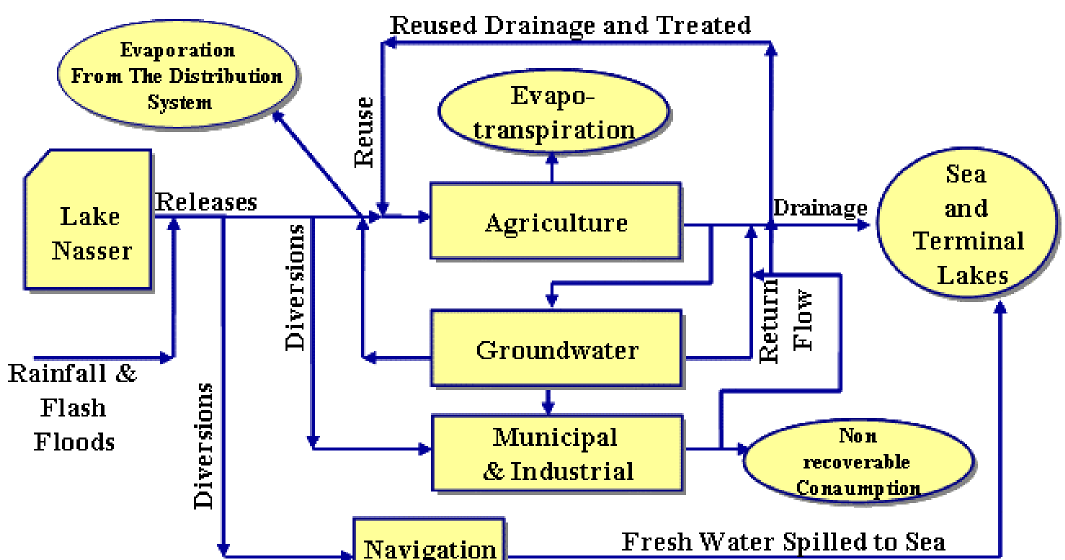
[1] Total agriculture land year 1990 = 7.4 million fed.
[2] Total agriculture land year 2000 = 7.4 + 1.2 = 8.6 million fed.
[3] Total planned agriculture land year 2025= 8.6 + 1.7 = 10.3 million fed.

Outflows to Sea

Water enters the system at the High Aswan Dam and flows to the sea as freshwater through the Rosetta and Damietta branches, and as drainage water through the main drains. Present outflows of drainage water into the sea and terminal lakes through the drainage network represent about 12.0 billion m^3/yr (Figure 6).

To conserve the Nile freshwater annually lost to the sea, several proposals have been studied to divert this water back to the annual budget:

- Storage in the old Aswan Dam
- Storage in the barrage pools as wedge storage
- Off-channel storage in depressions such as Wadi Elnatrun
- Artificial groundwater recharge
- Increased winter irrigation in reclaimed desert areas
- Storage in the coastal lakes (Edku, Maryut, Burollus, and Manzala)
- Staggering or eliminating the winter closure period.



Egypt's National Water Balance

Distribution system efficiency

Network conveyance efficiency can be expressed by calculating the system diversion losses starting at the source of feeding (intakes, regulators, water purification plants, pumping stations, and elevated tanks), through the distribution system, to the end users.

The diversion efficiency of the agricultural system is at 60-70 per cent, while for the municipal and industrial sectors it is currently at 50-60 per cent; some 8.9 billion m^3 of the return flow is being reused, and with system improvement, there is the potential to reach 17.2 billion m^3 in the future.

Although the seepage from the network flows to the groundwater where it can be pumped and used again, the difficulty in estimating the portion of reused losses results in accounting for these quantities as wasted. Distribution losses in the municipal sector are evaluated at 60 per cent in rural areas and at 40 per cent in urban regions. Efforts are being made to reduce the level of system losses to acceptable limits. These efforts include rehabilitation of the conveyance pipe network to eliminate leakage, a variable domestic water rate system with higher rates for higher consumption as an incentive for people to economize, and provision of domestic water-saving sanitary equipment.

Egyptian national experiences

To ensure more effective management of water resources and more efficient water use, MWRI has adopted a policy to increase participation of water users in water management and in operation and maintenance of the irrigation and drainage system.

Public awareness

MWRI is responsible for managing major activities that are directly linked to social and economic development. These activities include operation and maintenance of irrigation and drainage networks, implementation of basic infrastructure and pump stations for new agricultural lands, as well as survey work for horizontal expansion and other development projects.

The main objectives of this public awareness programme include:

- Informing the public, through different channels, of the role of MWRI in water management (its major achievements, and proposed and nearly accomplished projects)
- Advocating the significance of water saving in irrigation and domestic uses by demonstrating water saving consequences, and a new culture of water saving across society as a whole
- Mainstreaming environmental issues related to water resources use and future impacts that might result from specific new water use and saving techniques
- Formulating a simplified version of water resources policies and its associated strategies, and communicating MWRI's future plans to execute these policies through the media and in the parliament
- Achieving public participation in and commitment to water policies and programmes
- Increasing knowledge about new technologies in farm irrigation, and domestic uses to conserve water for future development.

Stakeholder participation

Given the long history of irrigation agriculture in Egypt, a number of traditional forms of farmer participation provide useful background for formal participation of the private sector in water management. Major informal forms of participation include the 'munawba and motarafa' system and the 'saqia' ring for collective water pumping. Stakeholder participation in water management has been developed over the past decade to allow more cooperation and coordination between the different stakeholders and MWRI in the water management process in order to achieve maximum use of available resources.

The National Water Resources Plan (NWRP)

The National Water Resources Plan will have to consider all components and functions of Egypt's water resources system and water-using sectors. Therefore, one of the essential elements in developing the plan is to create the necessary coordination mechanisms to develop consensus on the objectives and implementation of the NWRP between all stakeholders involved in the development and use of Egypt's water resources, both governmental (ministries, regional authorities) and non-governmental (industry, water users, organizations, etc.). All ministries involved with water supply and quality or which represent in some way the interests of categories of water users must be involved. In Egypt this means in principle some twelve to fourteen ministries.

Stakeholders at the regional government level

This includes twenty-six governorates and within each one an elected local council, representing the population, and a local unit representing the ministries concerned.

Public and private water users

These include: 1) in agriculture, farmers (sometimes organized in Water Users Associations or in Water-Boards) and fishermen and applies to irrigation, drainage, desalination and environmental issues; 2) organizations responsible for providing drinking water and sanitation (general authorities, economic authorities and companies); 3) public and private industry, with respect to water supply and environmental issues; and 4) citizens, in terms of awareness about drinking water and sanitation, leakage prevention, etc.

EPIQ Project

Escalating population growth rates, a desire for agricultural expansion, and increasing demands on surface water supply, in the face of limited water resources, puts enormous pressure on MWRI in terms of water resources management that meets all of these growing demands. Both MWRI and USAID are cognizant of the need to develop policy reform that will effectively address these and other issues on the level of use efficiency, productivity, and protection of water resources in Egypt. Through this project, the Ministry has developed a 'water resources results policy package' to produce the following results:

- Improved irrigation policy assessment and planning
- Improved private sector participation in policy change
- Improved capacity to manage the policy process.

Irrigation Improvement Sector

A package of demand-oriented measures has been prepared and applied to the Egyptian agricultural sector under the irrigation improvement project (IIP). Research and field trials in pilot areas have been undertaken by the National Water Research Center (NWRC) and MWRI to improve the overall efficiency in old lands. The IIP is made up of improved control structures using modern methods in land levelling/tillage, on-farm development, rehabilitation of main and branch canals and most of all mesqas, promoting equity of water distribution, and attaining a form of cooperation between the irrigation directorate and farmers by forming water users associations.

The Water Boards

At the branch canal level, under the Dutch Government-aided programme to Egypt, the water boards project has been formulated to develop a viable approach with respect to the diverse irrigation and drainage system in Egypt. The Fayoum Water Management Project's initiative to establish experimental 'local Water Boards' at the Secondary Canal was quite successful and between 1995 and 1998, a total of ten local Water Boards were established. Eight of these follow a 'joint management' model, whereby users and Ministry staff (District Engineers) form the board and are established by MWRI Decree of the under-secretary of state for Fayoum. The two remaining local Water Boards consist of users under law 32/1964 on Private Organizations and Unions.

The positive outcome of this experiment lead firstly to the formulation of a project to expand the experiment beyond Fayoum (the Water Boards Project) and secondly to the expansion of the experiment to the level above the Secondary Canal during the third phase of the Fayoum Water Management Project.

Legal Aspects

The currently applicable laws governing the government's control of water resources and related installations are incapable of meeting the government's needs in a manner consistent with its policy reform and economic plan. Therefore, it has become necessary to formulate new rules and amend current laws, including law 12/1984 and 213/1884.

Policy themes, programmes and projects

Recently, MWRI has adopted new integrated water resources policies focusing on three major aspects: demand management, resources development, and environmental protection. Presently, water resources planning focuses on increasing the water availability for all uses from various sources, in addition to saving and conserving water quantity and quality, while at the same time sustaining the environment as well as protecting people from water-related hazards. The following programmes and projects are being implemented as per the National Water Policy through 2017, as shown in Figure 7.

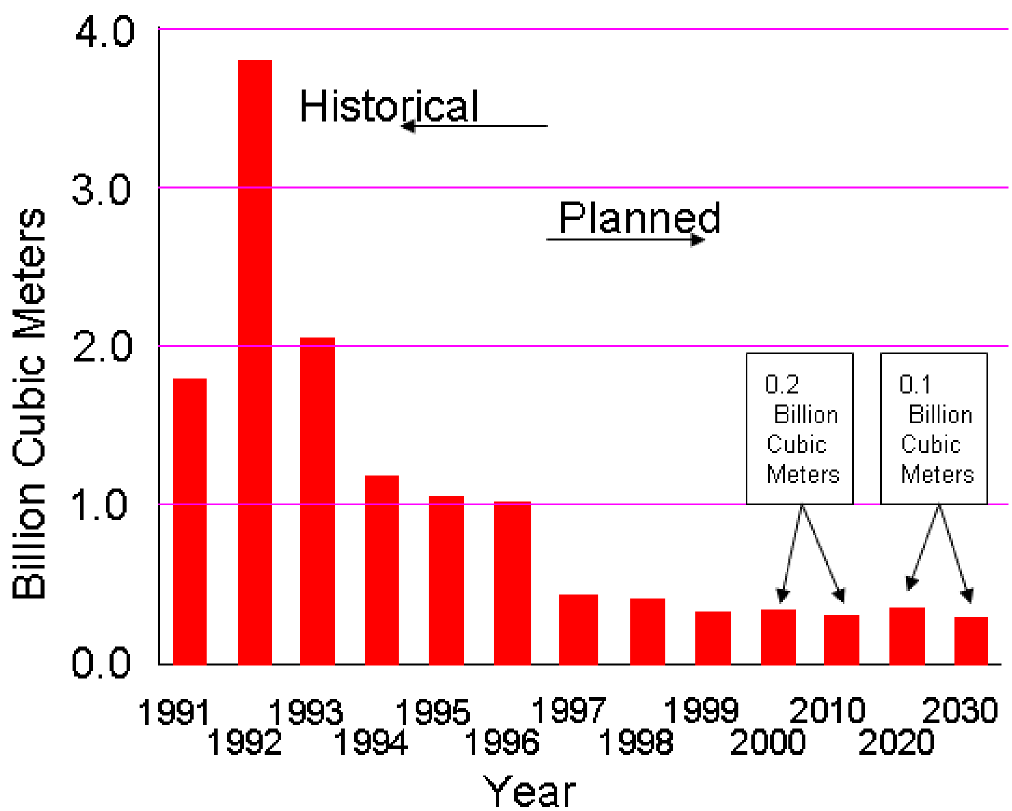
Optimal use of available water resources (water management for sustainable development)

Several programmes have been carried out by the MWRI to optimize the use of the limited and fixed available freshwater resources. These programmes will continue through 2017 and have so far achieved the following:

- Improvement of the irrigation systems on the branch and field canal level in an area of about 400,000 acres in the old land which is expected to result in saving irrigation water by 5-10 per cent

- Installation of tile drainage systems in an area of 5 million acres and rehabilitation of old drainage network in another 1.5 million acres to leach salt from the soil profile and improve soil fertility
- Rehabilitation of irrigation and drainage pumping stations
- Introduction of new varieties as early mature and salt tolerant
- Replacement and rehabilitation of the existing grand barrages and structure on the Nile and main canals.

Integrated water resources management of closed basins is practiced in all of Egypt's oases. The SIWA area is a good example of such a practice. The control of many wells in the basin and rehabilitation of the irrigation and drainage system has led to diminishing the rate of groundwater pumping and in turn of drainage water.



Fresh Water Annually Released to Mediterranean Sea

Figure (7)

Water quality protection and pollution abatement

The deterioration of drainage water in Egypt is caused by pollution from three main sectors: agriculture, industry, and domestic. Contamination arises from both point and diffuse sources. Inadequate industrial and domestic wastewater treatment plants and the rapid increase of population and industrial activities have created significant pollution problems with serious health implications.

The policy theme is realized through preventive measures and long-term policies. The preventive measures are carried out through the regular assessment of water quality and suitability for various uses, in addition to law enforcement to protect water resources against pollution. MWRI has established and operates a National Programme of Water Quality Monitoring in the Nile, canals and drains and in lake Nasser.

Development of new water resources in cooperation with the Nile Basin riparian countries (transboundary issues)

Bilateral cooperation with the River Riparian is carried out through joint agreements to develop the river-shared resources. On the regional scales and recognizing that cooperative development holds the greatest prospect of bringing mutual benefits to the region, the Nile riparian, including Egypt, took an historic step forward in the establishment of the Nile Basin Initiative. The Council of Ministers of Water Affairs of the Nile Basin formally launched the initiative in February 1999, which includes all Nile countries and provides an agreed basin-wide framework to fight poverty and promote socio-economic development in the region. The countries seek to realize their Shared Vision through a Strategic Action Programme, comprising basin-wide projects, as well as sub-basin joint investment projects. The basin-wide Shared Vision Programme is a broad-based programme of collaborative action, exchange of experience and capacity-building.

Capacity-building education, training, and awareness

MWRI has emphasized the need for capacity-building, education, and training. Within the last decades over 170 professionals from the National Water Research Centre have completed Masters and Ph.D. degrees from local and foreign universities across various disciplines in water resources management, irrigation and drainage.

Regional Centre for Training and Water Studies (RCTWS)

The main responsibility of the RCTWS is to organize and strengthen the regional water studies network and to develop an efficient programme for advisory services, information transfer activities and applied research findings. The mission of the centre is to offer specialized training programmes, workshops, and applied studies focused on integrated water resources management. The programme will concern related managers, professional engineers, technicians, and administrative staff, in Egypt as well as Arab, African and other Regional countries. The Centre carries out its objective and functions in close coordination with UNESCO water-related programmes and depends upon the extent to which international and regional support can be mobilized.

RCTWS-Egypt hosts three main programmes:

- The National Training Programme
- The Regional Training Programme for Arid and Semi-Arid Regions
- The Applied Training Project Programme for Nile Basin Countries.

Information

To strengthen the ministry's capacity for awareness raising, the Water Communication Unit was established. The unit publishes regular newsletters, media announcements and carries out public-awareness campaigns to prompt water saving and protection measures.

Research and technologies

Since its establishment, the NWRC of MWRI and its twelve research institutes have carried out mainly applied research and technology transfer that tackle the diverse problems that face Egypt's water sector. Research results and studies related to integrated water management have helped, among other things, to identify the quantity and quality of drainage water in Egypt that can be reused safely for irrigation, and to evaluate and adopt appropriate and improved irrigation systems for old and newly reclaimed areas, the hydraulic design and stability of the new Esna barrage, etc. In tackling these various problems, a multidisciplinary approach was used to ensure the proper coverage of all aspects and successful implementation, and local and foreign universities and consulting firms were called upon when relevant and needed.

To support the decision and management process of the water system, the use of new GIS technology and remote sensing were widely adopted along with mathematical models and decision-support systems. The MWRI and the NWRC are supported by a central library with strong links to other relevant libraries and entities in order to exchange research results and findings.

Financing

The Egyptian Government through the Finance Ministry funds all freshwater and related projects. Some of the water quality monitoring programmes are financed jointly by the government and international donors.

Cooperation

Egypt has involved and worked with many regional and international organizations that coordinate activities and share knowledge and experiences in the file integrated system. As one of the ten countries sharing the Nile water, Egypt is member in the Nile Basin Initiative established in 1999 and is also member of other similar organizations and networks in the Arab and Mediterranean regions.

Concluding remarks

The increasing discrepancy between water demand and water supply in the (near) future requires an ongoing and dynamic scenario for MWRI. The obvious and most logical scenario is for the government to gradually withdraw higher up in the system and concentrate on providing and supplying agreed quantities of water (and other defined services) to user management units, which will, over time and step-by-step increase in coverage. Participation of all stakeholders at the early stages in the planning and management processes will greatly impact on the success of the management.

The MWRI has already implemented several steps towards privatization and these required institutional and legal reforms in the Ministry mandates and activity domains.

The Ministry has also launched a public awareness programme to inform citizens on the importance of its water resources role in development plans and to invite water users to positively participate in the decision-making process.

The development of the New National Water Resources Plan is involving all stakeholders with the development and use of Egypt's water resources, both governmental (ministries, regional authorities) and non-governmental (industry, water users, organizations).

The Water Boards Project was formulated to develop a valuable national policy and legal framework for Water Board development. This is a clear indication that the government of Egypt has decided that for the future users need to be formally involved in water management.

The water sector in Egypt is facing many challenges including water scarcity and deterioration of water quality due to population increase and lack of financial resources, fragmentation of water management and lack of awareness about water. Increased technical and financial assistance on several levels might be essential at this stage in order to undertake numerous ambitious programmes.

Enhancement of private sector participation (PSP) in the management and operation of Egypt's water sector is expected to help face the above-mentioned challenges. However, several models for PSP have yet to be evaluated and tested. Furthermore, institutional reform is also needed for water-related ministries. Feasibility studies capacity-building and training are key factors to a successful transfer process, which in turn requires some additional funding.

Participatory Water Management Approach in Bangladesh

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Abstract:

In the last 50 years, Bangladesh has made considerable progress in the development of its vast water resources, with some 511 projects constructed (ranging from less than 1000 ha to more than 15,000 ha) for flood control, drainage and/or irrigation. Management performance of these projects, however, fell short of expectation. The poor operation and maintenance of the systems appear to be the major causes of the schemes' malfunctioning. In some cases, there have been serious environmental problems as well: depletion of fish stocks and deposition of silt and sands in the riverbed as well as on agricultural land. Absence of effective beneficiary participation in scheme development and management was found to contribute significantly to poor use of created facilities, and lack of maintenance of the scheme. The physical condition of the infrastructure deteriorates and after some time substantial rehabilitation is necessary. Many of the FCD/I schemes are in need of rehabilitation or improvement to meet the requirement of integrated water resources management. Recently, approaches to water management have increasingly reflected a shift from an exclusive focus on engineering aspects to integrated water management, and from a top-down approach to an emphasis on effective participation of all stakeholders. The participatory water management approach is now considered an effective way to manage the complexity of water management in Bangladesh. This paper describes Bangladesh's road map of participatory water management.

Country setting and water sector issues

Bangladesh is located in the northeastern part of South Asia, bordered by India on three sides, except in the southeastern corner by Myanmar and by the Bay of Bengal in the south. It has an area of 147,540 km^2, with a population of about 130 million.

The country is riverine. The Ganges, the Brahmaputra and the Meghna flow through Bangladesh, but only 8 per cent of these river basins lie within Bangladesh. Physiographically, the country can be divided into three broad categories: the hills, the terraces and the flood plains. The hills, situated in the southeast and northeast, make up 12 per cent of the country. The terraces occupy about 8 per cent of the country: the Barind in the northwest and the Madhupur tract in the central region. The flood plains make up the rest, 80 per cent of the country, about 10 per cent of which falls under the coastal zone. Except for the Chittagong Coastal Plains, the remaining rivers and their floodplains belong to the Ganges-Brahmaputra-Meghna River Systems.

Basically a floodplain country, Bangladesh consists of extremely low and flat land. Almost half of the area is within 10 metres above mean sea level (m.a.s.l.). Most of the lands in the coastal region lie within 3 m.a.s.l. In addition, some low-lying areas exist in the northeast, locally called haors (seasonally filled with water), where land-levels are within a few metres of the mean sea level. The floodplains contain a wide range of water bodies.

The rainfall and the river flows within the country exemplify the seasonal extremes and the conflicting situations they create. The average annual rainfall in Bangladesh is 2,500 mm, but this hides wide regional variations. The average annual rainfall in the basin of the Ganges reaches 1,400 mm, in Brahmaputra/Jamuna 2,100 mm, and in Meghna 5,000 mm. During the dry season, a net precipitation deficit occurs. The average net precipitation deficit in Bangladesh has been calculated at 320 mm. The maximum river flow in Bangladesh is recorded at 198,000 cumec, the minimum is 5,000 cumec. This is an extreme situation, showing a peak-season variation flow forty times higher than the minimum flow. It must be underlined that 90 per cent of river system flows originate outside the country.

A consequence of these extreme conditions is that the country suffers from both floods and droughts. The high volume of river flows accompanied by intensive local rainfall causes floods in Bangladesh. More than 20 per cent of the country's net cultivable area is inundated during the monsoon and more than 60 per cent at least once in every ten years.

Floods impact different people differently. At an aggregate level, most of the farmers want their land to be protected from early floods, so that they can switch to high-yielding *HYV-boro* rice cultivation. Protection becomes all the more urgent in the coastal areas where the environment is dominated by huge river flows, strong tidal and wind actions and tropical cyclones and their associated storm surges. Tropical cyclones are formed in the southeast Bay of Bengal and move towards the east coast of the country. Such tropical cyclones become deadlier when associated with water surges caused by a large mass of water in and around the storm centre.

The need for protection from the flood conflicts with the need of inland fisheries. Floods create favourable natural conditions for the growth and sustenance of living aquatic resources. During the rainy season, the excess water overflows the banks of the rivers and inundates the floodplains for a duration of about four to five months. In the process, various water bodies become connected with the rivers and provide a wide range of habitats congenial for fish reproduction. Early monsoon rainfall in conjunction with early inundation of flood plains provides the most ideal conditions for fish movement, migration and spawning. This unique ecosystem was home to more than 260 species of fish, but it is now under threat of gradual extinction due to incursions in the water regime.

Like flood management, the phenomenon of drought also brings into focus the inherent discord among different water uses. In the post-monsoon period, soil-moisture content declines rapidly and the deficit needs to be compensated by irrigation. Agriculture gets the lion's share of the available water and this in turn affects navigation, drinking water supply, environment, rural health and sanitation. Salinity intrusion, water logging and contamination of the groundwater aquifer by arsenic are some of the more recent additions to century-old woes caused by the water regime of the country.

By contrast, the net availability of surface water during the dry season is significantly reduced and erratic pre-monsoon rainfall can cause serious soil-moisture deficits. Moreover, Bangladesh shares fifty-four rivers with India and another three with Myanmar. Among these, the Ganges River is also shared with Nepal and the Brahmaputra River with Bhutan and China. A continuous and increasingly upstream withdrawal of waters from these rivers beyond the Bangladesh border is depriving Bangladesh from age-old traditional uses of waters and causing increasing stresses in water management within Bangladesh, particularly in the dry season.

Water is deeply embedded in the life and well being of the people of Bangladesh. In the last fifty years, Bangladesh has made considerable progress in the development of its vast water resources in the public sector, with some 511 projects (ranging from less than 1000 ha to more than 15,000 ha) for flood control, drainage and/or irrigation constructed. With these projects, about 5.3 million ha of land has been provided with flood-management facilities and 1.16 million ha with irrigation facilities with surface water. Another 3.3 million ha of lands, mainly in the private sector, are presently irrigated with groundwater.

Appropriate water management has played a major role in the growth of agriculture and consequent poverty alleviation in the country. Structural interventions in the coastal areas and floodplains in the country have been effective in reducing vulnerability by reducing the magnitude of flooding and substantially increasing rice production during the monsoon season. These have also significantly reduced the vulnerability of the poor to natural disasters and have created economic opportunities for them by ensuring increased agricultural production.

Management performance of the water sector projects, however, fell short of expectation. The poor operation and maintenance of the systems appear to be the major causes of malfunctioning. In some cases, there have been serious environmental problems as well: depletion of fish stocks and deposition of silt and sands in the riverbed as well as on the agricultural lands. The absence of effective beneficiary participation in project development and management is found to contribute significantly to poor use of created facilities and lack of maintenance of the scheme.

In addition, as water touches on almost every aspect of daily life in the country, it has led to the evolution of a complex system of institutional arrangements for its management. Great varieties of agencies have interests in water, interests that are sometimes complementary but more often competitive in nature.

Since the late 1980s, there has been growing awareness of the need for a more integrated, multi-sector approach to surface water management. It is increasingly felt that a new approach to planning, construction, operation and maintenance as well as the management of FCD/I schemes is required to address the water issues of the country. But most importantly, participation of all stakeholders is also considered to be crucial in order to ensure the long-term integration of social and environmental considerations. The emphasis has, therefore, been shifted from flood control to water management; from purely structural solutions to combinations of structural and non-structural measures, designed to meet a broader range of water management needs; and from purely consideration-based project development to stakeholder participation in all stages of project development. The participatory water management approach is now considered an effective way to manage the complexity of water management in Bangladesh.

National Water Policy (NWP)

The NWP, approved by the government in 1999, provides a comprehensive policy framework for dealing with such issues as river-basin planning, water rights and allocation, delineation of public and private domains, water supply and sanitation, preservation of the natural environment and the developmental concerns of fisheries, navigation and agriculture. The policy also provides guidance on its disposition towards water as an economic good, water pricing, and fuller participation by stakeholders, decentralized management and delivery structures. In addition, the policy formulates views on regulations, incentives, public investment plans and environmental protection and on the inter-linkages among them. Finally, it enunciates the basic principles for reforming the water-sector institutions.

The NWP makes clear the government's intention to pursue a policy of Integrated Water Resources Management (IWRM) and further pledges to take all necessary measures to manage the water resources of the country in a comprehensive, integrated, equitable and environmentally sustainable manner.

True to its objective of ensuring beneficiary participation at all stages of water resources management, the NWP specifically focuses on stakeholder participation at the service-delivery level. This concern is evident in the directive that participation of all project-affected persons, individually and collectively, is to be ensured in the planning, design, implementation and operation and maintenance of publicly funded surface water resources development plans and projects.

Participatory water management

Community participation in water management is not new to the people of Bangladesh. Historically, they would build small earthen dykes around their paddy fields or along riverbanks under the leadership of Zamindars (landlords), especially in the tidal flood plains of the south and *haors* (depressions) in the northeast of the country. At that time, water management was confined to protecting lands from monsoon and tidal floods by small dykes and limited irrigation with indigenous methods. Over time, however, the socio-economic scenario experienced dramatic and rapid changes and the Zamindari system was abolished in 1954. Increasing population, and hence the need for more land under agriculture, eventually led to the growth of public investments for the construction of massive coastal polders and several large irrigation projects. In subsequent years, the number of projects piled up and presently total more than 500 spread throughout the country.

BWDB is the major public sector agency under the Ministry of Water Resources responsible for developing flood control, drainage and surface-water irrigation projects. Earlier, this organization pioneered by tapping groundwater for irrigation in northern Bangladesh, but its role in groundwater development was subsequently overtaken by the Bangladesh Agriculture Development Corporation (BADC) and later on by the private sector. In the 1980s, there was a surge in private-sector involvement in groundwater extraction, mostly by shallow tube wells. Presently, the role of BADC is minimal. Recently, the Local Government Engineering Department (LGED) began developing small water resource projects with an area under 1000 ha.

Much effort has been expended in the past two decades to review stakeholder participation under the Dutch-aided Early Implementation FCD projects, and IDA/CIDA assisted small-scale FCDI projects. This initiative was later enforced through Flood Action Plan (FAP) studies and the System Rehabilitation Project (SRP) of the BWDB.

BADC, during its programme to expand groundwater irrigation, required that WUGs be formed. The Barind Multipurpose Area Development Project has successfully used cooperatives for water management. The Ministry of Agriculture has a shared experience in participatory management under the National Minor Irrigation Project (NMIP) where beneficiaries voluntarily re-excavated canals to support LLP irrigation. The Department of Public Health Engineering has also introduced participatory management to support rural water supply and sanitation programmes. An important development in participatory management has been in LGED’s Small Scale Water Resources Development Project. The beneficiaries have participated in water management projects from its initiation stage by making a percentage payment toward investment and for operating and managing the project entirely on their own. However, the experience of participatory management has mostly been mixed, perhaps due to some gap at the initial stage of project preparation when it might not have been possible to involve the beneficiaries at all stages of project cycle.

In 1994, the government of Bangladesh formulated the ‘Guidelines of Peoples Participation’, applicable solely to the water resources projects of BWDB. These guidelines focused mainly on irrigation projects and not on flood-control projects. Given the importance of the flood-control and drainage aspects in Bangladesh, the new Guidelines for Participatory Water Management (GPWM) was formulated in 2000 taking past experience into consideration. The GPWM will be applicable in all flood-control, drainage and irrigation projects of the country.

GPWM's institutional framework, in which local stakeholders will participate, is made up of a three-tiered Water Management Organization (WMO): a Water Management Group (WMG), a Water Management Association (WMA) and a Water Management Federation (WMF). WMOs will be responsible for planning, implementing, operating as well as maintaining local water schemes in a sustainable way and, depending on the type of scheme, will contribute towards the capital and operating costs of the scheme as decided by the government or on a voluntary basis acting in their own interest.

Institutionalizing a participatory approach

The GPWM is presently being followed in some water-sector projects, and community participation in water resources management is being institutionalized. The community participates in a number of important water sector projects, as described below.

Coastal Embankment Rehabilitation Project (CERP)

Along the coast of Bangladesh, hundreds of kilometres of embankments and drainage sluices were built to protect human lives and agricultural products, but devastating cyclones, floods and tidal bores system have repeatedly disrupted the embankment protection and caused gradual decay. In 1996, the government of Bangladesh, with financial assistance from the World Bank and the European Union, launched the CERP to undertake massive rehabilitation works for twenty-one coastal polders. The project activities are grouped into two categories: 1) rehabilitation of affected and damaged embankment systems by civil engineering works and 2) establishment of a community-based and improved O&M system.

A large number of squatters occupied the coastal embankments during the floods and cyclones. These settlements caused harms to the embankment system. A study recommended the inclusion of the squatters in the embankment maintenance system as an integrated project component. Accordingly, the squatters received reach of embankment on the condition of maintaining the surface on a regular basis in a specific manner. Stakeholders received vegetation materials and finances to cover the surface with plants. In order to grow the vegetation and perform maintenance activities, the embankment settlers received training with the help of NGOs, and those who more enthusiastically invested themselves within the maintenance system received assistance to develop other income-generating activities and health services. These settlers are assigned to cover the embankment surface with plants, which can also produce various commodities and bring them cash.

A community-based O&M plan was prepared in consultation with the community. The embankment settlers received training to pursue routine maintenance in their allotted embankment plots. Where there is no squatter, Embankment Maintenance Groups (EMGs) are formed. All routine maintenance is done at the community level, except for larger damages beyond community capabilities, which are undertaken by BWDB. As such, the need of annual O&M expenditure is expected to be considerably reduced.

Khulna-Jessore Drainage Rehabilitation Project (KJDRP)

This project is located in southwest Bangladesh, has a total project area of 127,800 ha and includes 1.1 million people. In the mid-1960s, Polders No. 24, 25, 27 and 28 were constructed under the Coastal Embankment Project in order to provide protection against saline-water intrusion and monsoon flooding. This provided enormous benefits by reclaiming land for a 'Grow more food' programme at that time.

However, over the years, the polders created ‘dead end’ conditions to tidal prism movement in the river systems. Furthermore, the embankments on either side of the rivers stopped lateral movement of tidal water. Siltation occurred within the riverbed starting from the dead ends which was not offset by natural flushing or regular maintenance. Due to river deterioration, the rainfall runoff created drainage congestion in the polder areas, causing the inundation of farmlands and households, and disrupting the internal communication networks, leading to acute environmental degradation, loss of agricultural production, decreased employment opportunities and lowered living standards of the people of the area. The study of the rehabilitation of the project was then started with assistance from ADB.

A community-focused participatory approach was adopted in June 1995. The community was associated with project management in the preparation of rehabilitation and tidal river management (TRM) plans. The community also participated in finalizing the design of the drainage structures and canal networks for ensuring effective drainage. The WMOs actively participated in the construction of perimeter embankments in some places by procuring land free of cost from the beneficiaries and helping the contractor to mobilize the labour force. WMOs helped collect basic data and information through field surveys and disseminated information among the beneficiaries.

This is a unique example of community participation in the design, planning and construction of a large drainage project and in viable solution finding. The drainage congestion of the affected areas has been considerably reduced.

Command Area Development Project (CADP)

This project seeks to bring about sustainable increase in dry season agricultural production, by realizing the full potential of the irrigated areas: 13,632 ha in the Meghna-Dhonagoda Irrigation Project (MDIP) and 18,870 ha in the Pabna Irrigation & Rural Development Project (PIRDP) thorough participatory management. The project was jointly financed by GOB and ADB.

The CADP has provided the rehabilitated physical facilities of flood control, irrigation and drainage to MDIP and PIRDP through water management training and O&M facilities to the community, as well as project staff for the development of command areas, integrated pest management training and the development of small-scale fisheries.

The WMOs participate in the decision-making process of the rehabilitation works, the O&M of the project facilities and the collection of irrigation service charges from the farmers. Small construction works are being done by the LCSs. Through this programme, the landless workers themselves profit from the contracts. In major civil work contracts, the community has been involved in construction supervision as members of Quality Monitoring Committees. The community has been involved in the operation of pumps, gates and in rotational irrigation.

Lessons learnt and future programmes

A review of past experiences as well as the findings of several evaluations of completed projects available in published form show very interesting findings. The lessons to be learnt from these project experiences are as diverse as the projects themselves. The major findings that run through several of these projects are enumerated here below:

- Institutional weaknesses are identified as the most enduring and intractable constraints in project effectiveness. They are the single most important cause for implementation delays, cost overruns and inadequate O&M of completed schemes. Such weaknesses are evident in planning, design, contract award and disbursement of funds.

- Inadequate stakeholder consultation and participation has been another major constraint. In recent projects, however, some progress has been made, but the sustainability of these achievements still needs to be proven.
- Inadequate O&M has been a perennial problem in all schemes. This phenomenon is not unique to the water sector. All public sector organizations are afflicted by this problem. As a result of poor maintenance, sustainability of schemes is limited. Approaches have been developed, but their full implementation in a systemic way still needs to be done.
- Cost recovery from the irrigation projects and cost sharing are widely recognized problems. Setting up a sustainable funding mechanism for O&M is a big challenge facing the water sector.
- Inadequate monitoring of project performance and project impact, linked with corrective action to rectify identified problems, hampers efficient management.
- There has been a general lack of integrated water management planning. The FCD/FCDI interventions have generally impacted negatively on inland fisheries of the country.

The reform initiatives already taken by the government have created an enabling environment for taking concrete action in the field of participatory water management. Further steps need to taken for carrying forward the momentum already generated by the government. Some initiatives need to be taken up to consolidate and build on recent achievements by introducing the participatory approaches for rehabilitation and improvement at scheme level, strengthening operation and maintenance and incorporating these changes in the main organizations in the water sector. These initiatives should also seek to develop a dependable database and a pragmatic analytical framework to facilitate the emergence of an integrated water resources management regime.

The government is now pursuing the Water Management Improvement Project with donor's assistance for enhancing the capacity of the local community to improve the performance of the water management systems. The overall objective will be to alleviate rural poverty by creating better livelihood opportunities for the local population. This project seeks to achieve this objective by initiating the participatory water management approach. The outcome of project will be an improved water resources management capacity, reduced vulnerability, enhanced livelihood opportunities as well as improved institutional performance and good governance. The project would support, through pilot testing, the establishment and strengthening of WMOs and subsequent mainstreaming of participatory planning and scheme assessment.

Conclusion

The lessons learnt from past water management efforts point out that the focus of integrated water resources management must go beyond flood control, drainage and irrigation and that environmental considerations must be integrated into water resources management. To achieve this, the need for reforming water institutions has become even more pronounced and it is felt that more attention must also be given to the social dimensions that promote stakeholder participation and the transfer of appropriate water management activities to the local communities. The present and planned future activities indicate that the participatory water management approach will be an effective way to manage the complexity of water management in Bangladesh.

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IWRM AND CAPACITY-BUILDING IN MALAYSIA

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Introduction

As the most important source of life, water must be managed in a holistic manner in order to ensure its sustainability so as to serve various users while protecting the essential ecological and physical processes. Its proper management therefore calls for serious commitments and full cooperation among all stakeholders concerned and Malaysia is no exception.[7]

Malaysia is blessed with more than 1,500 rivers. The annual rainfall of 2,500-3,000 mm is derived from the alternating northeast and southwest monsoon. The northeast monsoon occurs from mid-November to March, bringing with it heavy rains and floods, mainly hitting the east coast of Peninsular Malaysia. Although surface runoff is about 57 per cent, rapid population growth (approximately 158 per cent), coupled with urbanization and industrialization, has contributed towards increased water demand. It has been projected that by the year 2050 the total domestic, industrial and irrigation demand for Peninsular Malaysia will increase to 17,675 million m^3 from 10,833 million m^3 in 2000 (Kerajaan Malaysia, 2002).

There is increasing pressure from the general public concerning water management issues especially those related to the quality and quantity of water supply, notably complaints about recurring flash floods in urban areas that create huge losses. It has been estimated that about 29,000 km^2 or 9 per cent of the total land area in the country is prone to flooding, affecting some 2.7 million people. The average annual flood damage has been estimated to be RM100 (National Water Resources Study, 1982). Public pressure with respect to water resources mismanagement has placed the current water policy, which emphasizes a hard engineering approach rather than preventive mechanisms, high on the agenda. The establishment of effective water policy and regulations and empowerment are therefore prerequisites to sustainable water management.

The current water resources management system in Malaysia involves a multitude of actions by different authorities and organizations. As a result, it is largely fragmented by the implementation of diverse policies and laws. In addition, many existing statutes of course govern land and water use in Malaysia at both federal and state levels, operating within the requirements of the Federal Constitution, which often become a source of impediment to a coherent approach.

Quite recently, capacity-building in IWRM has been given close attention in Malaysia through its MyCapNet (Capacity-building Network for Integrated Water Resources Management, see http://htc.moa.my/htc/mcapnetold/mcapnet.html). This paper will also briefly describe the status and needs for IWRM capacity-building in Malaysia.

[7] The authors would like to thank the Director General of the Department of Irrigation and Drainage, Malaysia, for his sincere support in our participation in the workshop and presentation of this paper, and the RCUWM, for their financial assistance enabling attendance at the workshop.

Water resources management issues

Recently, prominent water issues have been debated by the public and stakeholders in light of frequent problems directly related to water resources and the environment, such as air pollution, flooding, landslides, hill slopes cutting, etc. Such problems have led relevant authorities to focus on legislation as a means to resolve these issues in five main areas: supply, demand, mitigation, legislation and policy, and institutional integration issues.

Legislative framework

Legislation is today seen as a tool for the systematic implementation of water management on a technical and non-technical level. Many national and local institutions responsible for water management and water service delivery do not work effectively and efficiently because of inappropriate policies provided for water management and unclear definition of the mandates of related institutions. The old Waters Act 1920 provides guidelines for all states in Malaysia regarding the control of rivers, etc. However there are presently numerous other federal and state enactments that enable a host of relevant authorities to implement their actions. There are four areas of concern: water use; water conservation; water quality and public health; and land development. The Federal Constitution, which empowers control of water resources to state governments, is already a limiting factor in legislative reform options.

To streamline the coordination of water resources development, the Federal Government of Malaysia proposed to undertake the administration of water management in all states by the end of 2003. This move was suggested by the National Water Council as some states are having financial problems managing their administration, including building water treatment plants and repair. This suggestion is only possible with the amendment of the Federal Constitution and state level water-related acts. Currently, water administration and management are handled by the respective state governments (New Straits Time, July 31 2003).

The planning, development and management of water resources is entirely the responsibility of the government. As far as land and water are concerned, the federal government constitution stipulates guidelines for the policy and regulation framework relationship between the federal and state governments. In general, land and water reside under state jurisdiction, in addition to town and country planning, public health, sanitation, drainage and irrigation, rehabilitation of mining land, etc., while shipping, navigation, fisheries, federal work on water supplies, rivers and canals, production of waterpower are all under federal jurisdiction.

Most recently, however, the cabinet on the use of Urban Storm Water Management Manual Guidelines and Procedures for Urban Drainage Development has endorsed a policy meant to replace the outdated Planning and Design Procedures No. 1 of Urban Drainage Design Standards and Procedures for Peninsular Malaysia. The manual incorporates the latest technology and practices employed for flood control at-source. This manual has not yet, however, been distributed to all states throughout Malaysia.

Integrated Water Resources Management (IWRM)

The much-used term, IWRM, was coined during the international conferences on water and environmental issues in Dublin and Rio de Janeiro in 1992 and has been more recently endorsed and reiterated by the 2nd World Water Forum and Ministerial Declaration at The Hague in March 2000. The Global Water Partnership (GWP) defines IWRM as ‘a process which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.'

Malaysia is very devoted to have IWRM as its main reference in developing a sustainable environment. The Eight Malaysia Plan (2001-2005) in fact stresses the need to address environmental and resource management issues holistically in an integrated manner. All identified environmental challenges are interrelated and impacting one another, whether it be competing demands for water resources, unsustainable use of agriculture and forestry resources, or pollution and waste management problems.

The Eight Malaysia Plan retains the emphasis on a balanced development with environmental considerations. One of the nine key implementation strategies of the plan is 'to adopt an integrated and holistic approach in addressing environmental and resource issues to attain sustainable development'. In order to advance this strategy, the government will need to put in place the enabling conditions for effective policy change.

A number of specific policies related to water resources management are highlighted in the Eight Malaysia Plan, notably to:

- Develop and implement a national water policy to provide the framework for water conservation and management
- Give more emphasis to the demand-side management of water and the sustainable use of groundwater resources.

In addition to these sectoral interests, cross-sectoral initiatives envisaged for the Eight Malaysia Plan includes efforts to:

- Intensify ongoing efforts and introduce new approaches to strengthen land use planning
- Enhance the level of environmental awareness and civic consciousness among the people
- Fulfil obligations under environmental conventions
- Improve management and interpretation of environmental information
- Promote the use of appropriate market-based instruments and self-regulatory measures among industries.

The Malaysian Government has recognized the contribution of the Malaysian Water Partnership known as MyWP, the national focus of GWP, in providing the national water vision for the country, which states that, 'in support of vision 2020 (towards achieving a developed nation status), Malaysia will conserve and manage its water resources to ensure adequate and safe water for all (including the environment).'

The accompanying framework for action includes, among other things, managing the nation's water resources efficiently and effectively (both quantitatively and qualitatively), and moving towards integrated basin management and the sustainable development of water resources (Salmah Zakaria and Zalilah Selamat 2002). One of the seven critical thrusts in the National Vision Policy introduced in the Third Outline Perspective Plan (2001-2010) envisages 'Pursuing environmentally sustainable development to reinforce long term growth.' Other critical thrusts include raising quality of life, eradicating poverty and strengthening human resources.

Water resources policy and management reform

Water resources planning and development in Malaysia often requires multi- and interdisciplinary approaches. Current policy approaches to irrigation, water supply, urban drainage, water quality management are not sustainable; in other words they lack an integrated approach. There is a strong need to integrate a holistic approach within the current institutional framework.

It is anticipated that some form of water sector reform in Peninsular Malaysia will have to be initiated, which will involve federal and state governments agreements on a number of constitutional and socio-political considerations. The matters pertaining to state and federal government responsibilities can be ironed out through the National Water Resources Council (NWRC) established in 1998. The NWRC formulates national water policy, master plans, guidelines on priority water use, advises state governments on preservation of dam catchments, coordinates and facilitates inter-state water transfer, coordinates water resources development projects that ensure the long-term sustainability of water supply, and addresses legal issues in terms of uniformity and international water resource commitments.

In addition, many states requested to establish a State Water Resources Council (SWRC) or a state Water Resources Technical Committee, or both, to manage their own water resources matters. The Selangor State has, for example, established a Water Management Board. In the case of portable water supply, some state governments have already set up a privatized body to manage water supply while the administration of water management has been undertaken by the federal government.

The National Water Resources Study (NWRS, Kalian Slumber Air, 2000) underlined the need to develop a holistic National Water Policy under federal and state government initiatives. The NWRC, with state and federal involvement, has undertaken to ensure coordination of federally-funded resources development in line with the National Water Policy.

In terms of management, the NWRS outlines the following principles:

- A clear cut responsibility in demand management to achieve reductions in metered water usage and non-revenue water
- Management of state-owned assets and adequate financial return on state investments
- Under a full-scale privatization arrangement, application of a user-pay principle in a transparent situation and high standard reliability in meeting water demands
- Major role for the private sector in the delivery of services to the sector and for the development of new water resources.

The conventional practice relying upon the ‘old concept’ of multiple involvements of water related agencies has caused overlapping jurisdiction and empowerment conflicts within the agencies. Hence, by redefining the roles and tasks of the relevant agencies, the situation can be controlled and existing policy constraints loosened in management protocols. The need to re-measure and re-allocate current boundaries based on hydrological boundaries should be done to improve existing governance. The natural boundaries that outline the original river basin or watershed are easier to manage than political boundaries. The new management approach can be based on comprehensive water resource assessments based on interlinked water investments in river basins by supporting decentralization, capacity-building and strengthening monitoring, evaluation, research and learning at all levels, particularly in public-sector institutions and the enhancement of good deeds among children to value the water and environment.

National physical planning system and the environment

According to the national physical planning system, the planning and management of integrated resources is being applied. This approach has been applied by the United Nations Development Programme (UNDP) and endorsed by the International Union for Conservation of Nature (IUCN). The national planning system is governed by the Rural and Town Planning Act 1976. The main focus of the act is to provide complete measures and guidelines for town and country planning under the jurisdiction of local authority in Peninsular Malaysia.

The environment is guided by the National Policy on the Environment, which supports the 'continuous economic, social and cultural progress and enhancement of the quality of life of Malaysia, through environmentally sound and sustainable development'. The objectives are to achieve:

- clean, safe, healthy and productive environments for present and future generations
- conservation of the country's unique and diverse cultural and natural heritage with effective participation by all sectors of society
- sustainable lifestyles and patterns of consumption and production.

Its principles are the following:

- Stewardship of the environment
- Conservation of nature's vitality and diversity
- Continuous improvement in the quality of the environment
- Sustainable use of natural resources
- Integrated decision-making
- Role of the private sector
- Commitment and accountability in the international community.

Various green strategies in education and awareness, effective management of natural resources and the environment, and integrated development planning and implementation have been formulated by the Malaysian Environmental Department. In addition, sustainable development strategies in terms of prevention and control of pollution and environmental degradation, the strengthening of administrative and institutional mechanisms, etc. have been developed.

Capacity-building in IWRM

Capacity-building concentrates on strengthening the capacities of the institutions working in the field of water, as well as on reinforcing the ability of a water-scarce society to face crises. This integrated approach translates into a long-term process that includes coordination between the different institutions and strengthening the ties between them. It also involves ensuring a steady flow of data about water resources and their use between the consumers and the producers of the information (Prince Talal bin Abdul Aziz, 2003).

The importance of the above statement has been underlined in several important international water forums, including the recent World Water Development Report, in an effort to raise awareness about water-related issues and as a warning as to the potential gravity of the water crisis.

Before discussing capacity-building proper, it is interesting to know the current status of IWRM in Malaysia. Table 1 has broadly categorized IWRM status into six areas as follows:

1. National water policy that reflects IWRM concepts
2. Water law that incorporates IWRM principles
3. Organizations that are in place at policy level for IWRM
4. Organizations that are in place at implementation level for IWRM
5. Capacity-building delivery systems for IWRM
6. Other aspects of IWRM implementation.

Table 1: Status of IWRM in Malaysia

IWRM progress	Status	Activities underway / planned activities	Priority capacity-building needs
1. National water policy	Ongoing. Water policy is in the process of being formed Various aspects of water policy are covered in the 8th Malaysia Development Plan and the 3rd Outline Perspective Plan	The Water Resources Council is drafting a new water policy with stakeholders to take into consideration IWRM concepts. Stakeholder Meetings	None
2. Water Law	The Water Enactment of 1920 is outdated and needs review The Selangor Water Enactment 1998 was passed by Selangor State Government to manage water resources in the state (SWMA or LUAS). Other states to follow suit	None Reviewing the enactment for better application in all states	Train a cadre of legal personnel to draft the water law to reflect water policy Train a cadre of water managers able to assist policy-makers on water policies that reflect IWRM
3. Policy-level organizations	Water Resources Council at the national level. Only one state is set-up, Selangor (SWMA /LUAS), to manage the water resources of the rivers in-state	None	Setting up water councils, water administrative councils, river basin authorities, etc.
4. Implementation-level organizations	Not started. River authorities planned for SWMA only but not fully operational	Discussions with water sector agencies for formation of river authorities under SWMA	Train water managers, river authority personnel and other water sector agencies
5. Capacity-building delivery systems	MyCapNet formed with representation from various sector organizations. Various sectoral organizations have some form of capacity-building. Formal capacity still confined to the academic institutions	MyCapNet began formal activities in terms of training water managers in 2003 Committees are being formed for deliver to the various public institutions and NGOs	Sustain MyCapNet as a dedicated association for capacity-building at all levels in IWRM
6. Other	The NGOs have various short term capacity-building but the area of influence is still cursory	Steps are being undertaken to capitalize on the existing work of the NGOs in terms of short-term training through the publications of training materials, etc.	

Table 2: Capacity-building needs in Malaysia

TARGET GROUPS	CAPACITY-BUILDING NEEDS	CAPACITY-BUILDING INSTITUTIONS
Policy and decision makers: Federal government level State government level Local authorities	**BRIDGING INFORMATION GAPS:** • Information • Skills: training • Knowledge: education-enhancement **DECISION MAKING TOOLS:** • Integrated decision making mechanisms • Command and control mechanisms • Economic Instruments • Strategic or holistic decision support tool • Research and Development	Academia, research institutions, department of statistics, specific govt. agencies INTAN, DID, DoE Academia EPU/PM's Dept., INTAN MoA, DID, A-G's Chambers EPU, Bank Negara (for financial institutions) INTAN, academia? Academia, research institutions
MANAGERS: Government Corporate/public bodies Government Corporate/public bodies Corporate	**INTEGRATED MANAGEMENT APPROACHES:** • Management methods • Management tools • Information for management • Mechanisms (coordination to networking) **Resources:** • Skilled and trained human resources curriculum development & training modules • Funding • Technological support **Self regulation:** • Voluntary mechanisms • Incentives	DID/MoA, Academia, INTAN, SEATEC? DID, SEATEC? Academia, Training Institutes, INTAN Min. of Education DID, INTAN and Academia EPU, Financial Institutions, International Donors MOSTE, Academia, Scientific Community SIRIM (ISO14000) etc Government, financial institutions, international donors
STAKEHOLDERS/BENEFICIARIES: • Public • NGOs • Community-based organizations • Other private sectors • Academia	• Awareness raising • Access to information • Advocacy towards public involvement • Mechanism for public involvement & contribution	DID, media, local authority DID or IWRM Council/Committee – one stop centre NGOs, CBOs, DID, local authority Local Authority, DID or IWRM Centre
TRAINERS/EDUCATORS/INNOVATORS Academia Research and Training Institutions	• R&D facilities • Curriculum development • Technological development	EPU, MOSTE, MoA/DID Min. of Education, INTAN, SEATAC? MOSTE, international and local scientific communities

The need for capacity-building in the water sector

According to UNDP, capacity-building is the sum of efforts to enhance and utilize the skills and capabilities of people and institutions at local, national, regional and global levels, aimed at sustaining development. It consists of the following elements:

- Creation of an environment with appropriate policy and legal frameworks
- Institutional development, including community participation
- Human resources development and strengthening managerial systems
- Sustainable funding (the addition of this fourth element is the outcome of subsequent consultations and field experience).

Water is a scarce commodity and an economic good. This is indeed true in many parts of the world especially in the arid zone. Even if water is seen to be apparently abundant, its management is of vital importance in terms of its quantity and quality. As such, highly-qualified professionals with local expertise are prerequisite to tackle issues such as integrated water resources development, the information and technology gap, decentralization and privatization, floods and draughts, threat of conflicts and anthropogenic land and water management problems. It is necessary to build capacity at the public, professional and institutional levels (see De Laat and Ramsundersingh, 2000), and there is hence a need to introduce new multidisciplinary approaches in all the sciences, including natural and social sciences (see Summary and Recommendations of the International Conference on World Water Resources at the beginning of the 21st Century, Water: A Looming Crisis?, Paris, 3-6 June 1998).

The capacity-building needs for Malaysia have been identified and summarized in Table 2. Clearly in need of capacity-building are areas concerning advocacy, policy formulation, awareness-raising/community action, building local improvement and participatory processes.

Malaysian Capacity-building Network for Integrated Water Resources Management

Malaysia's involvement in the above initiative led to setting-up MyCapNet (Malaysian Capacity-building Network for Integrated Water Resources Management) under MyWP (Malaysian Water Partnership) working in hand-in-hand with the CapNet – a new capacity-building network pioneered by UNDP to foster better exchange of information and human resources development for IWRM. It intends to serve as a global network, which operates as a support programme for regional and national networks of IWRM training and education institutions.

Objective and target group of MyCapNet

The overall development objective of MyCapNet is in line with that of the global CapNet, which is to enhance integrated water resources management and service delivery for improvement of livelihoods and the protection of the environment. MyCapNet's main thrust would be towards capacity-building with the focus on education and training. This would be achieved through the networking of various organizations and institutions with similar objectives, awareness creation, IWRM knowledge base and information exchange, and development of relevant materials and tools. The One-day Forum on Capacity-Building for IWRM (2001) reached a consensus on improved information dissemination, separate IWRM programme, inclusion of IWRM awareness in related water management subjects and building partnership. Some of these statements have been initiated: for example the development of curricula for Masters of Environmental Science in IWRM, National Study on Effective Implementation of IWRM, Planning Tool Assessment etc.

Criteria for cooperation

There must, to begin with, be a certain degree of potential capacity for and competence on IWRM among education and training institutions in Malaysia. As such, the general criteria for membership and cooperation among organizations and institutions joining MyCapNet are as follows:

- Commitment to IWRM principles
- Relevant experience
- A multi-disciplinary approach
- Commitment to a participatory and gender-sensitive approach
- Making available own resources (facilities, staff, budget)
- Mobilization of additional resources, and open collaboration with other institutions in the country or region to stimulate regional cooperation and enable participants from other parts of the country or region to have access to IWRM education and training.

Concluding remarks

In its stride towards vision 2020 (the status of a developed country), Malaysian awareness of the needs for good water management has been widely accepted and taken in the context of overall development. New approaches in handling sensitive water issues effectively, without creating internal conflicts, in order to balance the differences of interest between stakeholders and the public are a most welcome step forward. The management of water shall be reformed and re-organized in due course, to ensure the implementation of the three key words of managing water in an ***integrated***, ***holistic*** and ***sustainable*** manner . The traditional approach to water resources management, which consists of dividing up the responsibilities among specialized agencies, needs to be complemented and enhanced by the concept of 'capacity-building', which will tackle the water-related issues holistically by combining its elements into an integrated entity.

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Management of Shared Groundwater Basins in Libya

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Introduction

The Great Socialist People's Libyan Arab Jamahiriya occupies the north central part of the African continent, and covers a surface area of more that 1.5 km^2. It shares international borders with Egypt and Sudan in the East, Chad and Niger in the South and Algeria and Tunisia in the West. To the north it is bordered by the Mediterranean Sea, where the Libyan coast extends for more than 2,000 km. Libya shares large groundwater basins with neighboring countries, the most important of which are the Nubian Sandstone Basin with Egypt, Sudan and Chad, and the North Sahara Basin with Algeria and Tunisia.

The Libyan climate can generally be classified as a dry desert climate particularly in the central and southern regions, and is characterized by wide temperature variations between summer and winter seasons along with scarce and irregular rainfall. The north coastal strip, on the other hand, is situated within a semi-Mediterranean climate and receives winter rainfalls ranging from 200 to 400 mm/yr with moderate temperatures and high relative humidity.

The northern plains experience high population densities particularly in the coastal strips, where soils are suitable for a wide range of agricultural productions. More than 80 per cent of the Libyan population, estimated at approximately 5 million, is located in the large population centres of the Gefara and Benghazi plains and the other coastal cities. Population densities may exceed 120 persons/km^2 in the north and less than 1 person/km^2 in the desert areas in the central and southern regions.

Water Resources

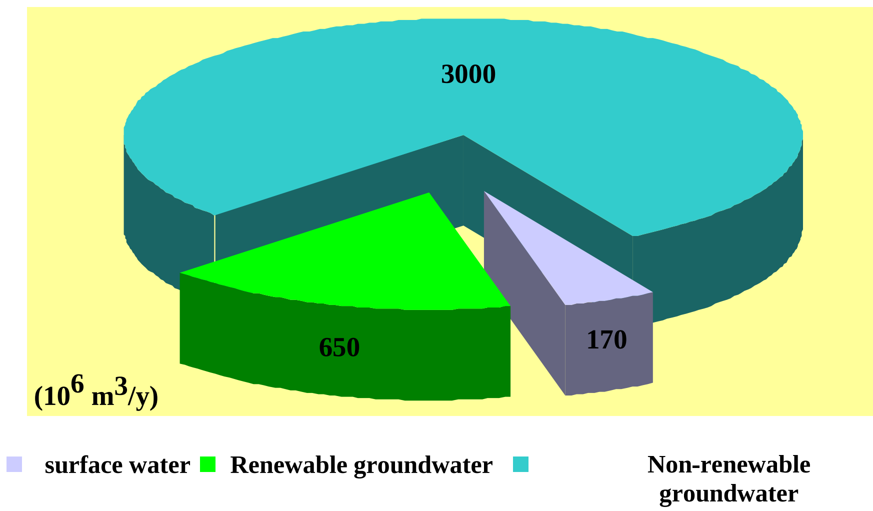
There are both surface and groundwater resources in Lybia. Surface water is rather limited and contributes to less than 3 per cent of the total water use for the different activities. In order to better control these resources, sixteen dams and several reservoirs were constructed for the collection of over 60 million m^3/yr. Natural springs of low to medium discharge provide water for different uses in the Jabal Akhdar, Jabal Nefusa and the central zone.

Groundwater represents the main source of water supply in the Jamahiriya. It is extracted through wells ranging from few metres to more than 1,000 m in depth. Groundwater aquifers are either renewable or non-renewable. The renewable aquifers are those located in the northern zones and fall under high precipitation rates. They range in age from Quaternary to Cretaceous and contribute more than 2,400 million m^3/yr against an annual recharge of less than 650 million m^3. This imbalance has provoked a continuous lowering of groundwater levels accompanied by deterioration in water quality due to seawater intrusion and invasion of saline water from adjacent aquifers.

The large sedimentary groundwater basins cover extensive areas in the central and southern parts of Libya and contribute large quantities of freshwater for local use and agricultural development. Recently, several well fields were developed to supply the Great Man-made River Project (GMRP). When completed, the GMRP will supply more than 6 million m^3/day to the agricultural fields and population centers in the north. According to the hydrogeological studies, GMRP water will minimize the water balance deficits in the affected zones.

Non-conventional water resources in the form of desalination cover only a small portion of the domestic and industrial water demand. Treated sewage is still very limited and is mainly used for irrigation purposes. Figure 1 displays the potential water resources.

Figure 1. Potential water resources

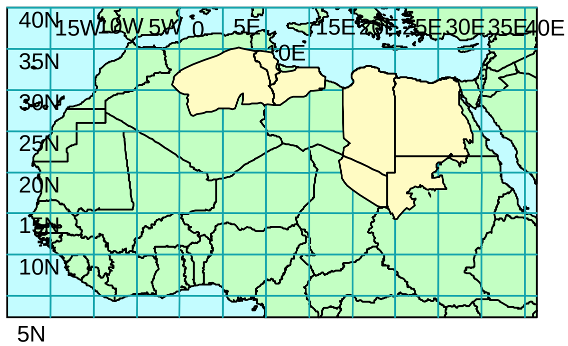


Shared Water Resources

The Sahara Desert in the northern half of Africa is well known for the existence of large sedimentary basins extending over thousands of square kilometers crossing through international boundaries (Figure 2). These basins consist of several aquifer systems, which belong to different geological ages. Most common are the Mesozoic aquifers, namely the Jurassic and Lower Cretaceous, which are made of thick sandstone and clay layers and are widely known as the Nubian Sandstone. This aquifer is shared between Libya, Egypt, Sudan and Chad. The other main sandstone aquifer is the Continental Intercalaire (CI) shared between Libya, Algeria and Tunisia.

These basins also contain other aquifers of great importance such as the Post Eocene in Libya and Egypt (Sarir Basin) and the Complex Terminal of Upper Cretaceous in Libya, Algeria and Tunisia. Although the latter group is of lower water quality, they enjoy great local importance and are widely developed to meet the increasing water requirements.

Figure 2. Shared Groundwater Basins



The Nubian Sandstone Basin

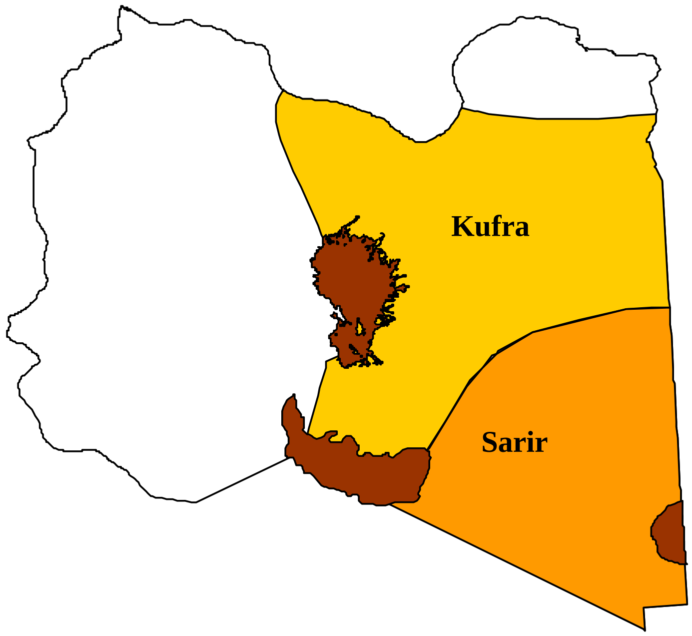
This basin, in its broad definition, includes the Paleozoic and Mesozoic aquifers in the south and the Neogene aquifers in the north. It extends over a surface area of more than 2.2 million km^2, 760,000 km^2 of which are in Libya. It is locally known as the Kufra and Sarir Basins, and has been used since the mid-1960s and early 1970s in the supply of local water requirements and the irrigation of major agricultural projects in Kufra and Sarir. This basin also supplies water for oil production activities, and more recently for the GMRP conveyance system. In Egypt the area of the Nubian Basin is of the order of 828,000 km^2, while it is limited to only 376,000 km^2 in the Sudan and 235,000 km^2 in Chad.

In Libya, the basin has been subjected to a number of local studies accompanied by deep exploratory drilling and extensive geological and geophysical surveys. The generated results helped in the determination of hydraulic properties and flow direction, and for setting a base for the continuous monitoring through a piezometric network of more than 150 wells. This network has enabled the construction of advanced mathematical models to study future aquifer behaviour. Figure 3 shows the local extension of the Kufra and Sarir aquifers.

The Kufra Basin

The Kufra basin covers an area of over 200,000 km^2 and consists of a deep Paleozoic aquifer and a more widely used upper aquifer known as the Nubian Sandstone. The saturated thickness of both aquifers exceeds 3,000 m in the central part of the basin south of Kufra town. Production wells drilled for agricultural water supply range in depth from 400 m to 500 m with productivity ranging from 100 m^3/hr to 300 m^3/hr and a water quality between 180 mg/l and 300 mg/l. Transmissivity from pumping tests falls between 300 and 3500 m^2 /day. Storativity is in the order of 0.0001 and 0.015.

Figure 3. Nubian Sandstone Basin in Libya



To the north of Kufra, Tazerbu well field was completed in depths ranging from 450 m to 600 m, with productivity reaching 400 m^3/hr and water quality of less than 500 mg/l. Tazerbu wells are tapping the lower aquifer (Paleozoic). Both aquifers are hydraulically connected at the regional level and are also in contact with the Miocene aquifer in the Sarir Basin to the north. Groundwater flow is from south to north and northeast in the direction of the natural depressions along the latitude 30 N such as the Qattara Depression in Egypt.

The Sarir Basin

Located to the north of the Kufra Basin, the Sarir Basin covers a surface area of more than 450,000 km^2 and consists of a number of aquifers belonging to the Post-Eocene. The basin is currently developed for agricultural activities in the Sarir area as well as for conveying water to the northern plains. Depth of wells tapping these aquifers range from 400 to 500 m with productivity varying from 150 to 300 m^3/hr and water quality in the order of 1200 mg/l. Transmissivity and storativity determined from pumping tests fall between 750 and 1500 m^2/day and 0.0005 and 0.0001 respectively.

The Joint Commission for the Study and Development of the Nubian Sandstone Aquifer

The hydrogeological studies and mathematical models that were conducted on the Nubian Sandstone aquifer in Libya have shown that large quantities of water are available for development for many decades to come. These studies also emphasized the need to determine the natural boundaries of the basin, its lateral extension and its hydraulic properties in neighboring countries. The basin should therefore be treated as one hydrogeological unit to enable the representation of its future behavior in accordance with the development schemes of the sharing countries.

The announcement of the creation of a Joint Commission for the coordination between Libya and Egypt in managing the shared groundwater aquifer was made in Tobruk during the summit meeting on 17 October 1989. The establishment protocol was signed during the third round of the Libyan-Egyptian Joint Committee meeting and members of the board of the joint commission were nominated. The internal code determined the objectives and functions of the commission as follows:

1. Collection of data, information and study results from concerned countries for classification, analysis and linkage.

2. Complementary studies to determine the present state of the aquifer from the qualitative and quantitative point of view.

3. Preparation of plans for the development of water resources and the proposal and implementation of joint policies for the exploitation and use of water resources at national and regional levels.

4. Management of the aquifer on sound scientific bases.

5. Cooperation in the field of training and capacity-building.

6. Call for rational use of the Nubian Sandstone aquifer water.

7. Study of environmental impacts of water development.

8. Organization of scientific workshops and dissemination of aquifer-related information and strengthening of ties with regional and international organizations of common interest.

Both Sudan and Chad joined the Commission at a later stage and became full members. The Commission has held six meetings, most of which were dedicated to the exchange of information and scientific data and follow up of the work progress in the Nubian Sandstone Aquifer System (NSAS) project.

The Nubian Sandstone Aquifer System Study Project

The Nubian Sandstone Aquifer System Study Project began in 1998 with the Center for Environment and Development in the Arab Region and Europe (CEDARE) as an executing agency. The project is financed in its first phase by the International Fund for Agricultural Development (IFAD) and with contributions from the concerned countries. It aims at reviewing previous studies, establishing a regional data base and preparing a mathematical model capable of representing the aquifer condition and simulating its future behaviour in response to planned development schemes. The model is also expected to study the effect of future withdrawals on water levels and the extension of drawdown cones in neighbouring countries. The project also aims at training national teams in the different activities of the study including the application of the mathematical model, data bases, GIS, and the use of advanced monitoring equipment. Member countries were supplied with field and office equipment, instruments and software needed for data collection and interpretation. National teams prepared national reports reflecting the state of the aquifer in each country at an early stage of the project and during the preparation of the mathematical model, several meetings of country representatives were held at the level of technicians and decision-makers. The meetings were dedicated for the validation of data, providing information needed for each stage of the model, approving model calibration, and determination of future development alternatives for the coming fifty years. This phase has been completed and a final report was produced. The present phase of the project covers socio-economic studies and is financed by the Islamic Development Bank (IDB).

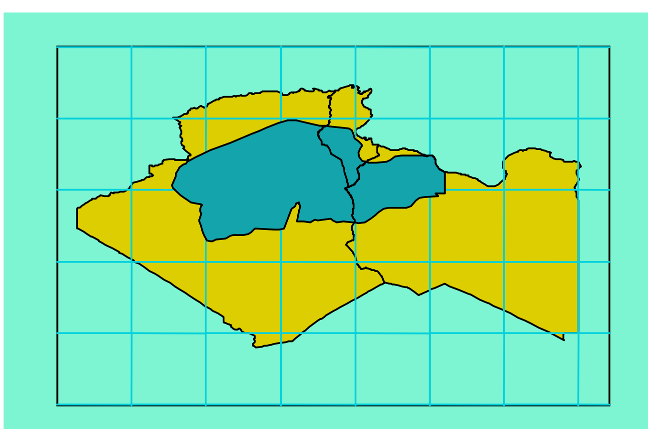
Future Horizons

The Nubian Sandstone aquifer countries have succeeded in establishing a strong base for cooperation, which enables them to manage the basin in a sound and efficient manner. They realize the need for dealing with the basin as one hydrogeological unit and securing the flow of information. Future cooperation in the field of data collection and storage will enable member states to easily exchanging information and updating the regional mathematical model and allowing its use as an effective management tool. It is of utmost importance to continue the periodical monitoring of water levels and water quality. Improving legislation that guarantees the protection of the shared resources from pollution and overexploitation should also be given special attention.

The North Sahara Basin

The North Sahara Basin extends over a surface area of over 1 million km^2, of which 700,000 km^2 are in Algeria, 60,000 km^2 in Tunisia and 250,000 km^2 in Libya and is therefore considered as one of the most important basins in the region. In Libya, it is known as the Hamada al Hamra Basin and is subdivided into two sub-basins: the Ghadames in the West and the Sawf al Jin in the East and terminates at the sabkha of Tawurgha along the Mediterranean coast (see Figure 4).

Figure 4. North Sahara Basin



The North Sahara Basin contains two main groundwater aquifers: the Upper Jurassic-Lower Cretaceous sandstone, known regionally as the Continental Intercalaire (CI) and locally as the Kikla aquifer and Upper Cretaceous limestone known regionally as the Complex Terminal (CT) and locally as Nalut and Mizda aquifers. In addition, a number of more recent aquifers belonging to the Miocene and Quaternary gain local importance in the northeastern parts of the basin despite their relatively limited lateral extension. Water of the Upper Cretaceous aquifer is characterized by high salinity, which limits its use in a great number of localities, leaving Kikla as the most economically important aquifer.

Several wells of more than 1,000 m in depth are drilled for water supply in different parts of the basin. The aquifer properties can be summarized as follows:

- Depth from 700 to 1200 m.b.g.l.
- Productivity from 50 to 200 m^3/hr.
- Salinity from 1000 to 1500 mg/l.
- Transmissivity from 400 to 1500 m^2/day.

Groundwater flow in the aquifer is from south to the north and north east in the direction of Tawurgha spring and from south to the north and northwest towards Shott Djerid in southern Tunisia**.** The aquifer is in contact with the Paleozoic aquifer in the Murzuq Basin in the south, which contributes partly to its recharge through lateral inflow.

The Kikla, as well as the Mizda and Nalut aquifers, receive direct but limited recharge through formation outcrops along the southern flanks of Jebel Nefusah, which is dissected by a dense network of wadies and falls under the 100 to 250 mm/yr isohyets. The Atlas Mountains in Algeria also contribute local recharge to the CT and CI.

The North Sahara Basin Study Project

The study of the basin started in July 1999 after an agreement with IFAD for financing the project was signed. Other donors also contributed to the finance of the project along with the three concerned countries. OSS was selected as an executing agency, and Tunis was chosen for hosting the project management team, which consists of representatives of the three countries, assisted by technical working teams in each country for data collection and transfer to the project headquarters.

The project, known as SASS (*Système Aquifère du Sahara Septentrional*) aims at defining the technical aspects of the basin and building of a data base and a GIS. Other objectives include the preparation of a model able to represent aquifer behavior under the proposed development schemes and act as a management tool for the basin to meet the common interests of the countries.

The first phase of the project is currently coming to an end. During this phase, several technical meetings were held at the level of water resources managers and technical teams. Several workshops and training courses on the different activities of the project were organized, in addition to the supply of equipment, software and vehicles that made data collection, interpretation and exchange possible.

The second phase of the project is financed mainly by the United Nations Food and Agriculture Organization (FAO) and partly by the concerned countries. This phase is concerned with the establishment of a consultation mechanism among the basin countries. It includes a review of current water resources legislation in each country and proposing necessary amendments for better management of the shared resource. It will also improve the administrative systems and initiate a framework to realize free flow of information to meet development objectives. Implementation of this phase has already started and it is expected to be completed by the end of this year.

Future Horizons

Cooperation between Libya, Tunisia and Algeria in the field of managing the shared aquifer system goes back to the 1970s. Periodical meetings of bilateral committees, and more recently in the framework of the Union of Maghreb Arab countries (UMA) are dedicated to the exchange of information on different water issues of common interest. A working group on water resources has been active since the creation of UMA and was recently promoted to a Ministerial Council for water.

Upon completion of the SASS project, it is recommended to establish a permanent institution similar to the Joint Commission for the Study and Development of the Nubian Sandstone Aquifer, in which the departments responsible for the management of water resources in the three countries are represented. The new institution will be entrusted with monitoring the state of the aquifer and collecting necessary data for updating the mathematical model and future scenarios in view of the newly adopted development plans.

The Need for Water Legislation

To meet the growing demand for water, development of all available resources including those of the non-renewable and shared basins becomes necessary. Basin development could be for local use when necessary, or for conveyance to remote areas of high demand and more suitable conditions. Prior to any development, it is necessary to conduct hydrogeological studies in order to determine the volume in storage and the rates of extraction and future impacts, especially with regard to the horizontal extension of drawdown curves and water quality changes. It is therefore necessary to systematically collect technical information and deal with the basin as a complete hydrogeological unit. As a result, coordination among neighbouring countries should take the form of a complementary approach, where determination of optimal extraction rates that satisfy the development policies of all countries, or amending such policies in view of the dominating hydrogeological conditions is implemented.

Planning for the development of water resources is of long-term nature and therefore requires solid legislation to regulate the use of shared water resources. Concerned countries must take necessary actions for the protection of water resources. Major issues that need to be given special attention in the new legislation dealing with shared groundwater resource management are:

- exchange of geological, hydrological and hydrogeological data and study results
- exchange of information concerning future development plans
- defining the allowed quantities for use by each country based on regional study results
- monitoring extraction and resulting drawdown
- setting rules for waste disposal control and prevention of industrial, chemical, and petrochemical pollutants.

Conclusion

Libya is witnessing a growing demand for water, which requires the adoption of remedial measures to secure continuous supply of this important resource. Such a supply could be met from the large groundwater basins in central and southern parts of the country, most of which are shared basins. In the last decades, Libya began a cooperation programme with neighbouring countries aiming at the adoption of a long-term strategy for managing shared water resources. This requires exchange of information related to the present and future extractions along with the results of water levels and water quality monitoring. These efforts lead to the launching of joint study projects and preparation of mathematical models, which reflect the present state of the aquifers and predict its future behaviour in accordance with the planned development schemes. In addition, establishment of a Joint Commission for the Study and Development of the Nubian Sandstone Aquifer was successfully accomplished and planning for the establishment of a similar body dealing with the North Sahara Basin is currently under consideration. These commissions will be responsible for the issue of legislation regulating the joint management of the shared basins and securing their protection from over-exploitation and pollution.

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Overview of Water Management in Iran

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Abstract

Due in part to recent Iranian socio-economic changes – notably structural transformations within the national economic system and in the demand-supply mechanisms for water – and in part to emerging signs of a regional and global water crisis, improvement of water resources management in Iran lies ahead as a clear-cut task. The present system, begun 70 years ago, is entering a new stage with widespread economic and environmental dimensions, and requires the adoption of coherent, farsighted, and comprehensive plans and actions.

This paper, originally prepared for the International Workshop on Policies and Strategic Options for Water Management in the Islamic Countries, sponsored by the Regional Centre on Urban Water Management (RCUWM-Tehran) and the Islamic Development Bank (IDB) (Dec. 15-16, 2003, Tehran), describes the needed elements and infrastructures for transition. First, the past and present situation of water resources management in Iran is presented, followed by an assessment of future changes, including long-term policies and a related action plan. Finally, a list of execution plans and some of their results with special stress on two important factors of 'conservation' and 'reuse' of water is presented.

Water resources management: then and now

Water management and socio-historical change

The present system of Iranian water resources management began 70 years ago and has evolved in relation to the specific historical and social conditions of the country. Some of the changes are outlined below.

Population growth, urbanization and related consequences

In the last century (since 1900) the country's population has increased about sixfold. The population growth rate, which was less than 0.6 per cent in the beginning of this period, soared in the 1976-1986 decade to reach the amazing rate of 3.19 per cent. Fortunately, it has considerably decreased once again in the past decade. Major population change (due to the reduction of mortality and the increase of natural growth rate) took place in and after the 1960s. In the last decade the immigration of Afghani refugees has had a major impact on population growth: between 1960 and 1996, about 37 million people (about 60 per cent of the existing population) were added to the country's population. In terms of urban versus rural populations, in the period between 1961 and 2000, about 31.7 million increased in the former and 11.0 million in the latter. While in 1956 only three cities existed in Iran with a population over 250,000, in 2000 seven cities had risen with a population over 1 million people.

The direct impact of population growth on the water resources management of the country increased the need for potable water in population centres. Indirect impacts included an increased demand for agricultural products, development of irrigation lands and the need for the creation of job opportunities and more income, especially in the agriculture sector. Rapid urbanization increased the domestic use of water especially for hygienic purposes and new needs for water emerged in light of city expansion and promotion of life standards. In such conditions, new responsibilities have been created for water resources management, notably an increased need to protect population centres against drought and flood, and an ever increasing importance of water treatment and the provision of hygienic water, as well as the collection and sound disposal of wastewater and drainage water.

Thus, more and better exploitation of water resources with respect to both the qualitative and quantitative limitations of these resources, and the need to economize and protect these water resources and the aquatic environment against water pollution, have gained in importance in Iran in light of population increase and urban development.

Political and administrative evolution

Since the 1960s, an increased centralization of Iran's political and administrative organizations, and the expansion of governmental and execution institutions (central government), has made possible better planning and budgeting of different sectors in the country. At the same time, following the 1979 Islamic Revolution, social and political changes have supported needed reforms through the parliament, encouraging public participation, privatization and liberalization of the economy. Such changes have included the water management system of the country and several projects on water resources development are in the works, or will be implemented in the future.

Fundamental economic changes

Existing information indicates that through the 1950s the national economic production increase was based on the provision of a minimum subsistence in the society. In the last years of the Third Development Plan of the country (1966), economic surplus for development planning of the country has been availed.

Such fundamental changes in the economic system of the country considerably brought in needed investment in the development of water resources (both by governmental and private sectors) and the system of water resources utilization encountered drastic changes.

Changes in the utilization system of water resources

Major changes in the water resources utilization system of the country began in the early 1960s when about 58 large reservoir dams were constructed and remain operational. The volume of their regulating water is more than 30 billion m^3 (bcm, 10^9). Substitution of deep and semi-deep wells instead of Qanats (subterranean canals) has led to the over-exploitation of groundwater: the volume of groundwater exploitation has increased by 2.7.

In total, in 1996, these changes have caused an increase in water exploitation (both from surface water resources and groundwater) from 40 bcm to 90 bcm (2.25 times), expanding the contribution of secure water (from 65 per cent to 82 per cent) on the one hand, and the exploitation of surplus water from watersheds and aquifers to about 5 bcm on the other.

The development of water resources and more distance between water supply centres and using points have exploded and complicated transmission systems and technology. In urban water supply systems, transmission pipelines, tunnels, pumping stations and physical treatment (with increase of the contribution of surface water in securing urban water) have become more important. There has been a general increase in the contribution of the governmental sector in the utilization system, along with implementation and operation of projects on water securing, water supply for cities, irrigation and drainage networks etc.

Changes in the water resources management system

Three trends in the water resources management system of the country can be seen: the commencement stage (1927-1963), a shaping stage (1963- 1979), and an evolving and transfer stage (1979 through today). Construction and/or technological activities within the system began in the 1960s.

Since the beginning of the First 5-Year Development Plan of the Islamic Republic of Iran, policies related to institutional reforms (privatization of more liabilities and mitigation of obstructive regulations and laws) have been on the agenda of the Cabinet and the Islamic Consultation Assembly (Parliament). With respect to these policies and the existing limitations for water-related services, the country's water management sector has put into force several actions and many others are under implementation, notably the establishment of independent urban water and wastewater companies committed to maintaining and operating irrigation and drainage networks to farmers and supporting them with financial provision facilities. A part of the investments pertaining to urban sewage and irrigation and drainage projects are based on the Constitution.

Baseline information

Potential water resources

From Precipitation

The country's water resources issue primarily from its annual precipitation. Studies carried out for the formulation of the Water Comprehensive Plan have yielded the following figures related to the main characteristics of annual precipitation and its processes of transformation into water resources as follows:

- Annual average precipitation 417 bcm
- Average annual evaporation & transpiration 299 bcm
- Surface currents 92 bcm
- Direct seepage to alluvial aquifers 25 bcm

According to the above figures:

- about 72 per cent of precipitation is not accessible due to evaporation and transpiration
- about 22 per cent of precipitation flows as surface water resources
- about 6 per cent of the precipitation that falls within the limits of the country is used for direct recharge of alluvial aquifers.

Consequently, about 117 bcm of water is directly and potentially accessible by people through precipitation (internal renewable resources) each year.

From precipitation and inflow currents through country borders

In addition to the water resources gained through the precipitation that fall within the limits of the country, about 13 bcm of surface flows enter into the country from across its borders. In total, the joining of these flows to the internal surface flows increases the country's surface water resources to about 105 bcm, of which about 13 per cent (13 bcm) is used for recharge of alluvial aquifers along their course.

Accordingly, annually about 130 bcm of water is accessible for people through precipitation and inflow currents through country borders (total renewable resources).

From natural processes and consumption

In addition to naturally processed water resources, about 29 bcm of exploited and consumed water from surface and groundwater resources reappears as exploitable surface water or penetrates to alluvial aquifers as reservoirs. Correspondingly, the country's total water resources, including water exchange processes, increases to about 159 bcm, of which 82 per cent (130 bcm) is renewable sources, and 18 per cent (29 bcm) is return waters that are discharged into surface and groundwater resources and are included in the calculation of total water resources. This aspect of water resources changes quantitatively and qualitatively along with annual changes in quantity and quality of consumption patterns.

Exploitation of potential water resources

In the year 2000, about 43 bcm of surface water resources including regulating flows are exploited by reservoir dams, pumping stations, small scale water supply projects and/or traditional stream systems.

Groundwater exploitation

Presently, the amount of groundwater is estimated at 47 bcm. In the year 2000, total exploitation of groundwater resources was 90 bcm, representing 70 per cent of renewable water resources and 57 per cent of total water resources (renewable, water exchange and return flow).

Sectoral consumption

Agriculture and aqua-culture

Agriculture uses the most amount of water, namely 83.5 bcm or 92.8 per cent of total exploitation, of which about 50 per cent is exploited from surface water resources and about 50 per cent from groundwater ones.

Industry and mining

Exploitation of water resources by this sector is about 1.1 bcm or 1.2 per cent of total exploitation. About 54 per cent of water use in this sector is from groundwater resources and the remaining amount is from surface water.

Urban and rural water supply

Withdrawal of water by this sector is about 5.4 bcm, which includes 6 per cent of total water exploitation of the country, of which about 68 per cent is from groundwater resources and from surface remaining water.

Water and Economic Activities

The importance of water and resources management services for relevant activities in this field is linked to economic structure and the trend of economic development. The existing economic structure of the country with respect to the importance of water is outlined below.

Water sector investments and cost price

Water resource managers and exploiters at different levels have benefited from high investments for improving and regulating related services. Governmental investments have been mostly nationwide and aimed at the control and distribution of surface water from the standpoints of consumption, energy generation and flood control. Private investments have been quite disorganized and in the form of local activities of groundwater exploitation or water pumping from adjacent rivers. Through today, total gross investment, based on the fixed prices of the year 2000, is estimated at 100,000 billion Rials (US$12.5 billion) of which about 40 per cent is private sector investment.

Gross capital investments represent about 1.2 per cent of GDP and 5.8 per cent of gross national investment. Final cost for water supply from reservoir dams based on fixed prices compared to 1960s is eightfold, and the cost of securing of water from wells has tripled.

Water in the national economy

The annual economic value of water and related services for provision and distribution of agricultural and urban use as well as energy generation based on 1996 prices is estimated at 9,700 billion Rials (US$1.2 billion). If the value of water supply in rural areas, usage by industry and mining, recreational use and aqua-culture activities is added to this figure, it increases by 10 per cent to 10,700 billion Rials (US$1.3 billion) per year, which represents 8 per cent of the GDP without including crude oil prices, and 6.7 per cent of the GDP including the oil sector.

Water and food security

Presently, the contribution of irrigation lands towards the production of cereals represents about 69 per cent and towards the production of other products (horticulture and orchards) represents about 90 to 100 per cent. Different forms of water resources exploitation contribute differently towards securing food supply. The condition of food security has improved to some extent in relation to the increase in the contribution of assured water resources in the total exploitation of water resources for agricultural purposes. However other factors, like productivity of water resources and irrigation standards, have not very much improved. Moreover, it remains necessary to strengthen drought management institutions and food security in drought periods of the country.

Structure of water management

Today, water resources management rests essentially in the hands of the Ministry of Energy, composed primarily a Deputy Minister for Water Affairs (Iran Water Resources Management Organization), regional water companies, a nationwide water and wastewater engineering company (nationwide), and provincial water and wastewater companies, especially in important cities (30 companies). In addition, about 124 consulting firms and 216 construction companies support the above sections.

In the framework of sectional planning, there is a reciprocal influence between an effective water resources management system and different social and economic sectors. Numerous ministries and organizations have had significant impacts on water management systems, notably the Ministries of Agriculture, Industry and Mining, Housing and Urban Development, Interior, Health, Roads and Transportation, and finally the Department of the Environment. The collaboration and coordination of the above ministries and organizations is assured by the recently established Supreme Council of Water, presided over by the President of the Republic. All related organizations and ministries, as well as parliament representatives, are members of this Council. It is worth mentioning that in the parliament different committees on water, agriculture, natural resources, budgeting and development supervise management activities all around Iran.

Possibilities and opportunities for water resources management

Existence of widespread natural possibilities

There exists vast areas of cultivable lands, big rivers, suitable sites for construction of dams in the Zagross and Alborz mountain ranges, extensive aquifers and suitable climatic conditions for the cultivation of different plants. In addition to the country's current exploitation of water resources, some capacities for physical development of water resources for consumption utilization of water up to 30 bcm and for energy production up to 50 bcm also exist, all the while observing economic, social and environmental limitations.

Cultural supports

These include the traditions and suitable social institutions that have been formed and have evolved historically in order to adapt to the varied geographical conditions, especially in arid and semi-arid regions. When sound, propagation activities can be carried out with more effectiveness.

Political facilities

These include a wide-ranged tendency for increased participation in public affairs, a strengthening of the parliamentary system, creation of NGOs, support of local management and a suitable political background for the development of the 'water and agriculture sector'.

Existing installations and equipment

These include large and small reservoir dams, extensive irrigation and drainage networks, water transmission pipelines and pumping stations, treatment plants and water reservoirs, urban water distribution network, etc.

Institutional capacities

These include possibilities for presenting consultative and construction services by experienced national experts, thereby reducing foreign exchange expenses to a considerable extent.

Suitable conditions for promoting economic value of water

Increased allocation of water for urban and industrial uses, expansion of the non-consumptive exploitation of water resources (hydroelectric generation and recreational use of water bodies) and the cultivation of profiting agricultural products have increased the economic value of water, entailing more capacity-building for sustainable and economic use of water resources. Limitations as well as increased competition will accelerate this process.

Suitable global and regional conditions

The policies for attaining sustainable development have entered a new stage in light of the many endeavours surrounding water resources management brought about by the attention of international organizations in the early 1990s. This attention was not confined to water resources and included natural resources, while it seems that water-based problems have their own complexity and severity. Learning from the previous obstacles inherent to implementing a sound action plan (since 1977 and International Conference on Water), new efforts have arisen to hold more sound international conferences and seminars in the near future. The past achievements of those countries with international water basins confronted with regional conflicts over water problems can considerably help to mitigate and solve the problems. Hence enhancement of international relations can create suitable opportunities for water resources management of the country, making the best use of existing knowledge of other countries in order to negotiate on common issues.

Low dependency on international water resources

One of the advantages of Iranian water resources management is its low dependency on international water resources. Only about 7 to 8 per cent of water resources are secured from international or common borders.

Challenges to water resources management

Water resources limitations

Renewable water resources of the country are estimated at about 130 bcm. Along with rapid population growth, its per capita has constantly decreased and will continue to do so in the future.

The distribution of Iranian water resources has not been consistent with population centres, especially in last two decades. Hence, there is a high need for spending more money for transfer of water in and between basins.

Changing agriculture sector

The transition stage from an agricultural economy has not yet been completed and renewal of the agricultural structure has not been fully undertaken. Land ownership and agricultural activities have not evolved properly and agricultural development is mainly done only through expansion of irrigating lands.

Needed infrastructures

In spite of previous efforts, it remains necessary to strengthen the following aspects:

- Policy formulation
- Laws, regulations, criteria and standards
- Organizational improvement (coordination, cooperation, different specialization and decision-making processes)
- Water allocation system
- Manpower planning and management
- Financial and economic management
- Information systems and data banks
- Technological research and development.

Risk reduction management and related issues

There is various evidence suggesting both natural and social reasons for the occurrence of destructive floods throughout the country. Hence, prevention and mitigation of adverse impacts and losses of destructive natural hazards are of utmost importance. Normally, cities are more vulnerable in this respect. Coordination between different responsible organizations plays a vital role in this regard.

Periodic occurrence of droughts is always possible at regional and national levels. This matter is of key importance with respect to domestic food production and its contribution in securing the fundamental needs of the population. Thus, forecasting and adopting appropriate measures with the participation of water management authorities and other organizations is very important from the point of view of national security.

Social and environmental issues of large-scale water resources development projects

Adverse impacts of water-related actions are aggravating the social problems related to the management of water resources developments. Distinction, measurement and solution-seeking are key to upgrading the validity and accuracy of decisions, as is observance of environmental criteria and standards vis-à-vis different activities of water resources management. The full scale of impacts of large-scale projects in water resources development as well as exploitation of groundwater resources must be paid due attention.

Essential improvements for the future

The current system of Iranian water resources management and exploitation was shaped with the events of the 1960s and produced conditions of increasing importance for national management of water in the macro planning of the country. This trend will undoubtedly continue in the future, with increased expansion, in three groups as follows:

- Group one includes those conditions and trends that in the past and present have determinant impacts on water resources management system and will continue in future, such as:

    - population growth and rapid urbanization and increase of per capita consumption of urban water that cause the increment of water utilization in population centres
    - growth of industry and rapid industrialization of the country that will give rise to increasing the contribution of industrial water consumption
    - increased importance of planning and future forecasting especially in long-term planning that will cause promotion of the role of water resources management in development plans.

- Group two includes those recent trends that will be accelerated in future, such as:

    - increase of the non-consumptive exploitation of water resources for energy generation, aqua-culture (cold water fishes) and recreational purposes
    - more sensitivity and awareness on the pollution of water resources and its economic and environmental consequences
    - more sensitivity and awareness on the environmentally adverse impacts of water resources development projects
    - increase of the cost for securing additional water
    - prevention of the irrational utilization of groundwater resources
    - increase of the relative contribution of small-scale projects with increased participation of local exploiters

- increase of the contribution of substitute management and renewal of installations
- reduction of urban and agricultural water loss especially in transmission and distribution phases
- collection and sound disposal of urban sewage.

- Group three relates to trends that have not yet been obvious or did not exist at all, such as:

    - increasing stress on the development of surface water resources compared with groundwater
    - collection and sound disposal of industrial wastewater
    - treatment and reuse of urban and industrial wastewater
    - participation of local residents and exploiters and stakeholders in financing large-scale water resources development projects
    - reduction of water loss on farms
    - increase in the importance of financial resources mobilization and costing for projects and implementation programmes
    - more participation of the national and regional management of water in foreign policies, national spatial strategy plans, national physical plans and regional planning, in parallel to the incremental importance of shared water basins and water exportation, the role of water in national security and food security and the necessity of adopting basic solutions in critical water basins.

It is anticipated that these trends and related changes will evolve in such a way that the national management of water resources will enter a new stage with wide socio-economic and environmental dimensions. The start of this stage will create new responsibilities for water managers who will need training. In this respect, major actions include the removal or mitigation of inadequate infrastructures and water management systems, and capacity-building in water management especially from demand management points of view.

A more detailed view of the main changes in trends, duties and new abilities in the field of water resources management is shown in Table 1, which includes some selected indexes relating to the base year (2000) and target year (2021).

Exploited water and available water

The annual capacity of available water for consumptive exploitation will increase from 96 bcm to 130 bcm (according to the suggested scenario). In total, about 34 bcm of new capacities will increase, about 92 per cent of the total capacity of available water will be exploited, and the volume of exploited water will increase by138 per cent compared to the base year.

Extra exploited water relates in part to existing unused capacities and in part to the use of new capacities. Unused capacities pertain to large reservoir dams. For the time being, about 8.5 bcm out of total capacity of 25.4 bcm is not exploited.

Action plan and activities

An action plan has been formulated in order to fulfil fundamental principles and help determine the main course of action from present to future conditions. This plan includes five general principles and thirty-seven adjustable strategies. In other words, an independent execution programme can be prepared for each strategy and the relations of total strategies can be obtained through determination of general objectives.

The main objective is efficient and equitable development and use of Iranian water resources in accordance with socio-economic and environmental needs of present and coming generations.

Table 1: Water Resources Management Vision in terms of statistics

Indicator	Unit	2000	2021 (selected scenario)	Ratio (%)
1. Volume of exploited water	**bcm**	**97**	**120**	**130**
2. Share in water resources				
- Groundwater	**%**	**52**	**42**	**8**
- Surface water	**%**	**48**	**55**	**114**
- Recycled (from domestic/Indus)	**%**	**…**	**3**	**-**
3. Share in consumption:				
- Agriculture and aqua-culture	**%**	**94**	**86**	**93**
- Urban & rural	**%**	**6**	**7**	**117**
- Industry & Mine	**%**	**1.2**	**3**	**250**
4. Water loss				
- Agriculture	**%**	**64**	**60**	**94**
- Urban	**%**	**27**	**10**	**37**
5. Volume of return flow	**bcm/yr**	**29**	**40**	**138**
6. Effluents & Wastewater	**bcm/yr**	**4.5**	**8**	**178**
- Urban		**3.7**	**5.5**	**149**
- Industrial		**0.8**	**2.5**	**312**
7. Investment				
- Total gross investment	**10^{12} Rls.**	**41**	**262**	**635**
- Contribution of private sector	**10^{12} Rls**	**40**	**32**	**80**
8. Importance in national economy (NE):				
- Contribution of water investment from GDP	**%**	**1.2**	**2.6**	**217**
- Contribution of water value and related services in NE	**%**	**7.5**	**9.8**	**131**
9. Contribution of capital return of expenses of governmental projects				
- Urban water	**%**	**22**	**50**	**231**
- Agriculture water	**%**	**6**	**23**	**400**
10. Economic revenue of water in different sectors (average)	**Rls./cm**	**1614**	**5018**	**311**
11. Economic revenue of water in farming sub-sector				
- Productivity of agriculture water	**Kg/ m^3**	**0.6**	**1.1**	**180**
12. Water and food security				
- Role of water in the production of cereals	**%**	**69**	**73**	**107**
- Role of water in the production of other yields	**%**	**90-100**	**90-100**	**…**

The general principles (policies) taken into consideration in the preparation of this programme and approved by the Expediency Council, are:

- the establishment of a comprehensive system of management in total water cycle based on principles of sustainable development and the 'national spatial strategy plan' in water basins of the country
- the improvement of productivity with due attention to the economic, security and political values of water in exploitation, supply, protection and consumption
- the increase in the rate of water exploitation and minimizing losses of water through every possible means
- the compilation of a comprehensive plan for observing proportions in the implementation of projects on dams, watershed management, aquifer management, irrigation networks, water quality, combat against drought and famine, flood prevention, recycling and utilization of unusual water resources, promotion of knowledge, know-how, technologies, and encouraging public roles in water exploitation
- the control of outflow water bodies and prioritizing utilization of joint water resources.

The suggested strategies and policies of the action plan are laid out in **Chart 1**.

Accomplished actions

In view of the fact that approval of long-term policies coincided with the commencement of the Third 5-Year Development Plan of the country, the first two years produced important endeavours, notably:

- The allocated budget for the water sector in the Third Plan has increased by 300 per cent (tripled) compared to the Second Plan
- Financial resources have diversified in the water sector to include making use of foreign investments
- Two Ministries of Agriculture and Jihad Sazandegi (Crusade for Construction) were merged to help upgrade agricultural and natural resources activities. This will play an important role in sectional coordination
- The Supreme Council of Water was established, presided over by the President of the Republic with membership of high level experts and authorities
- A fifty-four volume Comprehensive Water Plan for 2021 has been prepared
- A Comprehensive Water Plan of the country was prepared and put on the agenda of the Cabinet regarding present and future changes
- In order to strengthen regional cooperation, RCUWM-Tehran was established in 2001 in collaboration with UNESCO in order to undertake the following duties: the transfer of know-how and experiences, promotion of awareness and capacities in all aspects and dimensions of urban water management for attaining the aims of sustainable development and making use of the results of activities for relative welfare of human beings in the countries of region. Recently a contract has been concluded with UNESCO-IHE as well.
- For supporting research activities in water sector, the Water Research Institute has been established. The activities of this institute will be concentrated on the assessment of water resources of the country and enhancing the quality and quantity of related data and information
- Implementation of optimum consumption patterns in agriculture sector with provision of extensive programmes in national level was begun. It is anticipated that with implementation of this programme, major steps will be taken for management of demands in the agriculture sector and promotion of water value

- A new system of water allocation was compiled and put into force regarding existing demands
- Wastewater treatment and water reuse were paid due attention regarding quality management
- Some quantitative goals have been set out, notably: 1) with the construction of twelve new reservoir dams, about 3,700 bcm of regulated water was supplied to different sectors, 2) about 140,000 ha of irrigation and drainage network were constructed, and 3) with the implementation of small scale water projects more than 352 MCM was secured as a regional equilibrium factor in water resources development projects.

Chart 1 : Long Term Policies and Strategies for National Management of Water Resources

Policies	Strategies
Establishment of a comprehensive management system for the total water cycle based on sustainable development principles in water basins of the country	• **Establishment of an integrated management system for the water resources of the country and continued observance of elements of the water cycle**
	• **Strengthening the main institution of water resources management with special stress on establishment of comprehensive system for water allocation**
	• **Establishment of suitable multi-sectional coordination institutions in national and local levels as well as in water basins**
	• **Decentralization and development of water resources management abilities at different levels (capacity-building)**
	• **Integration of development, exploitation and protection of water resources plans with other national and regional plans**
	• **Promoting the role of water resources management of the country in planning systems and suitable reflection of goals, limitations, possibilities and strategies governing over the system of water resources management in the process of formulating national and regional plans**
	• **Promotion of financial management and capital mobilization in accordance with changes in water resources management**
Increased productivity and attention to the economic, political and security value of water in exploitation, supply, protection and consumption	• **Promotion of public awareness, improvement and transparency of tariffs and utilization of technical, economic and managerial instruments**
	• **Improvement of exploitation systems of water resources based on qualification of manpower and natural potentials as well as social and local institutions**
	• **Anticipation of necessary instruments for financial resources mobilization compatible with value added from development of water resources (appropriate contribution from GDP**
	• **Balancing efficiency and social equitability**
	• **Promotion of the role of water resources management in food security and national security with stress on relative advantages**
	• **Promotion of productivity capacity in the process of water management cycle and effective factors in economic value of water**
	• **Encouraging research, education, propagation and information systems**
Increasing the quantity of water exploitation with minimal water loss	• **Development of water resources under national plans, comprehensive plans of water basins and approved planned programmes**
	• **Preparation, compilation and execution of comprehensive research plans for reduction of water loss (including natural and unnatural water)**
	• **Preparation and compilation of needed research programmes**
	• **Promotion of skills, technical know-how for adaptation with**

	indigenous skills and optimizing prices • Creation of needed capacities for development and mobilizing non-governmental and foreign financial resources
Compilation of a comprehensive plan	• Creation of time coordination in preparation and execution of complementary water projects • Strengthening water quality management in water resources management systems • Strengthening multi-sectional coordination instruments for enforcement of water quality management policies • Enforcement of organizational changes for internal and external decentralization with stress on public participation • Making the best use of administrative, financial and educational instruments for encouraging public participation • Preparation and implementation of water resources management comprehensive programmes for flood and watershed management in water basins level • Preparation and compilation of necessary programmes for combating against drought and crises management • Preparation of master plans and implementation of projects on water recycling and utilization of extraordinary waters • Creation of suitable changes for management of water resources in promotion of knowledge, know-how and information sharing • Support and enforcement of upper-hand industrial plans needed by water resources management • Preparation and compilation of engineering master plans for rivers and river banks • Encouraging collection and processing systems for dissemination of baseline information by all possible means
Control of water flow from shared water resources	• Paying due attention to controlling border waters in comprehensive plans and prioritizing them, adopting independent execution programmes with securing financial needs and other possibilities • Encouraging regional cooperation and exchange of information • Establishment of needed structures for coordination in policy and decision-making in this respect • Prioritizing the establishment of data collection and processing systems for qualitative and quantitative information