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**ECONOMIC AND SOCIAL COMMISSION
FOR WESTERN ASIA**

**TRANSBOUNDARY WATER RESOURCES
IN THE ESCWA REGION
UTILIZATION, MANAGEMENT AND
COOPERATION**



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ECONOMIC AND SOCIAL COMMISSION FOR WESTERN ASIA

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ABBREVIATIONS

1. Units of measure and technical terms

AHP	Analytical hierarchy process
BCM	Billion cubic metres
Feddan	0.405 hectare
GIS	Geographical Information Systems
Gwh	Gigawatt hour
GDP	Gross domestic product
GW	Groundwater
ha	Hectare (2.469 acres)
km ²	Square kilometres
km ³	Cubic kilometres
kW	Kilowatt
kWh	Kilowatt hour
l/c/d	Litres per capita per day
l/sec	Litres per second
MW	Megawatt
m	Metres
m.a.s.l.	Metres above sea level
m/d	Metres per day
m ³ /sec	Cubic metres per second
mm	Millimetres
mm/a	Millimetres per annum
MCM	Million cubic metres
MCM/a	Million cubic metres per annum
mgd	Million gallons per day
MSF	Multi-stage-flash
ppm (mg/l)	Parts per million (milligrams per litre)
Q	Rate of discharge
RO	Reverse osmosis
SW	Surface water
TDS	Total dissolved solids

2. Organizations and institutions

ESCWA	Economic and Social Commission for Western Asia
FAO	Food and Agriculture Organization
GAP	Greater Anatolia Project (also known as Southeast Anatolia Project)
GCC	Gulf Cooperation Council
ILA	International Law Association
ILC	International Law Commission
JVA	Jordan Valley Authority
NOAA	National Oceanographic and Atmospheric Administration
NWC	National Water Carrier

ABBREVIATIONS (*continued*)

UNWC	United Nations Water Conference
WAJ	Water Authority of Jordan
WHO	World Health Organization
WMO	World Meteorological Organization

Introduction

As a technical publication, this document is intended to address the main issues related to regional water resources, both surface and groundwater. It contains technical information and relevant data based on the country papers presented at expert group meetings and symposia organized by the Economic and Social Commission for Western Asia (ESCWA) and other organizations active in the water sector in the region. These gatherings include the Ad Hoc Expert Group Meeting on Water Security, held in Damascus in 1989; the Regional Symposium on Water Use and Conservation that met in Amman in 1993; the Expert Group Meeting on the Implications of Agenda 21 for Integrated Water Management, held in Amman in 1995; and the Expert Group Meeting on Water Legislation, held in Amman in 1996. In addition, the information for this study was gathered from a number of recent regional and international publications on the subject.

This document is presented as an output for activity No. 3.a (v) entitled, "Coordination of national efforts for optimal utilization of shared water resources in the ESCWA region", under the 1996-1997 work programme of ESCWA.

The document attempts to relate the management of transboundary water resources (surface and groundwater) as well as the impact of their utilization and water availability constraints to overall economic development and social structure in the ESCWA region, particularly those in regard to scarcity, maldistribution and sharing. The document outlines the nature and extent of transboundary water courses and regional ground water reservoirs, and reviews related controversies. It highlights the prevailing situation for water resources, the trends in water resource development and management and the general features of water strategies of member States that share water resources. It proposes a conceptual framework for regional cooperation and possible resolution of transboundary water resource conflicts.

Chapters I and II introduce the current water resource situation and outline the need for planning and management of water resources. These chapters also suggest a methodology for water sector planning and provide an overview of the trends in water resource development and management in the ESCWA region. Chapters III and IV describe the major river basins, the Nile, Euphrates-Tigris, Jordan-Yarmouk and Orontes, and the major aquifer systems that occur in the region. This part reviews the main practices in the utilization of these water resources and the status of agreements, if any, to control utilization of regional water resources (surface and groundwater).

Chapter V presents the main features of the proposed water strategies in countries sharing water resources. Shared water resources exist in Egypt, which depends on the water of the Nile River; Jordan, where the peace treaty will affect water strategy for the Jordan and Yarmouk rivers; Iraq and the Syrian Arab Republic, whose water in large part comes from the Euphrates and Tigris rivers; and the shared aquifer systems of Gulf Cooperation Council countries, which must also rely on the development of non-conventional water resources.

In chapter VI a conceptual framework for the management of shared water resources, both surface and groundwater, is introduced. Technical input was provided by a consultant, who proposes a model linking the principles of international law and hydrological/hydrogeological considerations. This model, the Analytical Hierarchy Process, or AHP, establishes priorities in the decision-making process.

The document concludes with a summary of the prevailing status of transboundary waters in the region and includes recommendations for some measures that can be taken to facilitate regional cooperation and conflict resolution regarding such water resources.

I. THE CURRENT SITUATION FOR WATER RESOURCES IN THE ESCWA REGION

The Economic and Social Commission for Western Asia (ESCWA) is made up of thirteen member countries: Bahrain, Egypt, Iraq, Jordan, Kuwait, Lebanon, Oman, Palestine, Qatar, Saudi Arabia, the Syrian Arab Republic, the United Arab Emirates and Yemen (figure I).

The region covered by the ESCWA member countries is about 4.75 million square kilometers, and 97.7 per cent of this area is desert. Water is a valuable resource and its development and management require considerable investment. Climatic conditions, availability of water resources, socio-economic conditions, national borders, conflicts of interest and politics play an important role in hindering development in many countries of the ESCWA region. Water resource issues are probably more significant in this region than in any other part of the world. When present and projected water requirements for all purposes are compared with the available surface and groundwater resources, serious questions arise concerning the long-term economic and environmental sustainability of existing water resource development and water use patterns. Under existing patterns of water use, it is unlikely that the expansion of irrigated agriculture can proceed without water shortage problems. In addition, increasing water scarcity in the region is likely to impose significant constraints upon meeting growing domestic and industrial demand. Some of the member States of ESCWA are meeting demand by securing water supplies through desalination of sea and brackish groundwater, as well as reclaimed waste water.

In the Arabian peninsula subregion, surface-water resources are limited and rely on irregular, sporadic and unpredictable flood occurrences. Groundwater and non-conventional water resources (desalinated water and treated sewage effluent) are the major components of the water supply in the subregion. The main producing aquifers are composed of Palaeozoic sands; Mesozoic sands and carbonate rocks; and Tertiary carbonate rocks and Quaternary alluvium. Groundwater quality generally deteriorates as one moves from the mountain ranges towards the inland basins or the sea coasts.

The limited water resources of the subregion have not been able to meet increased water demand. This situation has led the authorities concerned, particularly in the Gulf States, to undertake the desalination of sea and brackish ground water in order to produce enough water to meet their demand.

In the northern and north-east subregion which encompasses Egypt, Iraq, Jordan, Lebanon and the Syrian Arab Republic, surface-water resources predominate, although groundwater resources do occur and are well developed in some member countries. Surface-water resources in the subregion are appreciable and are represented by the following main rivers: Nile, Euphrates, Tigris and tributaries, Yarmouk, Orontes, Barada, Litani, Hasbani and Jordan. Efforts to regulate floodwaters and develop surface-water resources have been remarkable in the subregion, as represented by Al-Tabaka Dam in the Syrian Arab Republic, Qaroun Lake in Lebanon, and other projects in Egypt, Iraq and Jordan. Groundwater resources occur in Palaeozoic sandstones, Jurassic-Cretaceous-Palaeogenic carbonate rock aquifers, Tertiary volcanic rocks and Quaternary alluvia. The quality ranges from excellent to brackish.

It is possible to classify the ESCWA member countries into three groups. The Group I countries (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates) are situated in arid zones and lack sufficient natural water resources and fertile soil; in addition, they suffer from adverse climatic conditions. They have to desalinate sea water to obtain most of their fresh water needs and to reuse sewage

effluents to meet the needs of their high rate of population growth and rapid development. All group I countries share the western coastline of the Gulf. Group I countries with long coastlines include Oman (the Arabian Sea); Saudi Arabia (the Gulf and the Red Sea); and the United Arab Emirates (the Gulf).

Group II countries are situated in relatively arid zones and include Jordan, Palestine and Yemen. These countries have a better natural water potential than those in group I, but they all face imminent water shortages.

Group III countries are situated in semi-arid zones and include Egypt, Iraq, Lebanon and the Syrian Arab Republic. The most important water resource problem of this group is that a substantial percentage of their surface water is shared among themselves and with neighbouring countries. The water resources of group III are adequate only for the coming decade and only if these countries conserve, develop and manage these resources properly. However, studies have indicated that the countries in this part of the world are now, or are expected to be by the year 2000, at a point where the total demand for water will be about equal to or exceed the estimated available resources. In some ESCWA member countries, water shortages are already a reality. Others have almost fully developed their fresh (renewable) water resources. Depletion of non-renewable water resources as a result of over-pumping from exploited aquifers is also a serious and common phenomenon. Consequently, degradation of water quality caused by increasing salinity is common in a number of countries in the ESCWA region.

It is recognized that the largest user of water in the ESCWA region is agriculture, and many of the member countries follow subsidy and incentive policies in this sector. It has now been proven that such policies hamper agricultural development in the long run. Subsidies and incentives encourage increased water application rates and subsequently deplete aquifers, diminish stream flows, and cause waterlogging and soil salinity. In addition, rapid urbanization and improvement of the quality of life in terms of health, sanitation and social services, have resulted in a sharp increase in water demand for municipal purposes. When combined with industrial and agricultural uses, high demand for water has caused an imbalance between water availability and water required for socio-economic development.

Major surface and groundwater resources in the region are shared between countries lying both within and beyond the region. The most significant river basins are those of the Jordan, Nile and Euphrates/Tigris, all of which are subject to continuous riparian issues. A significant agreement exists only in the case of the Nile, and then only between two countries (Egypt and the Sudan). Large aquifers are shared by countries in the Arabian Peninsula, Iraq, Jordan, and the Syrian Arab Republic, yet agreements on abstraction do not exist.

Lack of appropriate cooperation and coordination for shared water resources at regional and interregional levels is a source of concern. This issue is highly affected by the prevailing political situation in the region, as well as within adjacent regions. Mutual cooperation and coordination in managing the shared surface and groundwater basins would help to achieve sustainable development within the region. Taking into consideration a variety of issues related to the socio-economic factors prevailing in the countries of the region, coordinating management of water resources would ensure their rational development, utilization and conservation.

An estimate of available water resources, based on hydrological and hydrogeological investigations carried out in the ESCWA region, may be summarized as follows:

	1990	2000
A Available	154 BCM	166 BCM
D Demand	143 BCM	179 BCM
B Balance	11 BCM	- 13 BCM

Table 1 provides an idea of the close relationship that exists between availability of water resources and present and future water demand. Many member States in the ESCWA region will reach their development limits by the year 2000, owing to the expected acute water shortages which are even now a reality in many member countries. In some cases, if present regional water-use practices continue, the estimated demand for agricultural water will not be met at all, preventing some countries from achieving food self-sufficiency.

The available surface-water resource figures shown in table 1 for both the Syrian Arab Republic and Iraq, and to a certain extent for Egypt and Jordan, may change in the future, owing to water-resource development activities which are underway in the neighbouring upstream countries that share the same water sources, as well as to the absence of registered riparian rights.

For each country, the volume of available groundwater resources shown in table 1 is based mostly on reconnaissance surveys. Groundwater over-exploitation resulting from excessive and uncontrolled pumping, as well as deterioration in water quality, are common features observed in many regional basins such as those in Jordan, Saudi Arabia, the Syrian Arab Republic and Yemen. Groundwater quality is deteriorating because of sea water intrusion into the aquifers underlying the coastal plains in Bahrain, Oman, Qatar, the United Arab Emirates and Yemen. All these factors have resulted in a progressive reduction in available groundwater resources in the ESCWA region, to the extent that sustainable agricultural development may be hindered in the future. Expensive non-conventional water resources are being produced in desalination plants to meet the increasing water demands in the region, particularly in the Gulf Cooperation Council (GCC) member States. Surface-water resources are increasingly vulnerable to pollution from different sources.

Great efforts are being exerted in the ESCWA region to develop additional water resources. In all large river basins, major storage reservoirs have been built or are under construction (the Euphrates, the Nile and the Tigris); in other parts of the region (Jordan, Saudi Arabia and the Syrian Arab Republic), a number of smaller dams are at different stages of planning or execution. In addition to the large river basins shared by several countries, which form the main water resources for these countries, there are 37 groundwater basins considered to be shared basins.

Figure I. ESCWA member countries

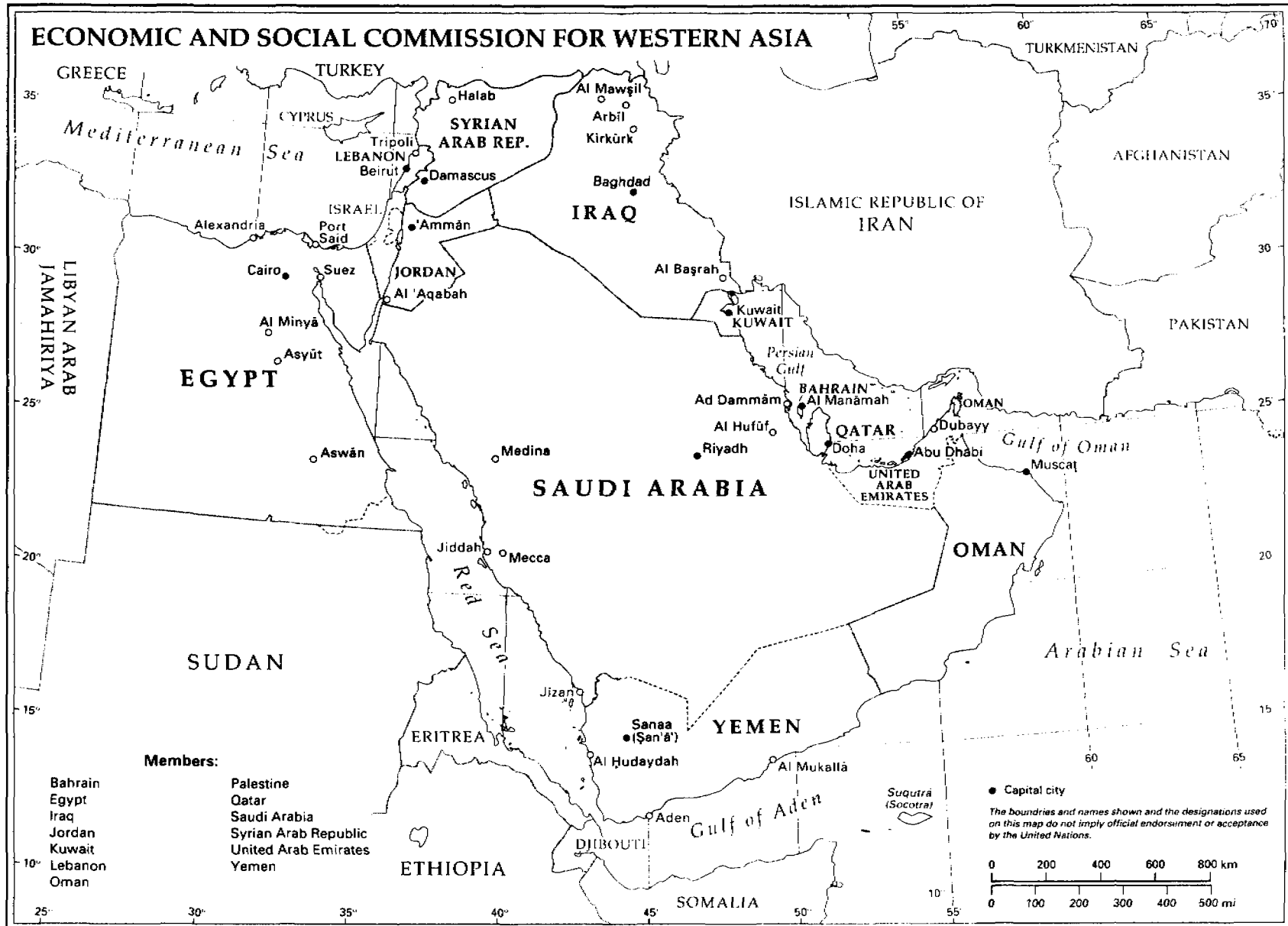


TABLE 1. ESTIMATED SUPPLY, DEMAND AND BALANCES FOR WATER RESOURCES IN THE ESCWA REGION
(Millions of cubic metres)

Country	1	2	3	4 (1-2)	5	6	7 (1+5)	8 (1+6)	9 (7-2)	10 (8-3)
	Estimated				Non-conventional water		Total available water resources		Estimated balance	
	Available water resources	Water use (1990)	Water demand (2000)	Water balance (1990)	1990	2000	1990	2000	1990	2000
Bahrain	100.20	308.00	400.00	-207.80	71.00	186.00	171.20	286.20	-136.80	-113.80
Egypt	56150.00	60100.00	70609.00	-3950.00	7000.00	7500.00	63150.00	63650.00	3050.00	-6959.00
Iraq	62480.00	49420.00	53830.00	13060.00		7.40	62480.00	62487.40	13060.00	8657.40
Jordan	935.00	917.00	1548.00	18.00	37.00	87.00	972.00	1022.00	55.00	-526.00
Kuwait	160.10	329.00	675.00	-168.90	356.00	547.00	516.10	707.10	187.10	32.10
Lebanon	2800.00	1002.00	2300.00	1798.00		3.70	2800.00	2803.70	1798.00	503.70
Oman	1468.00	1231.00	1525.00	237.00	66.00	86.00	1534.00	1554.00	303.00	29.00
Palestine	215.00		520.00				215.00	215.00	215.00	-305.00
Qatar	51.40	196.00	286.00	-144.60	198.00	274.00	249.40	325.40	53.40	39.40
Saudi Arabia	6080.00	16300.00	14627.00	-10220.00	1160.00	1534.00	7240.00	7614.00	-9060.00	-7013.00
Syrian Arab Republic	19775.00	9000.00	26152.00	10775.00	177.00	1273.00	19952.00	21048.00	10952.00	-5104.00
United Arab Emirates	310.00	1490.00	2170.00	-1180.00	402.00	513.00	712.00	823.00	-778.00	-1347.00
Yemen	3525.00	2899.00	3971.00	626.00	9.00	12.00	3534.00	3537.00	635.00	-434.00
Total	154049.70	143192.00	178613.00	10857.70	9476.00	12023.10	163525.70	166072.80	20333.70	-12540.20

Sources: United Nations, Economic and Social Commission for Western Asia, "Progress Achieved in the Implementation of the Mar del Plata Action Plan in the ESCWA Region" (E/ESCWA/ENR/1992/5), updated; national papers submitted to the Fifth Meeting of the Permanent Arab Committee on the International Hydrological Programme (IHP), Cairo, 9-11 November, 1992; country reports presented at the Expert Group Meeting on the Implications of Agenda 21 for Integrated Water Management in the ESCWA Region, Amman, 2-5 October, 1995; and direct consultation with Government authorities during missions undertaken to ESCWA member States.

Notes: Brackish groundwater predominates in the Arabian Peninsula. The flows of the Tigris and Euphrates rivers will be reduced by upstream abstraction in Turkey. Some figures on water resources and water demand are not confirmed, but are based on reconnaissance surveys.

II. WATER RESOURCES: THE NEED FOR PLANNING AND POLICY REFORM

A. BACKGROUND

The adequacy of water resources is a critical issue in the ESCWA region owing to the need to meet water demands imposed by a vastly expanding population and development activities. Natural water scarcity, increasing water demand in various sectors and degradation of water quality are among the conditions that contribute to water supply limitations. The magnitude of renewable water sources remains the same, therefore, the imbalance between supply and demand is being bridged mainly through the mining of non-renewable and non-conventional sources. The water situation is further complicated by the fact that substantial volumes of available surface and groundwater are being withdrawn from rivers and aquifers, some of which are shared among countries within and outside the ESCWA region.

Future solutions involve efficient management of water resources, within national boundaries and throughout the region, through improvement of the state of knowledge of water resources, reliability in the assessment and prediction of water requirements, the strengthening of both institutional arrangements and capacity building and the enhancement of regional cooperation in the water sector. Some aspects of the problem can be addressed through the formulation of policies and strategies as components of long-term water plans, and the enactment of regulations and legislative procedures to enforce efficient management of water resources. In order to achieve a balance between water availability and the growing amount of water required for socio-economic development, rational management and conservation of water resources are needed. It is against this background that most of the ESCWA countries have taken the initiative to improve the state of knowledge of their regional water resources, and have augmented water supplies through desalination and reuse of renovated water in order to meet rising requirements. Demand management measures are being carried out as a viable option to reducing requirements.

Many member countries have recognized the need for concurrent development, conservation and management of their vital water resources. Water assessment and planning help to determine the most appropriate allocation of resources to various water users. These measures also help to formulate medium- and long-term policies and guidelines for the exploitation, utilization and subsequent management of water resources, which were the objectives and targets considered during the last decade in many member countries of the ESCWA region.

Recently, significant efforts have been made by many of the ESCWA member countries to formulate, implement and update their water plans. However, planning goals and objectives are still oriented towards providing safe and adequate water supplies for domestic purposes, as well as irrigation, in order to promote self-sufficiency in food production. Future development calls for a fundamental change in the water planning process to establish long-term, flexible plans that focus on an integrated approach towards development and management of water resources, in order to promote optimum utilization. Integrated development and management of water sources call for increasing efforts in supply management through augmentation of natural sources. These non-conventional sources have already become major supply components, especially in the countries of the southern ESCWA region. Supply augmentation provides a viable alternative to bridging the gap between supply and demand. However, additional efforts are needed to reduce the cost of production, treatment and assessment of environmental consequences.

The management of water resources also requires improvement in institutional arrangements in water and water-related sectors. Some of the countries in the region have taken steps to centralize their national

institutions and establish central water bodies responsible for planning, environmental preservation and water conservation. These efforts, however, are still far from the establishment of effective institutional arrangements that mandate optimal development and utilization of water resources. In addition, past water legislation governing the development, utilization and protection of water resources requires further updating or modification to accommodate the requirements of integrated water resource development and management.

Significant efforts have been made by some countries to inventory, administer and manage their available and potential water resources. However, despite all the work carried out so far, the countries are far from achieving integrated management of their total water resources. Some countries of the region have taken steps to centralize institutional arrangements for national water resources, while in other member States, various independent water-related institutions still exist. Most of the ESCWA member countries now have specialized ministries or departments for the environment. The functions of these ministries include exerting a positive influence on water institutions in order to achieve environmentally sound sustainable development.

Water legislation in the region is generally complex and outdated *vis-à-vis* modern water management practices and techniques, and has resulted in the fragmentation of administrative responsibilities. Provisions which regulate water resource development and management are often contained in different laws and regulations, or originate with traditional and customary uses which form an integral part of the prevailing social structure of some member countries. With growing scarcity, coherent legislation will become increasingly necessary to avoid paying the high cost of ad hoc approaches to water allocation and control. Administrative weaknesses will inevitably constrain the effectiveness of legislation. Even so, enforcement of rights and standards will remain critical to resource management, and the need to strengthen administrative efficiency cannot be avoided.

Human resource development in the water sector, through continuous training, education and research and development, must be given due attention, focused on the management of water sources, from the local to the decision-making level. Capacity-building should be geared towards all levels, as well as the application of modern techniques for proper supply and demand management.

The significant efforts of countries within the ESCWA region have resulted in good progress in the assessment and development of water resources, despite limited financial resources. However, with the increasing demand for water, further efforts are still needed to focus on integrated water resource development and management schemes, comprehensive long-term planning, and the strengthening of both capacity-building and institutional arrangements.

B. METHODOLOGY FOR WATER SECTOR PLANNING

The methodology for water sector planning presented here takes into consideration the existing physiographic, geologic, hydrologic and hydrogeologic conditions as well as the prevailing socio-economic conditions in the region.

A substantive knowledge of all aspects pertaining to the water sector at the national level is a prerequisite for water planning. Once basic information is developed within a systematic framework, comprehensive planning is possible. Such knowledge can be achieved by acquiring basic data that has already been compiled on water, land and manpower resources, as well as by collecting new data after establishing a minimal monitoring network throughout the country. This will furnish an initial database and thus permit substantive resource assessment. Water sector planning at the national level is only possible if the following questions can be answered:

- (a) How much water is available in the short, medium and long term?
- (b) What is the present use and what will be the future demand in the same ranges?
- (c) To what extent will the available and potential water resources satisfy the demand for all sectors?

Based on this supply and demand approach to planning, certain measures to cope with the prevailing situation can be proposed:

- (a) Exploration of new sources to be exploited;
- (b) Reallocation of resources among various users;
- (c) Control of per capita and/or irrigation consumption rates and water demand in general;
- (d) Performance of feasibility studies on the basis of these findings to ascertain possible alternative strategies;
- (e) Establishment of water policies.

The first two activities above have some social and political implications which have to be carefully dealt with in developing a master plan for the water sector. The third embodies financial and institutional arrangements.

The planning process should be as comprehensive as possible in order to achieve:

- (a) A comprehensive water database;
- (b) A sound monitoring system;
- (c) An assessment of the available resources (water, land and manpower);
- (d) Projections for water use or demand;
- (e) A plan formulated according to the above assessment and projections;
- (f) Institutional arrangements to follow up on implementation of the plan.

Formulation of a reliable plan is totally dependent on the availability of water sector data, their adequacy, and their reliability. Therefore, the work plan will focus on data acquisition. Sound cooperation between public and private institutions active in the water sector at the national level is required during the planning process. In addition, it must be kept in mind that water planning should not be rigid, so as to permit modifications and revisions in line with the availability of more data and/or the overall changes in socio-economic conditions at the national level. This means that the final product of the work is a National Water Master Plan based on available water sector data and socio-economic conditions prevailing during the formulation of the master plan.

In order to develop a water sector plan that is consistent with the overall national development plan, the following activities should be undertaken:

- (a) Review of goals and objectives for national development;
- (b) Development of sectoral objectives and determination of preliminary growth targets for national development goals and objectives;

- (c) Performance of a sectoral review, collection of relevant data, and revision of growth targets;
- (d) Determination of a time-line for planning and projections for future development of the sector;
- (e) Description and analysis of alternative strategies for achieving planned targets for the sector;
- (f) Formulation and analysis of programmes to be carried out in order to achieve the sector's growth targets and objectives;
- (g) Assessment of the financial requirements for implementation of the projects and programmes, including preparation of a yearly financial plan for the given period as well as determination of possible sources of financing.

Although the above sequence of activities provides a logical framework for preparation of the sector plan, it does not preclude the possibility of deviation from the suggested sequence. The sequence only suggests that the information generated by one component can serve as an input to organize the work for the next component. In reality, the planning process can proceed simultaneously on more than one component because the suggested components are interrelated.

Below is a brief elaboration of each of the above required activities.

1. *National development goals*

The term "planning" generally refers to the process of allocating scarce resources in a manner that will maximize the achievement of selected objectives. Goals and objectives for development are most frequently defined in terms of high economic growth, better income distribution, less inflation, and a high level of employment.

2. *Sectoral objectives and growth targets*

In order to accomplish the national development goals, the economy is divided into various economic sectors, and objectives and growth targets are set for each sector. There is a distinction between an objective and a target; the latter may be defined as the quantitative transformation of the former. Sectoral growth targets are generally rationalized on the basis of interrelationships, the relative importance of a particular sector, and the potential availability of physical and financial resources.

3. *Diagnostic surveys and sectoral review*

The diagnostic surveys and sectoral review studies to be carried out in support of water sector planning should proceed as follows:

- (a) Data acquisition, analysis and review of the available literature;
- (b) Assessment of conventional (surface water and groundwater) and non-conventional water resources in terms of availability and reliability in quantity and quality;
- (c) Identification of water-consuming sectors, water requirements and projection of water demand;

- (d) Determination of the water supply/demand gap at the national level;
- (e) Provision of water development projects to bridge the gaps, considering the on-going and planned water projects and the scheduling of their financing;
- (f) Performance of cost-benefit analysis and feasibility studies considering the prevailing socio-economic conditions;
- (g) Survey of water losses and/or water use efficiency in various water-consuming sectors and provision for possible water conservation measures, including water legislation;
- (h) Identification of the environmental impact of water management practices;
- (i) Creation of capacity-building infrastructure, including institutional arrangements for water resource management, administration and execution of the master plan.

4. Time-line for planning and future projections

The planning exercise can be carried out for the planning horizon, which could be either short-term (annual plan), medium-term (five-year plan), or long-term (10 years or longer). In most of the ESCWA member countries, planning for the medium-term is a common planning horizon. Medium-term plans can be reviewed periodically and adjusted to reflect changes in overall economic conditions over time.

5. Alternative strategies

In order to achieve an objective, or a target, or both, a development strategy is needed. The development strategy may be defined as a framework that consists of different policies, programmes, projects, and measures which help to attain a particular objective.

The selection of a strategy is mainly guided by the nature of the objective; therefore, before adopting a particular strategy, its usefulness must be examined and compared with other possible strategies within the context of the time available.

6. Programmes for water resource development projects and policy formulation

The next step is to prepare a detailed programme of policies and projects which is consistent with the overall development strategy. In the whole planning process, policy-making is a relatively complex and difficult task. Policy reforms introduced in one sector can easily influence the performance of other sectors. Therefore, before a policy is implemented, it is important to analyze its possible economic effects on other sectors of the economy. A proposed project can be viewed as another variant of the policy. Sometimes projects are conceived and prepared in support of the policies formulated to achieve sector objectives. In this case, the project can be viewed as a measure taken to implement a policy.

7. Financial assessments

The financial resources required to implement the plan during the allotted time have to be assessed. Financial requirements should be projected over the planning period to identify the amount needed to implement plan activities and development projects in each year. It is also necessary to facilitate annual

updating of the sectoral budget, if needed, and to make intersectoral comparisons in terms of funds needed and development projects to be implemented. Generally, in the ESCWA region financial resources are scarce; hence it is important to identify the possible sources of funding for each activity defined in the plan. In addition, financial requirements should be examined against the background of the national budget, within the context of socio-economic development goals and priorities.

C. TRENDS IN THE DEVELOPMENT AND MANAGEMENT OF WATER RESOURCES IN THE ESCWA REGION

In reviewing the available literature pertaining to water resource development plans and conservation in the ESCWA region, it can be observed that the design of these plans varies from one country to another. The plans rely on many factors related to the prevailing hydrologic and hydrogeologic set-ups, overall socio-economic conditions, the objectives and goals identified, and the planning time-line. It can be concluded that surface-water impoundment for both water storage and/or flood control is the most common practice in the water planning process, in addition to the continuous conventional exploitation of surface and groundwater resources.

During the last two decades, appreciable efforts have been made to develop surface-water resources at the national level in Iraq, Jordan, Saudi Arabia and the Syrian Arab Republic. A number of surface-water reservoirs have already been built in these member States, and plans for new projects are being carried out.

The total storage capacity of the existing and future reservoirs in Iraq (when completed) is estimated to be 95,000 MCM/a. About 15 reservoirs have been constructed in Jordan; the total capacity of these dams is about 126 MCM. A number of dam sites with a potential total storage capacity of about 387 MCM have been identified in different localities in the country; studies and construction of some of these structures are underway. In the Syrian Arab Republic, about 125 dams were recently constructed, including the major Euphrates dam with a storage capacity of 14.1 BCM. Currently, construction work is being carried out at 23 sites in the Yarmouk, Orontes, Al-Badiya, Euphrates and Al-Khabour basins (25),(34). About 300 small and large dams have been constructed so far in Saudi Arabia, with an estimated total storage capacity of 750 MCM. These dams are mainly for making use of flood waters for irrigation, livestock and/or artificial groundwater recharge. 52 dams have been or are being constructed in Oman, the United Arab Emirates and Yemen for the same purposes (29).

Development of groundwater resources has been a remarkable trend in water sector planning in most of the ESCWA region. It consists of water stored in both shallow and deep aquifers. Carbonate aquifers are predominant in Jordan, Lebanon and the Syrian Arab Republic, while sandstone is prominent in northern Egypt and southern Iraq. Shallow quaternary *wadi* deposits located in the coastal plains and inland basins, as well as the alluvia of river flood plains, contain groundwater of good quality that is frequently recharged by perennial river flow. Egypt's Nile delta and the shallow aquifers in Iraq, Jordan, Lebanon and the Syrian Arab Republic hold groundwater reserves adequate to partially meet water requirements. This region also contains aquifers of large areal extent in which significant reserves of groundwater, with varying degrees of salinity, are stored. However, water quality in relation to salinity and their location at considerable depths may limit their usefulness in water development. Alluvial deposits along the main *wadi* channels and flood plains of drainage basins make up the shallow groundwater systems in Oman, Kuwait, Saudi Arabia, the United Arab Emirates and Yemen. Groundwater in shallow aquifers is the only renewable water source for these countries. Another main source of water for Bahrain, Kuwait, Qatar and Saudi Arabia is non-renewable fossil groundwater stored in deep sedimentary aquifers. These aquifers cover two-thirds of Saudi Arabia and some of them extend into Bahrain, Kuwait, Oman, Qatar, the United Arab Emirates, and Yemen, as well as

into Iraq, Jordan and the Syrian Arab Republic. In the central and northern regions of Saudi Arabia, and to a lesser extent, the other countries of the peninsula, vast amounts of groundwater stored in deep aquifers serve as a dependable source of water for irrigation and limited domestic requirements. Although the water in the deep aquifers is ample in quantity, the quality varies greatly and is suitable for domestic consumption in only a few areas. The amount of total dissolved solids (TDS) in the deep aquifers ranges from 400 to 20,000 ppm.

Because of their limited water resources and the rapidly decreasing quantity and quality of the water, as described above, many oil-producing countries of the region have turned to the sea for their freshwater supply; considerable progress in desalination activities has been achieved in recent years, and these countries have become world leaders in the desalination of sea and brackish groundwater for domestic use. Two-thirds (63%) of the world's desalting capacity is located in these countries. Out of 18.8 MCM per day of desalination capacity, the countries of the GCC account for over half of the world's production (15%). Saudi Arabia alone accounts for one-fourth of world capacity in desalination. The present annual designated desalination capacity of Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen, has reached 2.02 BCM (actual production of 1.6 BCM), compared with a worldwide capacity of 5.68 BCM (52). Water production volumes for desalination in the northern and southern ESCWA countries is showing (table 2). The major producers of desalinated water are Saudi Arabia (51%), United Arab Emirates (22%), Kuwait (15%), Qatar (5%), Bahrain (4%), Oman (2%) and Yemen (1%) (Bushnak 1993). GCC countries have always been major users of desalination technology and will continue in the future (32).

Treated wastewater effluent as non-conventional means of augmenting water supplies has become an important developmental activity in the region. Wastewater reuse has been practiced by some member States of ESCWA for a considerable period of time; however, its application has been limited, and plans have only recently been formulated for large-scale development of this non-conventional supply source. Lack of knowledge about the long-term effects of treated sewage effluent used for various purposes and the availability of other water resources has prevented the reuse of treated wastewater on a wider scale; however, the development of new technologies and the rising cost of desalinating water have led to a higher, more substantial rate of wastewater reuse in the ESCWA region during the past decade. Egypt, Jordan and the States of the Gulf Cooperation Council practice wastewater reuse in agriculture and public gardening. Most GCC countries have ambitious plans for full utilization of treated municipal wastewater. However, planning for full utilization of treated effluent remains in the early or middle stages, and the regional treatment capacity is sufficient to handle only 40% of the domestic wastewater generated. Reuse of renovated wastewater has been practiced in varying degrees for urban landscaping and irrigation. Good quality renovated wastewater can help alleviate water shortages, particularly in the industrial and agricultural sectors. However, this option is not available for domestic requirements because it is not socially acceptable, and the uncertainty that exists concerning water-borne viruses discourages large-scale usage of such resources. Treated wastewater production is presently rated at about 1,290 MCM/a and an additional 1,140 MCM/a is planned for Bahrain, Egypt and Jordan by the year 2000 (22). In the ESCWA region as a whole, treated wastewater meets only a small fraction of water demand (2%) (52).

Considerable attention has been given to water-saving measures in water resource development plans in the region in recent years. Such measures are related to irrigation or agricultural water use and drinking water supply schemes. Water conservation measures are being applied effectively in a number of ESCWA member countries. Such measures mainly include: a water tariff schedule based on water consumption, price incentives, water supply rehabilitation, leak detection, public awareness and community participation. In general, irrigation and agricultural water use projects have received a lot of attention in ESCWA member States in recent years, particularly in Egypt, Iraq, Jordan, Oman, Saudi Arabia and the Syrian Arab Republic.

Major projects have been executed extensively in Jordan and Saudi Arabia, while rehabilitation of the existing irrigation and drainage networks in Egypt and Iraq is progressing well. In the Syrian Arab Republic, several irrigation projects and parallel dam construction activities are also in progress. Studies of the use of treated drainage water are being considered in Egypt and Iraq, where the amount of drainage water reused reached 12.168 BCM (28),(34), in 1989. Some of the ESCWA member countries, in particular, Iraq, Oman and Saudi Arabia, are proceeding with plans to increase agricultural production through the implementation of modern and efficient irrigation/drainage projects in order to become as self-sufficient in food production as the available water resources will allow.

All ESCWA member countries have executed drinking water supply projects aimed at improving the living standards of their populations. Most of the member States' national development plans include the year 2000 as the target date to secure a safe and adequate water supply for the total population within the region. In recent years, the GCC countries have carried out several drinking water supply and sanitation projects. In Bahrain, Kuwait, Qatar, and the United Arab Emirates, 100% of the urban areas are supplied with piped water. Water supply projects vary from one country to another according to the water supply source, relying on surface-water resources in Egypt (the Nile River) and in Iraq (Tigris and Euphrates rivers) and equally on surface and groundwater in the Syrian Arab Republic (Euphrates, Orontes and Al-Khabour rivers). The rest of the ESCWA member States depend largely on groundwater for their water supply. This source is not reliable, as it is a depletable source which deteriorates in quality when over-pumped; over-pumping is already occurring as a result of the increased water demand in large cities such as Amman, Aden, Riyadh and San'a. Sources are also frequently distant from inhabited areas. There is groundwater of poor quality in Bahrain, Kuwait, Qatar and the United Arab Emirates; brackish groundwater is blended with desalinated water to provide adequate water supplies in these Gulf States.

III. REGIONAL WATER RESOURCES

A. TRANSBOUNDARY SURFACE-WATER RESOURCES

1. *Surface-water resources in the ESCWA region*

The sources of surface water are rainfall, rivers, springs and lakes. Surface run-off amounts to only about 15% of rainfall. Only 3% of this amount can be developed by constructing dams and water structures.

The major rivers in the ESCWA region receive 60% of their water from outside the region. For this, as well as for political and economic reasons, the full utilization and development of the potential resources of such rivers are not possible.

The yield from surface water resources produced internally in the ESCWA region is about 39.8 billion m³ (8% of the total annual rainfall). To this amount is added 136.5 billion m³ from international rivers originating outside the region. The amount of surface water thus totals 176.3 billion m³ as shown in table 2 below.

TABLE 2. SURFACE-WATER RESOURCES IN THE ESCWA REGION
(Billions of cubic metres)

ESCWA member States	Internal yield	Yield from outside ESCWA region	Total
Iraq, Jordan, Lebanon, Palestine and the Syrian Arab Republic	30.8	81	111.8
Arab Peninsula (Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen)	9 from seasonal wadis	-	9
Egypt		55.5	55.5
Total	39.8	136.5	176.3

Source: M. A. Abu-Zeid, "Evaluation of existing status for water resources in Arab nations", paper prepared for the Arab Center for the Study of Arid Zones and Dry Lands (ACSAD), June 1993.

A brief account of the major river basins or watersheds shared by two or more countries in the ESCWA region is given below.

(a) *Nile River basin*

The Nile constitutes Egypt's principal water resource. Groundwater is important, especially in the New Valley. The Nile ranks among the greatest rivers in the world. Its basin area is about 2,960,000 km² and its total length is about 6,825 km, crossing ten countries which share the river basin: Burundi, the Democratic Republic of Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, the Sudan, Uganda and the United Republic of Tanzania.

According to the water master plan of Egypt (41), the flow characteristics of the Nile River can be summarized as follows:

In Khartoum, the annual discharge of the Blue Nile into the White Nile is about 54 MCM. The total flow rises to about 82.5 BCM. To this flow is added the final gain from the Atbara River (12 BCM), thus increasing the annual yield to about 94.5 BCM. Annual flow arriving at Aswan is 84 BCM. Present annual flow available for use in Egypt is 55.5 BCM, after deducting the Sudan's entitlement as per the Nile Water Agreement between Egypt and the Sudan (35).

As regards water quality, the total dissolved solids (TDS) for the Nile range from 175 ppm to 180 ppm at Aswan and from 200 ppm to 210 ppm at the Delta Barrage.

The first structure erected on the Nile for its entire course was Al-Qanater Al-Khairiya Barrage; the dam was in operation by 1886. The Delta Barrage was constructed a few kilometers to the south in 1930. A dam was built at Aswan between 1898 and 1902, with a capacity of 1 BCM. Its height was raised twice (in 1912 and 1934) to reach a maximum storage capacity of 5 BCM (35).

Several other dams and water structures have been constructed in the area:

Egypt: Naja' Hammadi, Isna, Assiut, Zifta and Edina barrages;
The Sudan: Jabal Aulia, Sennar, Khashm-Al-Gibra and Roseires dams;
Uganda: Owen Falls dam;
Ethiopia: Jabal Aulia Dam, Baro Pibor Sobat, Bahr Al-Ghazal and Bahr Al-Jabal Swamps.

The Aswan Dam is now known as the Old Aswan Dam in order to distinguish it from the recently built High Aswan Dam, which was constructed between 1960 and 1968. All the dams mentioned above were designed on the basis of annual storage.

The Government of Egypt recently initiated the implementation of the New Valley Canal Project (Toshka Canal). The Canal will have its water (about 150 m³/sec) piped through a pumping station at the intake at the eastern bank of Lake Nasser. The station will be capable of pumping water from the lake with water levels ranging from a minimum of 147.5M to a maximum of about 178 m.a.s.l. The intake is situated about 8 km from the entrance of Khor Toshka. The canal is supposed to provide irrigation water supplies to about 200,000 feddans in Toshka Depression. The irrigated area may be increased to about 500,000 feddans covering the arable land up to Kharga Oasis.

The concrete-type canal is designed to be 310 km long. As part of the project, studies are being conducted pertaining to water losses, soil classification, irrigation water consumption and other relevant questions.

The first phase of the project, construction of the first segment of the Canal (67 km), is expected to be completed by 1999. In the second phase, completion of construction of the total length of the Canal, 310 km, is expected by the year 2000 (unpublished materials from the Ministry of Public Works and Water Resources of Egypt, 1997).

(b) *Euphrates River basin*

The Euphrates River is formed by the joining of two branches: the western Furat *sou* and the eastern Murat *sou*. The headwaters of the Euphrates River are found at an altitude of about 3,000 m in the Turkish highlands (Taurus mountains). The river basin covers an area of about 444,000 km² and the river's length

is 2,330 km (27),(29). 28% of the basin is situated in Turkey, 17% in The Syrian Arab Republic, 40% in Iraq and 15% in Saudi Arabia.

The catchment upstream from Keban Dam in Turkey has an area of 64,000 km² (6). More than 50% of this area exists at altitudes exceeding 1,600 m. Average annual precipitation in the headwater area ranges from 500 mm to 900 mm, and most of the precipitation occurs as snow in winter. Precipitation decreases to 300 mm and 450 mm in southern Turkey and in the north-eastern Syrian Arab Republic, the catchment area of the Khabour, the main tributary to the Euphrates River. In the steppe areas south of the Euphrates River, the catchment areas of ephemeral streams receive an average rainfall of about 150 mm to 200 mm. Run-off occurs mainly after intense rainstorms or thundershowers in autumn or spring; gentle rains in winter rarely cause run-off.

The average annual stream flow of the Euphrates in the Syrian Arab Republic is about 29.8 BCM (5),(6). Discharge at Al-Thourah is 850 m³/sec. Between 1924 and 1973, the maximum recorded discharge was 6,720 m³/sec, and the minimum discharge was 142 m³/sec (6). The annual flow, prior to river development in Turkey, was been estimated at 31.5 BCM (Kolars 1992, p. 107).

The Euphrates River is regulated by several dams, the largest of which are: Ataturk (49 BCM capacity); Keban (30.6 BCM capacity); and Al-Thourah (11.6 BCM capacity). The average annual yield of the watershed above Keban Dam is 19.4 BCM, while downstream it is 7.4 BCM (6).

Perennial tributary streams include the Sajour, Belikh and Khabour. The Sajour's average flow is about 4 m³/sec. The Belikh River has an average annual flow of about 150 MCM (6). The Khabour is the largest tributary in the Syrian Arab Republic, with an annual flow of about 1.5 BCM and an average discharge of 50 m³/sec. Maximum discharge during the recorded period is 386 m³/sec (6). A smaller dam has been constructed downstream from Al-Thourah to regulate the flow from Al-Thourah Dam.

At Hit, the Euphrates passes the depression of Al-Thourah on its left. Level with the Iraqi capital, the Euphrates divides into two branches, one to the east and the other to the west. Subsequently, it joins the Tigris at Al-Kurah to form the Chat-el-Arab. The flow of the Euphrates descends to about 100 m³/sec during the summer months, reaching 7,000 m³/sec during the months of winter. 89% of the Euphrates River water potential and 52% of that of the Tigris come from the same basin situated in Turkey (27).

Recently Turkey, the upstream country, has announced plans for the ambitious Greater Anatolia Project (GAP), which is composed of an enormous system for irrigation and hydroelectric energy and includes the construction of 21 dams and 17 electric power stations (43).

(c) *Tigris River basin*

The river issues from the southern slopes of the Taurus Mountains in Turkey. One of its main tributaries originates at elevations of 1000-1500 m.a.s.l., and the other, the Butman river, originates from higher altitudes (2,500-4,500 m). The total length of the Tigris River is 1,718 km, of which 1,418 km are within Iraq. The mean annual rainfall over the river basin is about 800 mm and ranges from 440 to 1,600 mm/a (27).

Floods occur along the Tigris River during winter and spring as a result of the rainfall and snowmelt in the mountainous areas (166,155 km²) in Iran, the north-east of Iraq and Turkey. The average annual volume of surface-water flow through the river and its tributaries is about 48.69 BCM. The minimum

measured flow in 1930 was 19 BCM while it reached 106 BCM in 1969. At Mosul, the maximum recorded flow was 7,539 m³/sec, and the minimum flow was 88 m³/sec. Flood probability analysis indicates that the Tigris River has a probable maximum flow of up to 30,000 m³/sec (27).

The estimated annual safe yield of the Tigris River alone, without considering the constructed dams, is about 15.6 BCM. It reached 23.1 BCM after construction of Derbandi Khan and Dukan dams, and it will be about 31.7 BCM when the Mosul Dam has been completed. Bekhma Dam construction will raise the estimated safe yield of the river up to 34.5 BCM (27).

Tigris River tributaries:

- (i) Greater Zab River: This is the largest tributary of the Tigris River. Its headwaters originate from the Ararat mountains, at an altitude of 4,636 m. The total catchment of the river is 25,810 km², of which 16,000 km² are in Iraq (27). The length of the river is 392 km and it joins the Tigris south of the town of Mosul. The average annual stream flow is about 13.18 BCM. The maximum recorded discharge is 10,570 m³/sec and the minimum flow is 67 m³/sec (27);
- (ii) Lesser Zab River: Headwaters of the Lesser Zab River drain about 21,475 km² at the border zone between Iraq and Iran (15,975 km² in the Iraqi territory). The length of the river is 400 km; it joins the Tigris River north of Fatha (27);

The average annual river discharge for the Lesser Zab is 7.17 BCM; maximum and minimum annual discharge is 17.01 BCM and 3.02 BCM, respectively. The recorded maximum is 3,420 m³/sec. Annual safe yield after construction of the Dokan Dam (6.8 BCM capacity) is about 5.07 BCM (27).

- (iii) The Al-Adheim River: The headwaters of this river rise at the Kura Dagh and Shwam highlands, and drain over a 13,000 km² area which lies entirely within Iraq. The length of the river is 330 km. The average annual discharge is 0.79 BCM; maximum and minimum annual discharge is 1.85 BCM and 0.18 BCM respectively. The Al-Adheim River is an intermittent stream subject to flash floods which reach up to 13,000 m³/sec. The flow usually stops between June and October (27);
- (iv) Diyala River: The headwaters of the Diyala River (386 km long) are in Iranian territory. It drains an area of about 31,896 km², 24,072 km² of which are in Iraq. The principal tributaries of the river are the Seirawan and Tanjaro. The annual average, maximum and minimum flows are 5.74 BCM, 14.27 BCM and 2.44 BCM, respectively. The flow has been regulated through the construction of two dams: Derbandi Khan (3 BCM capacity) and Hemrin Dam (3.95 BCM capacity) (27);
- (v) Al-Tayib River: The Al-Tayib River originates in the Zagros Mountains and drains an area of about 5,000 km². The average annual discharge is about 1 BCM. The length of the river is 80 km (27);
- (vi) Dweirij River: This river originates in the Zagros Mountains. It is about 110 km long, with a basin area of about 3,000 km (27);

- (vii) **Korkha River**: The headwaters originate on the south flanks of the Zagros mountains in Iran. The Korkha River drainage basin area is about 46,000 km²; its average annual flow is about 6.3 BCM, and it empties into Hor Hweiziya (27).

Several major storage facilities and diversion structures have been built on the Tigris River and its main tributaries. All these dams and hydraulic structures serve to control the flow of the Tigris River and have paved the way for the execution of large irrigation projects, including integrated irrigation-drainage systems. These dams and hydraulic structures are: Dalcar, Tharthar, Fatha, Mosul, Bakhma, Derbandi Khan and Hemrin.

(d) *Jordan River basin*

The Dan, Baniyas and Hasbani Rivers form the headwaters of the Jordan River. The point of confluence of the headwater tributaries is about 4 km south of the northern borders of the occupied territories. It lies at an altitude of 90 m above sea level, with a drainage area of about 18,300 km² and a length of 225 km (19).

Precipitation in the higher catchment area ranges from 800 mm to 1,600 mm. Snowfall contributes about 25% of the annual yield of the Upper Jordan Basin. Precipitation in the Yarmouk basin and other lower catchments ranges between 250 mm and 600 mm.

The Jordan River empties into the Dead Sea. The average annual discharge at its mouth (Lake Tiberias) is about 875 MCM. Maximum and minimum annual flow is 1,650 MCM (measured 1942-1943) and 648 MCM (1933-1934) respectively (21). The average annual flow of the river at the Dead Sea is estimated at 1250 MCM (21).

Major tributaries of the Jordan River:

- (i) **Dan River**: The Dan River source is at Tel Al-Qadi in the occupied territories near the Syrian border. Average annual stream flow between 1950 and 1975 was 240 MCM (21). Average annual flow was recently estimated at 260 MCM. Maximum yearly discharge for the same period is 285 MCM (1949-1950), while minimum annual flow is 217 MCM (1961-1962);
- (ii) **Baniyas River**: Its source is Baniyas cave near the foot of Mount Hermon in the Golan, at an altitude of 329 m. Stream flow is variable; annual average yield is 120 MCM for the period 1950 to 1975 (21). Maximum and minimum annual flow recorded during the last twenty years is estimated at 190 MCM and 63 MCM respectively;
- (iii) **Hasbani River**: The Hasbani River source is on the northwestern flank of Mount Hermon in Lebanon, at an altitude of about 900 m. Average annual stream flow of the Hasbani River (between 1950 and 1975) was 153 MCM (21). Maximum total flow for the period 1947 to 1975 was about 236 MCM, and the minimum in a water-year (October-April) was about 635 MCM in 1960-1961 (21);
- (iv) **Yarmouk River**: Tributaries of the Yarmouk River either rise on the western flanks of Jebel el-Arab and flow westward, or rise in the Golan and flow southward. The annual flow (run-off and base flow) of the main tributaries and the principal streams (Rakad, Aalan, Zeizon, Muzeirib, Al-Thahab and Al-Zeidi) is estimated at 181 MCM of run-off and 265 MCM of base flow, totalling about 446 MCM/a (21). The Yarmouk River is the largest tributary of the Jordan River system.

The potential resources of this system, except for a major part of the base flow, have not been fully exploited;

- (v) Zarqa River: The drainage area for the Zarqa River is about 4,056 km², which is by far the largest area on the east bank of the Jordan River. Estimated average annual stream flow of the Zarqa River is 95 MCM; measured flow for the period 1951 to 1966 was about 71 MCM (14);
- (vi) Small east bank side wadis: The eastern flank of the highlands bordering the Jordan Valley is drained by small *wadis*. The total drainage area of the small east bank *wadis* is about 2,180 km². Estimated annual flow in these *wadis* is about 112 MCM (14);
- (vii) Small west bank side wadis: After emerging from Lake Tiberias, numerous small *wadis* join the Jordan River. Their total drainage area is 2,344 km². No information is available on their contribution to the Jordan River.

(e) *The Orontes basin*

The Orontes River originates in Lebanon (in northern Beka'a) at Al-Labweh spring near Baalbek, at an elevation of 400 m. It has a drainage area of about 216,000 km² and a length of 487 km (9). The river and its tributaries drain highlands or plateau areas situated on both sides of the Rift Valley. The western mountains receive annual precipitation ranging from 600 mm to 1,500 mm. Snowfall in Lebanon and the Syrian Arab Republic coastal mountains contributes to the stream flow. Average annual precipitation in the eastern catchments is much lower, ranging from 400 mm to 600 mm; consequently, the eastern tributaries are all ephemeral streams. The average annual flow of the Orontes River is estimated at 2,400 MCM (24). Maximum and minimum daily discharge is 10 m³/sec and 400 m³/sec, respectively. The mean annual discharge of the river increases steadily in the upper reaches, and nearly doubles in the lower reaches.

The mean discharge of the Orontes at Cheizar, the head of the elaborate irrigation installations of the Ghab Valley, is 25 m³/sec or 790 MCM/year. This flow is variable, ranging from 40% of that value during dry seasons to eight times that value during the major floods produced by heavy winter rainfall. River discharge reaches a peak in February and March and declines steadily in late spring and summer. In January, after winter rains have had nearly two months to replenish its underground sources, its flow rises abruptly from the low level of the late summer and fall.

The annual discharge of the Orontes varies with the rains. Until the recent construction of dams along its middle course in the Syrian Arab Republic, years with heavy rainfall brought disastrous flooding to many areas along the river's banks. The flow of the stream is perennial, however, due primarily to groundwater recharge from the complex of permeable materials that underlie the river along much of its course. An additional 250 MCM/year enters the lower Orontes via its major tributary, the Afrine (45).

B. MAJOR REGIONAL AQUIFERS

Groundwater exists in different aquifer systems; the amount varies depending on the aquifers' geological structure, hydrological and hydrogeological characteristics and the extent of their areal distribution. It has been noted that some of the hydrogeological groups in the ESCWA region are connected to each other and feed some other aquifer systems according to the piezometric pressures in each of them. Physical feeding resources are difference from one aquifer system to another and from site to site according to the differences in porosity, recharge and yield.

In the ESCWA region, there are shared groundwater basins which vary in the range of their geographic extensions. Some of them have limited extensions, some have medium extensions, and some have large extensions. The most important shared basins with a huge groundwater reservoir are:

(a) Eastern Mediterranean basin: This basin covers an area of 48,000 km² extending through Jordan, Lebanon, the Syrian Arab Republic and the occupied territories. This basin feeds the Lebanese rivers (Orontes, Litani and others) and the Jordan River, which represent the major drainage area of this basin;

(b) Horan and Arab Mountain basin: This basin covers an area of 15,000 km² extending through Jordan, Saudi Arabia and the Syrian Arab Republic. The Golan plateau constitutes the main occurrence of water resources for this basin, which is considered a main source of the Yarmouk and Azraq basins through the springs of Mazreeb, El-Hamma and El-Azraq;

(c) East Arab Peninsula basin: This basin covers an area of 1.6 million km² extending through the Gulf, Iraq, Jordan, the Syrian Arab Republic, and Yemen. Rainfall is the main water resource at the north of the basin and feeds the eastern section of the basin;

(d) Nubian sandstone basin: This basin covers an area of 2 million km² extending through Chad, Egypt, the Libyan Arab Jamahiriya and the Sudan. It has a huge groundwater reservoir though limited in the segment from Chad to the Sudan, and perhaps the Ethiopian plateau. Springs, oases and depressions represent the major drainage areas of this basin.

TABLE 3. GROUNDWATER RESOURCES IN THE ESCWA REGION

ESCWA region members	Yield recharge (million m ³)	Underground storage (billion m ³)
Iraq, Jordan, Lebanon, Palestine and the Syrian Arab Republic	5.75	12
Arab Peninsula: Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, United Arab Emirates and Yemen	4.71	859.5
Egypt (from Nubian sandstone basin)	4.5	6 500
Total	14.96	7 371.5

Source: M. A. Abu-Zeid, "Evaluation of existing status for water resources in Arab nations", paper prepared for Arab Center for the Study of Arid Zones and Dry Lands (ACSAD), June 1993.

The major shared aquifers in the region are briefly described below:

1. *Eastern Mediterranean carbonate aquifer system*

(a) Aquifer: The eastern Mediterranean carbonate aquifer is a regional complex of rocks comprising two major hydrogeological units: a Lower Jurassic unit composed mainly of limestone and dolomite; and an Upper Cenomanian-Turonian aquifer, also composed of limestones and dolomites;

(b) Occurrence: This regional aquifer system is best observed in the following areas:

- (i) The Alouite mountains (Syrian Arab Republic);
- (ii) The Palmyrian mountains (Syrian Arab Republic);

- (iii) The Anti-Lebanon range (Syrian Arab Republic and Lebanon);
- (iv) Mount Hermon (Syrian Arab Republic and Lebanon);
- (v) The Lebanon mountains (Lebanon);
- (vi) The eastern and western highlands (Jordan).

2. *Jebel el-Arab basaltic aquifer system*

The main aquifer is made of basalt, but the basalt is a complex layering of flows of different ages, and variations do occur on the micro and macro scales. The thickness of the basalt layers also changes markedly from one area to another, from the vast volcanic plateau of the southwest Syrian Arab Republic to eastern Jordan and northern Saudi Arabia; accordingly, the saturated thickness and degree of saturation varies from one place to another. The aquifer is composed of several lava flows, with total thickness ranging from 300 m near Jebel el-Arab to 20 m to 80 m in the Hamad basin.

3. *Jejira Tertiary limestone aquifer system*

(a) Aquifer: This aquifer, essentially limestone and dolomite, is of the Middle Eocene age and may extend into the Oligocene (30). It forms one hydrogeological unit in the Jezira area of the Syrian Arab Republic and is some 200 m to 300 m thick in Turkey. The thickness of the Palaeogenic limestones increases in an eastwardly direction, to about 560 m in the Jezira of the Syrian Arab Republic, and to 1,034 m in Qaratchik. In spite of its great thickness in the eastern area, the aquifer is hydrogeologically more important in the northwestern part of Jezira;

(b) Occurrence: The water-bearing limestone formation outcrops in Turkey to the north of the border zone, extending from the Belikh area to the Khabour River in the Syrian Arab Republic. The aquifer extends along the Syrian Arab Republic border with Turkey, from Ain Al-Arab east of the Euphrates to Ras Al-Ain and beyond. The Khabour River channel between Ras Al-Ain and Hassakeh forms the southern border of the aquifer system, which also extends southward as far as the Jebel Abdel Aziz area in the Syrian Arab Republic. Groundwater recharge to the aquifer system is estimated at 1,600 MCM/a, and discharge occurs via two large springs in the Syrian Arab Republic: Ras Al-Ain (40 m³/sec) and Ain Al-Arus (6 m³/sec) (30).

4. *Jejira Lower Fars-Upper Fars aquifer system*

The well-known Lower and Upper Fars formation consists of gypsum beds interbedded with limestones, clags and marls. It extends over the vast Mesopotamian plain of the Lower Jezira of the Syrian Arab Republic and in Iraq from the Belikh River in the west to the Tigris River and Tharthar depression. The southern boundary more or less coincides with the middle reach of the Euphrates (from Raqqa in the Syrian Arab Republic to Al-Ramadi in Iraq).

5. *Western Arabia sandstone aquifer system*

(a) Aquifers: Four principal sandstone aquifers—the Saq, Tabuk, Wajid and Minjur—are recognized in the Arabian peninsula. They range in age from the Cambrian to the Triassic periods. Hydrodynamically, they can be subdivided into three major subsystems:

- (i) The Rum-Saq-Tabuk sandstone aquifer subsystem, extending from northern Saudi Arabia to Jordan;
- (ii) The Minjur sandstone aquifer subsystem, occupying the middle of the Riyadh area;

- (iii) The Wajid sandstone aquifer subsystem, which mainly occurs in southern Saudi Arabia and in northern Yemen.

(b) Groundwater quality: Water of good quality for domestic uses, industry, irrigation and livestock watering is available from various members of the Palaeo-Triassic aquifer system. The dissolved-solids content of groundwater from the Saq aquifer does not generally exceed 1,000 ppm, although water in the deeper horizons usually has a higher dissolved-solids content and is of a sodium-chloride type. Fresh water from the Wajid aquifer is of a bicarbonate type; the dissolved-solids content is commonly less than 1,000 ppm. Water from the Tabuk aquifer (mainly at lower and middle levels) is generally fair to good quality; it ranges from 400 ppm to 3,500 ppm of total dissolved-solids (30). Water from the Minjur aquifer is of a calcium-sodium/sulphate-chloride type; the concentration of sodium and chloride ion concentration increases with depth. The thermal waters of the formation contain considerable amounts of carbon dioxide.

Data from the constant rate and the step drawdown pumping tests were analysed by a series of analytical solutions that are well known in hydrogeological literature.

Rum aquifer: The parameters of prime concern are the horizontal hydraulic conductivity and the storage coefficient. The former varies from 1 m/d to 2 m/d, and the latter between 0.002 and 0.005. When applied to a regional system, this range of values could give significantly differing design parameters for a well field that was planned to operate for long periods (53).

Confining layer: The data set for this is severely limited, as tests to evaluate the confining layer have never been carried out in Jordan. The values obtained from the pumping test could be particularly unreliable because of borehole construction factors, but the vertical hydraulic conductivity value obtained suggests that it could be 0.04 m/d. The confining layer is not considered to have any storage in it.

Leaky aquifer: Data suggests that horizontal hydraulic conductivity may be 0.01 to 0.1 m/d, but the results may be unreliable because of borehole construction factors, as in the confining layer (53).

Rum aquifer: The core plugs analyzed in the laboratory suggest that the hydraulic conductivity varies from 0.3 to 5 m/d, and the total porosity varies from 15 to 25%. Such a range of variation is normal in plug analysis, as the plugs represent point samples, reflecting the natural variation in formations.

Enhancements to the mathematical model of the Rum aquifer have produced a calibrated transient model in which there is a good degree of confidence. This applies particularly to areas of the aquifer in Jordan where national well fields are located.

6. Central Arabia sandstone aquifer system

(a) Aquifers and areal extent: The Cretaceous aquifer system is comprised of the Biyadh and Wasia sandstones in Saudi Arabia. Their combined thickness is about 1,000 m. Groundwater occurs under unconfined conditions, especially in the outcrop of the aquifer, which extends over a vast area (from Wadi Al-Dawasir in Saudi Arabia to Rutba in Iraq). The total dissolved solids (TDS) content of the lower member, the aquifer in the outcrop (recharge) area, is about 150 ppm. In the Kharj area, the dissolved solids range from 550 ppm to 900 ppm. The water quality of the Wasia sandstone aquifer varies widely from one place to another. The TDS ranges in the outcrop area from 1,000 ppm to 3,000 ppm, while the water in the Biyadh aquifer stagnates, and its TDS values rise substantially—from 4,000 ppm to 80,000 ppm to 150,000 ppm. The Wasia aquifer then flows on with a TDS content of 4,000 ppm to 5,000 ppm (11);

(b) Groundwater resources: According to a number of consultants, groundwater resources in the Biyadh and Wasia aquifers are estimated to have a potential annual recharge of 252 MCM (11) and 420 MCM (30), respectively. The quantity of water in storage is estimated at 120 BCM, though it is probable that storage amounts to as much as 290 BCM.

The hydraulic characteristics of the Cretaceous aquifer system vary widely in the extensive confined and unconfined parts of the hydrogeological systems. For many areas in Iraq, Jordan, Kuwait and northern and southern Saudi Arabia, information is scarce or incomplete. In some areas, the aquifer is either saline or unproductive, and its development is consequently not feasible.

7. *Eastern Arabia Tertiary carbonate aquifer system*

Aquifers and areal extent: The aquifers consist primarily of limestones and dolomites. The whole sedimentary complex is hydraulically interconnected and is a recharging-discharging aquifer system (11). The subdivisions (or main aquifers) are as follows:

(a) The Umm er Radhuma aquifer is composed of limestone and dolomites, and ranges between 240 m and 700 m in thickness. It occurs in Iraq, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates;

(b) The Dammam aquifer is composed of limestone and dolomite interbedded with shale, with a thickness ranging between 20 m and 500 m. It occurs in Bahrain, Kuwait, Oman, Qatar, Saudi Arabia and the United Arab Emirates;

(c) The Neogene aquifer is composed of sandstone, sandy marl and chalky limestone of variable thicknesses. It occurs in Kuwait, Oman, Qatar and the United Arab Emirates.

Research on the Tertiary carbonate aquifers of eastern Arabia was conducted by the Food and Agriculture Organization of the United Nations (FAO) (11). Groundwater recharge into the aquifers is estimated at 1,150 MCM, while the estimated discharge from the system is 1,200 MCM. Other estimates for the recharge of the Umm er Radhuma, Dammam and Neogene aquifer members are 406 MCM, 200 MCM and 238 MCM (30), respectively. Fresh water is relatively rare in the aquifer complex, occurring in the upper and lower zones of the hydrodynamic system.

Water in the unconfined part of the Umm er Radhuma aquifer is mainly of a sulphate or chloride type. The TDS concentrations range from 300 ppm to 700 ppm, though water of good quality (900 ppm to 1,400 ppm) may be encountered in some localities. In Bahrain and Qatar, the aquifer is highly saline, with a TDS content of 6,000 ppm to 17,000 ppm. The TDS content in the Dammam aquifer member ranges from 1,000 ppm to 6,000 ppm. In the upper reaches of the aquifer system, good water quality may be encountered.

8. *Nubian sandstone aquifer system*

This system is made up of a sequence of continental sandstones and sands intercalated with argillaceous beds of the Carboniferous to the Middle Cretaceous ages. Its thickness reaches up to several thousands metres (30).

In the eastern desert of Egypt, the Nubian sandstone complex is a water-bearing formation where groundwater occurs under confined artesian conditions (flowing wells). Water can be obtained there from

shallow carbonate and deep sandstone formations. The deeper water-bearing formations are, more extensive and contain larger quantities of groundwater. The thickness of the Nubian aquifer complex in the central eastern desert is about 400 m.

In the Sinai Peninsula, the Nubian sandstone complex is the principal aquifer. The depth to the aquifer is, on the average, 700 m to 900 m in central Sinai, increasing northwestward, to about 2,500 m along the Mediterranean coast. Artesian pressure in central Sinai is about 200 m above sea level.

Groundwater encountered in the Nubian sandstone aquifer system is generally of excellent quality. Its TDS content ranges from 100 ppm to 800 ppm. The volume of stored groundwater in the aquifer system in Egypt (western and eastern deserts and Sinai) is estimated at 5,000 BCM. Local groundwater is extracted in the eastern desert, but quantities do not exceed 5 MCM to 10 MCM (30).

Groundwater extraction for agricultural use in the Sinai occurs predominantly along the northern coastal (Al-Arish) area. Average annual withdrawal is about 30 MCM (12).

IV. NOTES ON COOPERATION, UTILIZATION AGREEMENTS AND PRACTICES FOR REGIONAL WATER RESOURCES

A. REGIONAL AND SUBREGIONAL SURFACE-WATER BASINS

1. *Nile River system*

The water resources of the Nile are shared by ten sovereign states: Burundi, the Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, the Sudan, Uganda and the United Republic of Tanzania. To date there is no basin-wide agreement with regard to the management and utilization of the Nile. At present, significant use of the waters of the Nile is made by the two downstream countries, the Sudan and Egypt, the latter being the prominent user. The other upstream countries, who contribute the bulk of the total annual flow of the Nile (Ethiopia is the major contributor at 86 per cent), have not as yet used the waters of the Nile to any appreciable extent (Tamrat 1995).

The legal and institutional arrangements that presently exist within the Nile basin reflect the disparity in use between the downstream and upstream riparians. The two downstream countries have allocated the main annual flow of the Nile (as measured at Aswan) between themselves, disregarding the needs and development targets of the upstream riparians.

Egypt and the Sudan created a model for cooperation in 1959 through a bilateral agreement which not only governs the sharing of the Nile waters, but contains an instrument for settling controversies by negotiation. In 1959, Egypt and the Sudan signed an agreement to establish the Permanent Joint Technical Commission of the Nile River, which is a mechanism for proposing and implementing mutual cooperation projects between the two countries as well as with other countries of the Nile basin. The Technical Commission has the right to review the uses of the Nile water in the two countries as compared with the shares stipulated by the 1959 agreement. Since its establishment in 1960, the Technical Commission has been meeting regularly four times a year, alternatively in Cairo and Khartoum. In accordance with the 1959 Agreement, Egypt was allowed to go ahead with plans to construct the High Aswan Dam for over-year storage, impounding and controlling the full discharge of the river at Aswan. This amounts to a total of 84 BCM; of this, the share for the Sudan was increased to 18.5 BCM, and Egypt's share was increased to 55.5 BCM. To a great extent, the dam has mitigated the conflict between the Sudan and Egypt caused by the restrictions of the earlier 1929 Agreement, limiting the amount of water withdrawn by the Sudan from December to July and increasing Egypt's share. The 1959 Agreement also recognized other riparians' rights.

As per the 1959 Nile Waters Agreement, Egypt and the Sudan have asserted that their existing use of the Nile waters be given absolute recognition and that it is to be non-negotiable in any future water allocation. The downstream countries (Egypt and the Sudan) would be entitled to an additional share from the Nile waters if the proposed Nile River Water Conservation Projects were implemented. These projects include several major water works designed to regulate and conserve the Nile River flood waters in upstream States. They were stopped as of November 1983 owing to the political situation in the upstream region.

In 1964, the Technical Commission, with assistance from the United Nations Development Programme (UNDP), began to draw up a mechanism for cooperation with the countries of the Equatorial Lakes region. The idea was a success and resulted in the establishment of a project for a hydroelectric-meteorological survey of the Equatorial Lake Plateau in 1967 (Hydromet). In 1977 the Technical Commission began formulating a comprehensive mechanism for providing continuous cooperation among all the riparian

countries. In 1978 the draft by-laws of the suggested Nile Basin Commission were drawn up and sent officially to all basin countries.

More recently, under the aegis of the United Nations, further efforts have been made to help the Nile basin countries establish a mechanism for overall cooperation in the development of the Nile basin. The following points are considered essential to the success of the venture:

- (a) Agreement on the historical rights of different parties;
- (b) Agreement on exchanging the data required for development projects;
- (c) Acknowledgment of prior agreements, especially those which deal with shared water resources;
- (d) Acceptance of criteria for prioritizing suggested development programmes;
- (e) Within each country, consideration of the possibility of using existing resources other than Nile water.

Various international forums have set out to encourage meaningful cooperation among Nile riparians in its utilization and management. Although these efforts constitute a step forward, basin-wide cooperation has not yet been achieved. All parties understand and accept the need for cooperation but have failed to reach an agreement on the modalities, including the legal framework, for such cooperation. Other factors contributing to this situation are the lack of political will and distrust among watercourse States; feelings of vulnerability and uncertainty in the two downstream States, particularly in Egypt, with regard to the impact of upstream water resources projects; the absence of political stability in certain watercourse States; and the lack of adequate financial resources and technical expertise, especially in the upstream States.

The Ministers responsible for water affairs in the Nile Basin countries met in Kampala, Uganda, in December 1992, and discussed their future cooperation on water resource matters. They agreed that these matters should be pursued over a three-year transitional period, under the name "Technical Cooperation for the Promotion of the Development and Environmental Protection of the Nile Basin" (TECCONILE). An agreement to this effect was signed by ministers from six countries: the Democratic Republic of the Congo, Egypt, Rwanda, the Sudan, Uganda and the United Republic of Tanzania (20).

Following one additional ministerial meeting and two international conferences (Nile 2002 Conferences), the Nile countries agreed on a list of practical measures for supporting regional cooperation in water management.

A workshop was held in Entebbe, Uganda, in June 1994. The main purpose of the workshop was to develop a draft Action Plan for the Nile River Basin. A second workshop was held in Cairo, Egypt, in November 1994. The purpose of the second workshop was to provide an opportunity for the country participants to review and revise the draft report on the Action Plan which was developed as a result of the Entebbe workshop. Representatives from Burundi, the Democratic Republic of the Congo, Egypt, Eritrea, Ethiopia, Kenya, Rwanda, the Sudan, Uganda and the United Republic of Tanzania participated in this second workshop.

The third Ministerial meeting took place in Arusha, United Republic of Tanzania, in February 1995. The Action Plan was presented and approved by the Council of Ministers for Water Affairs of the Nile Basin States.

The Action Plan, as initiated and agreed to, has five main components that include a total of 22 individual projects:

1. Integrated water-resource planning and management (five projects).
2. Capacity-building (eight projects).
3. Training (one comprehensive project).
4. Regional cooperation (five projects).
5. Environmental protection and enhancement (three projects).

2. Euphrates-Tigris River system

A second example of rivers shared by different countries is the case of the Euphrates and Tigris rivers. The Euphrates and Tigris rivers get their water from the Anatolian plateau south-east of Turkey. This plateau has an annual rate of rainfall of about 1,000 mm.

The basins of these two rivers are international: Iraq and the Syrian Arab Republic share the Euphrates basin with Turkey; they share the Tigris basin with the Islamic Republic of Iran and Turkey. The Euphrates River has a catchment area of about 444,000 km² that lies within Iraq, the Syrian Arab Republic and Turkey. Some small rivers (the Sagour, Baliekh and Khabour) join the Euphrates in its flow through the Syrian Arab Republic. The volume of the Euphrates discharge at the Syrian border is estimated at 29.8 billion m³ of water, and the total length of the from its source until it joins the Tigris is about 2,700 km (Kolars 1994, p. 51). The Tigris River has a catchment area of about 471,606 km² that spreads out across Iraq, the Islamic Republic of Iran, the Syrian Arab Republic and Turkey. Some small rivers (the Greater Zab, the Lesser Zab, Shut Al-Adheim and Diyala) join the Tigris within Iraqi boundaries. The discharge of the Tigris is 48.7 billion m³ of water and its length is 1,800 km. The Chat-el-Arab (190 km long) is the river where the Euphrates and the Tigris meet at El-Kurnah. The Chat el-Arab discharges 21 billion m³ of water at El-Bagrah and 35.2 billion m³ at its end when it drains into the Gulf.

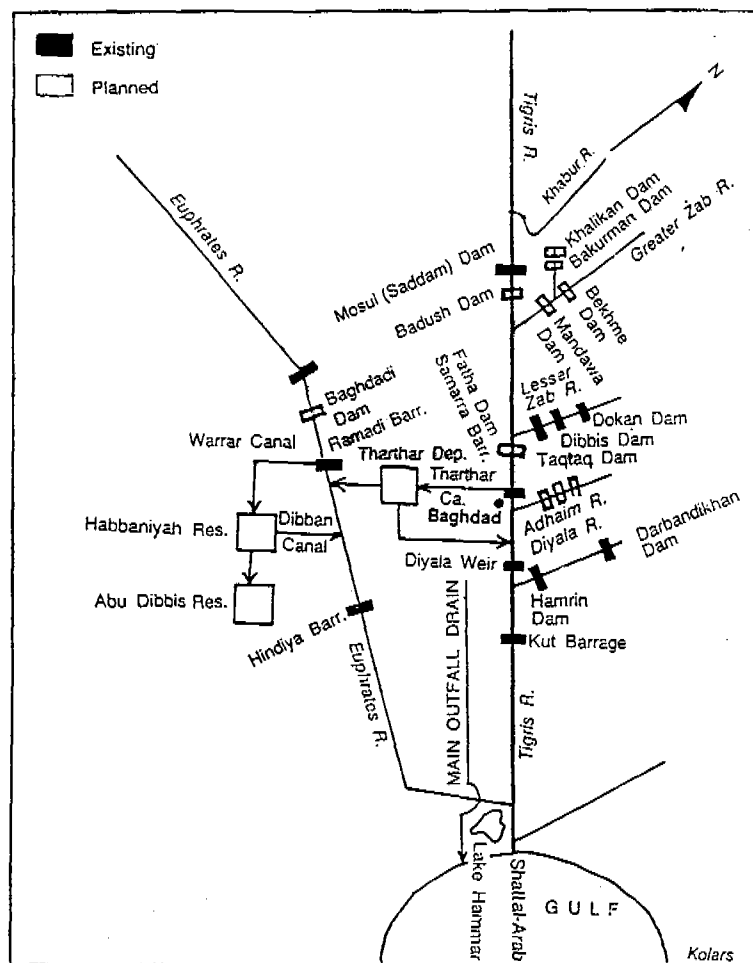
Several hydraulic structures have been already constructed on the the Euphrates and the Tigris Rivers by the four riparian countries for the purposes of flood control, power production or implementation of irrigation schemes at national levels, thereby satisfying each country's objectives but without effective cooperation between the countries. However, no substantive development plans to exploit the Euphrates river water were executed by Iraq, the Syrian Arab Republic or Turkey prior to 1973. During the French and British mandates in the region, the exploitation of Euphrates-Tigris waters was in general governed by some old protocols and agreements. These were the Franco-British Convention of 1920 regarding the utilization of water in Mesopotamia; the Franco-Turkish agreements, from 1920 to 1930, regarding utilization of the Koveik (Quwayq) River and partial use of Euphrates and Tigris waters; and the Turkish-Iraqi Protocol of 29 March 1946, for the exchange of information on the subject of flood prevention as an annex to the Treaty of Friendship and Good Neighbouring Relations. As per this protocol, the main purpose of the agreement was the construction of protection and observation posts on Turkish territory and the harmonization of water projects on both sides (Chalabi and Majzoub 1995, pp. 189-234).

None of these treaties, agreements and protocols received the attention of the riparian States. On the contrary, each State started to implement policies to direct or exploit the waters of the Euphrates without consultation with the other States. During the sixties, the waters of the Koviek were diverted, and the Afrin waters suffered the same fate at the beginning of the seventies (Chalabi and Majzoub 1995).

The exploitation of the Euphrates river waters can be divided into two phases: during the first phase, from 1946-1960, no far-reaching water projects were undertaken with the exception of a project related to the collection of rainfall returns and the acquisition of hydroelectric-meteorological information. The second phase, from 1960 until now, has been marked by the construction of a series of water projects which were all exemplified by an almost complete lack of cooperation among the three riparian States.

The three riparians, Turkey, the Syrian Arab Republic, and Iraq, have all formulated plans and implemented projects over the years to achieve flood control on the Euphrates and to use its waters for large scale irrigation schemes and the generation of hydroelectricity. Little effort has been made to coordinate planning and no formal agreement has been reached regarding the allocation of water. Iraq, whose use of the Euphrates for irrigation dates back 6,000 years, was the first of the three States to build modern water works on the river. The Hindiya Barrage was completed in 1913, and the second barrage built at Ramadi in 1950 allowed Euphrates flood waters to be diverted to Lake Habbaniyah and the Abu Dibis depression. The Al-Haditha Dam, upstream from Ramadi, was put into service in 1982. In addition, numerous water structures and waterworks were either planned or built to make use of the Tigris River waters for irrigation, flood protection and hydroelectric-power production purposes (figure II).

Figure II. River development in Iraq: schematic representation

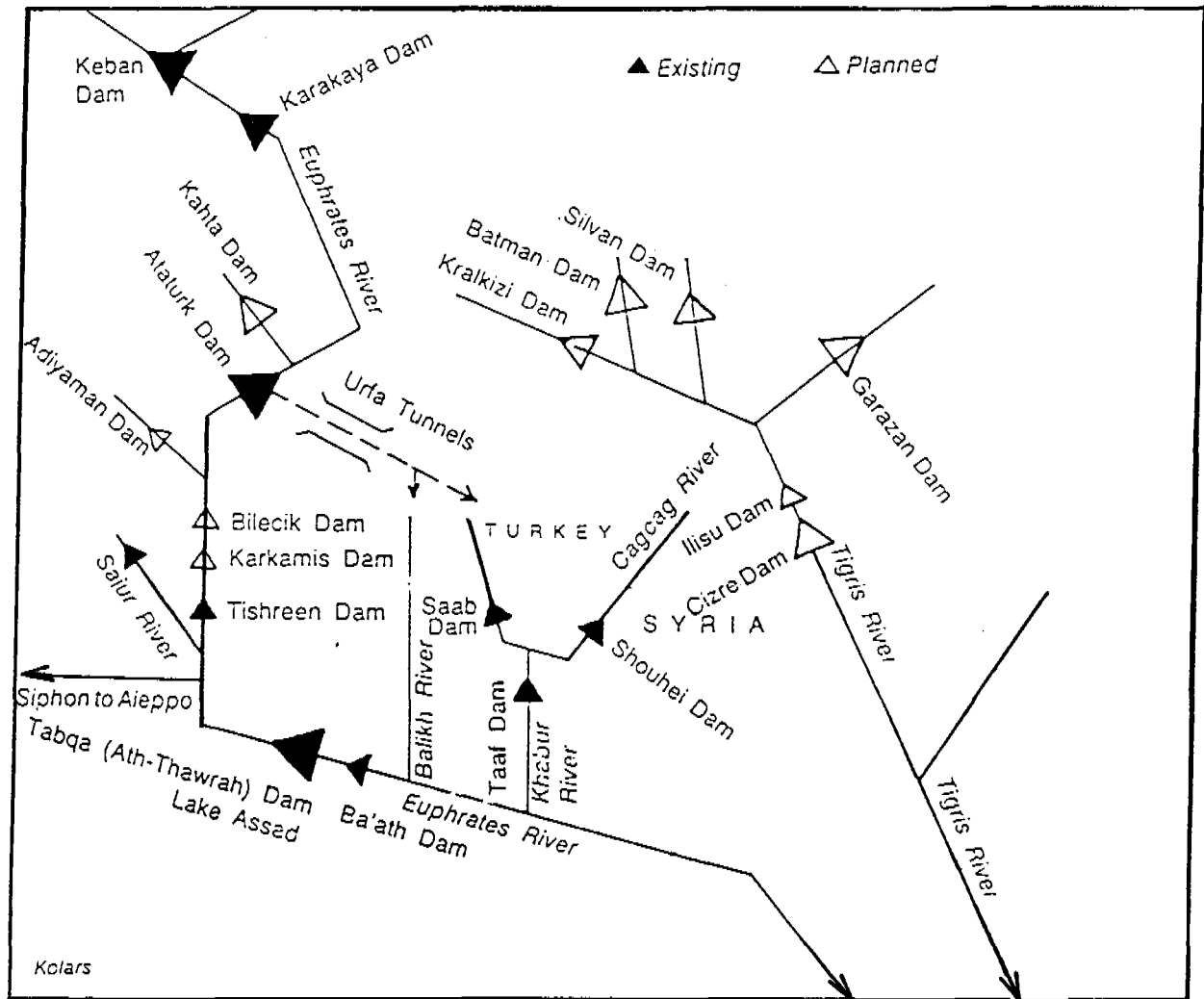


Source: John Kolars, "Problems of international river management", *International Waters of the Middle East*. Water Resources Management Series, vol. 2, edited by Asit Biswas (Bombay, Oxford University Press, 1994).

This figure was considered appropriate at the time of implementation of the study and does not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delineation of its frontiers or boundaries.

In the Syrian Arab Republic, the Tapqa dam was put into service in 1973. Two other dams; the Al-Baath dam, which was completed in 1988, and the Tishrin dam, upstream from the Tapqa Dam, which was started in 1990, were built, in addition to three other smaller dams constructed on the Khabour river within Syrian territory (figure III).

Figure III. The Euphrates-Tigris basin: existing and planned developments (not to scale)



Source: John Kolars, "Problems of international river management", *International Waters of the Middle East*. Water Resources Management Series, vol. 2, edited by Asit Biswas (Bombay, Oxford University Press, 1994).

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One of the largest development projects which has been implemented in the Euphrates-Tigris river system is Turkey's Greater Anatolia Project (GAP; in some sources, also referred to as the Southeast Anatolia Project). The GAP incorporates the construction of 21 dams and 17 hydropower plants on the Euphrates and Tigris rivers. One million hectares of land are scheduled to be irrigated with water from the Euphrates and 625,000 ha from the Tigris. The GAP will have a total of 7,500 MW installed capacity with an average annual production of 26 billion kWh. These figures represent 19 per cent of the 8.5 million ha of the economically irrigable land in Turkey, and 20.5 per cent of the country's hydropower (Kolars 1994, p. 48) (figure IV).

The main components of the GAP project are: the Keban Dam constructed in 1974 with a storage capacity of 30.6 BCM; the Ataturk Dam, completed in 1983 and refilled in 1990 and 1991; and the Karakaya Dam (9.54 BCM), which was completed in 1988. The GAP project was launched in 1984 as an integrated project for the development of Euphrates-Tigris waters through the construction of dams, irrigation systems, and hydropower generation. In addition, 14 dams on Euphrates and eight more water projects on the Tigris within Turkish territory are proposed within the framework of the GAP project. Another structure, which is the 26.4 km-long Urfa Tunnel for canalization of the water (328 m³/sec flow) from the Ataturk reservoir, was constructed to irrigate about 143,000 ha at Harran and Sanliurfa plains in Turkey (Chalabi and Majzoub 1995, p. 205).

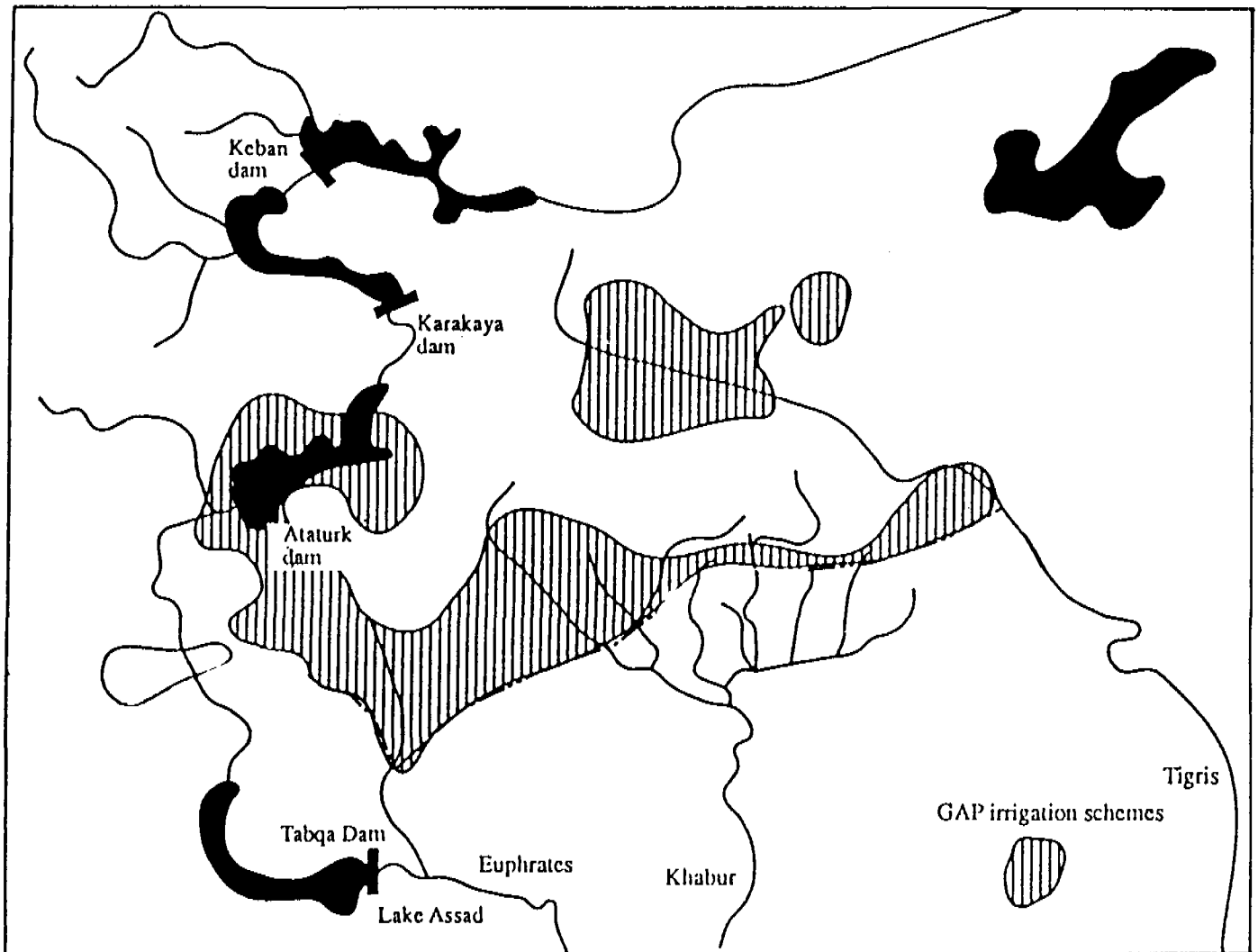
It has been reported that once the above projects are completed the annual flow of the Euphrates will fall from about 30 BCM to about 16 BCM in the Syrian Arab Republic and to about 5 BCM in Iraq. The quality of the river waters will deteriorate accordingly (Chalabi and Majzoub 1995). Thus, the Syrian Arab Republic and Iraq are concerned about the impact of the GAP project on the Euphrates-Tigris waters, particularly on the Syrian side, as the Euphrates is the only river of considerable size to flow through the country. This situation may be aggravated due to the absence of mutual agreements or treaties among the riparian States in the region that would regulate the sharing of the multinational rivers and determine the rights and obligations of each country involved. All recent and past negotiations have failed because of the determination of each of the riparian States to keep exclusive control of the Euphrates-Tigris river waters in their respective territories.

The main dispute over the Euphrates-Tigris waters stems from the different attitudes of the riparian States in regard to the international river or transboundary river. The Syrian Arab Republic and Iraq consider the Euphrates and Tigris to be international rivers, and consequently claim a share of their waters. Although Turkey recognizes the international character of these two rivers, it only speaks of rational and optimal utilization of the single and unique cross-frontier river basin, the transboundary waters or cross-border waters. Moreover, Turkey sees the unlimited use of these waters according to its needs as its most natural right. Turkey makes a clear distinction between an "international" river and a "transboundary" river. An international river is defined as a river, the two banks of which fall under the sovereignty of two or more States. These waters have to be shared by the riparian countries through the median line or *talweg*. For transboundary watercourses, or rivers crossing State borders, Turkey merely holds that the waters should be used in a fair, reasonable and optimum manner (Chalabi and Majzoub, p. 213).

All attempts at negotiation, notably in 1962 and later in 1982, have failed. No agreement among the three riparian countries to share the Tigris and Euphrates waters has been reached, as Turkey continues to claim exclusive control of the water from the two rivers. There exists only a Protocol, signed in 1987, by which Turkey verbally agreed to deliver 500 m³/sec of the Euphrates river water to the Syrian Arab Republic, although Iraq and the Syrian Arab Republic have asked for a flow of 700 m³/sec. A tripartite committee for the exchange of technical information is the only forum accepted for cooperation between the riparian States.

J. Kolars (1994) has reported that the GAP when fully implemented would conceivably have three main impacts on downstream countries: first, the diminishing of downstream flow to about 360 m³/sec, instead of the agreed-upon volume of 500 m³/sec, as a result of water loss by from storage reservoir surfaces; second, the detouring of significant quantities of water from the main channel through the Urfa Tunnel to the Urfa-Harran-Mardin irrigation projects; third, the possible pollution of mainstream and tributary waters by the return flow from irrigated fields and, hence, deterioration of water quality which would take place on the Euphrates and Tigris waters as more and more irrigation projects came on line in the upstream country.

Figure IV. The Greater Anatolia Project (GAP) showing the extent of the proposed irrigation schemes in Turkey.



Source: H. Chalabi and T. Majzoub, "The Euphrates and public international law", *Water in the Middle East: Legal, Political and Commercial Implications*, J.A. Allan and Chibli Mallat, eds. (London, I.B. Tauris, 1995).

This figure was considered appropriate at the time of implementation of the study and does not imply the expression of any opinion whatsoever concerning the legal status of any country, territory, city or area, or of its authorities, or concerning the delineation of its frontiers or boundaries.

3. Jordan River system

The catchment of the Jordan River, excluding the upper basin, is all arid to semi-arid. The total catchment area of the Jordan River is 18,300 km², of which 3 per cent lies in pre-1967 Israel. The lower Jordan River between Lake Tiberias and the Dead Sea has a catchment area of 1,050 km². The Jordan River originates in the southwestern Anti-Lebanon range, on Mount Hermon, which is covered with permanent snow. The river flows through Israel, Jordan, Lebanon, the Syrian Arab Republic, and the West Bank. The discharge that feeds the upper part of the Jordan River is derived principally from a group of karstic springs located on the western and southern slopes of Mount Hermon. The river flows southwards for a total distance of 228 km before emptying into the Dead Sea. Its principal tributary, the Yarmouk, forms the border between the Syrian Arab Republic and Jordan and divides Israel from Jordan in the Yarmouk triangle. The lower reaches of the Jordan River border on the Israeli-occupied West Bank to the west and Jordan to the east for a distance of about 80 km (Naff and Matson 1984; Murakami and Musiaka 1994, pp.117-154).

The quality of water in the headwaters of the Jordan River is excellent, with salinity less than 15 to 20 mg/l of chloride. The flow in the lower reaches of the system is supplemented by groundwater of such poor quality that it degrades the quality of the river flow, to the extent of several thousand parts per million of total dissolved solids (TDS) at the Allenby Bridge near Jericho (Murakami and Musiaka 1994).

The major headwater streams and their average annual flows that contribute to the Jordan River system are: the Yarmouk (446 MCM/a), the Dan (245 MCM/a), the Hasbani (138 MCM/a), the Banias (121 MCM/a), the Zarqa (95 MCM/a), the Mujib (42 MCM/a) and the Hasa (41 MCM/a) (Murakami and Musiaka 1994).

Conflict over the Jordan River system has been intractable because this complex hydrological structure is shared by four hostile riparian States: Israel, Jordan, Lebanon and the Syrian Arab Republic. The Arab-Israeli conflict has overshadowed efforts to reach an agreement on cooperative utilization of the river water system. Development schemes to utilize the Jordan River system date as far back as 1913. Some of these development plans considered the Litani River as part of the Jordan River system, while other schemes excluded the Litani waters, as it is a totally Lebanese river in its origin and course.

Water allocations to the riparian States as per the development plans drawn up by different sponsors for the Jordan River system are as follows:

(Millions of cubic metres)

Plan	(Source/Year)	Lebanon	The Syrian Arab Republic	Jordan	Israel	Total
Main Plan	(UN:1953)	-	45	774	394	1 213
Arab Plan	(Arab:1954)	35	132	698	182	1 047
Cotton Plan	(Israel:1954)	451	30	575	1 290	2 346
Johnston Plan	(USA:1955)	35	132	720	400	1 287

Source: M. Murakami, and K. Musiaka, "The Jordan River and the Litani", *International Waters of the Middle East: from Euphrates-Tigris to Nile*, Water Resources Management Series, vol. 2 (Bombay, Oxford University Press, 1994), p. 119.

Government authorities of the riparian countries have failed to agree on any of the plans cited above. This stalemate in negotiation persists for political reasons. The situation was seriously aggravated by the

1967 war. Jordan, the Syrian Arab Republic and Lebanon (co-riparians), responded to the Main Plan with their 1954 plan based on the fact that 77 per cent of the waters of the Jordan River system originate in Arab countries. Their plan reaffirmed the principle of exclusive in-base use of the water, rejected storage in Lake Tiberias, and rejected the integration of the Litani River (Naff and Matson, 1984, p. 40). With the failure of negotiations the riparians decided to proceed with water development projects situated entirely within their own boundaries on a unilateral basis.

In March 1953 Jordan and the United Nations Relief and Works Agency for Palestine Refugees in the Near East (UNRWA) signed an agreement to execute what was known as the Bunger Plan which included the diversion of water from the Yarmouk River via the construction of two dams at Maqarin and Adasiya and canalization of water into the Jordan Valley. In June 1953, Jordan and the Syrian Arab Republic agreed on sharing the Yarmouk water. However, these agreements were faced by protests from Israel.

Afterwards, unilateral water development projects were undertaken within the riparian territories. Jordan has carried out water resource projects on the Yarmouk River and in the east Jordan Valley, with three major components. They are:

(a) The East Ghor Canal (EGC) project to divert part of the Yarmouk River base flow (maximum flow volume of 158 MCM/a) with the conveyance of about 45 MCM/a of water (Deir Alla project) to meet growing water demand (municipal and industrial) for the capital, Amman, and surroundings. The EGC project started in 1964 and reached the Dead Sea in early 1980s;

(b) The construction of a number of dams on the main Jordan Valley side *wadis* (Wadi Arab, Ziglab, Zarqa, Shueib and Kufraïn). These side *wadi* dams, which were executed between 1968 and 1987, were intended to make use of flood waters as well as to store treated sewage effluent from the main treatment plants serving the populated centers in Jordan (Amman, Zarqa and Irbid);

(c) The third project included in the Jordanian plan was the construction of the Al-Wahda Dam on the Yarmouk River. As per the agreement between the Syrian Arab Republic and Jordan in 1988, the dam was intended to have a gross storage capacity of 225 MCM and an effective storage volume of 195 MCM annually. The stored water volume would be used to irrigate sites in the Jordan Valley and to convey 50 MCM/a to the greater Amman area. It was also expected to generate about 18,800 kWh of electrical power. The project was not implemented owing to Israeli opposition before and after the 1967 war.

In Israel, the National Water Carrier (NWC) is the major water development project that has been carried out. The NWC diverts water from the Jordan River Fork at Eshed Kinrot at Lake Tiberias to the coastal plain and the Negev desert. The project began in 1953 and was completed in 1964. The initial diversion capacity of the NWC was 180 MCM/a in 1964. This capacity was soon increased to 360 MCM/a in 1968 and is believed to reach a maximum capacity of 500 MCM/a (Murakami and Musiaki 1994, p.135). It has also been reported that at present, the Israeli national water grid interconnects supply-demand areas with approximately 1,400 MCM/a, or about 90% of Israeli water resources, and that more than half of this water is obtained from the Jordan River (upper Jordan River system) and tributaries located outside its pre-1967 boundaries (Naff and Matson 1984, p. 49).

In addition to the NWC, Israeli control over area water resources was extended by the 1967 occupation of the Golan Heights and the West Bank. In 1984, six reservoirs in the central Golan were completed, thus preventing about 20-25 MCM/a from flowing into Lake Tiberias, besides the transference of about 50 MCM/a

from the water-rich upper Jordan River system to the Golan Heights to meet the irrigation and domestic demands of settlements in the Golan (45).

The Syrian Arab Republic has implemented a number of small and medium sized dam development schemes within the framework of the Upper Yarmouk.

In addition to the above development schemes undertaken by the riparian States, other proposed projects to be carried out on either a unilateral or bilateral basis include the Mediterranean/Dead Sea and Red Sea-Dead/Sea Canal projects. These projects relate to hydroelectric power generation and they are at the feasibility study stage at present.

The above water development schemes would affect water flow rates in both the Jordan and Yarmouk rivers as well as lead to the deterioration of water quality at the lower reaches of these rivers for the riparians downstream. As conceived, these schemes would lower the level of the Dead Sea. Upstream diversions and/or inter-basin water transference to meet irrigation project expansion would reduce plantation in the downstream countries as well as dump saline waters from the deep-seated sub-marine salty spring waters in Lake Tiberias into the Jordan River.

In the context of the Arab-Israeli peace process, Jordan and Israel signed a treaty on 26 October 1994. Negotiations with the Syrian Arab Republic are still underway and the Palestinian Authority has postponed discussion of the water issue to the final stage of the negotiations with Israel.

The treaty on water between Jordan and Israel seeks to achieve a comprehensive and lasting settlement of all the water problems between them. Paragraph 1 states: "The parties agree mutually to recognize the rightful allocations of both of them in Jordan River and Yarmouk River waters and Wadi Araba groundwater in accordance with the agreed acceptable principles, quantities and quality as set out in [Annex II of the treaty], which shall be fully respected and complied with".

Jordan and Israel agreed on seven articles on such water-related matters as allocation, storage, water quality and protection, groundwater in Wadi Araba, notification and agreement, and cooperation including the formation of a joint water committee, which is indicated in Annex II of the treaty.

In regard to allocation of water from the Yarmouk River, it was agreed that Israel would pump 12 MCM and that Jordan would get the rest of the flow in the summer period of each year. In the winter period Israel would pump 13 MCM and Jordan would be entitled to the rest of the flow subject to the provisions outlined below. Under the terms of the treaty, Jordan concedes to Israel the pumping of an additional 20 MCM from the Yarmouk in winter, in return for Israel conceding to Jordan during the summer period 20 MCM from the Jordan River. In the winter period of each year Jordan is entitled to store for its use a minimum average of 20 MCM of the flood waters on the Jordan River, and it is also entitled to an annual quantity of 10 MCM of desalinated water produced from about 20 MCM of water from a saline spring now diverted to the Jordan River (16).

The treaty provides for cooperation between Jordan and Israel in finding sources for the supply to Jordan of an additional quantity of 50 MCM/year of water of drinkable standards. To this end, the Joint Water Committee is charged to develop, within one year from the entry into force of the Treaty, a plan for the supply to Jordan of the above-mentioned additional water. The plan is to be forwarded to the respective Governments for discussion and further action decision (16). In June 1995, a pipeline which brings drinking

water from Lake Tiberias to Jordan was opened. According to the treaty, it is expected to carry some 30 MCM of water per year (Economic Intelligence Unit, *Jordan Country Report*, No. 3 1995, p. 9).

Water issues were paramount in the October 1994 treaty signed by Israel and Jordan. Both parties agreed to hold meetings to discuss the improvement of water sources and their more efficient exploitation (*Middle East Economic Development*, 27 January 1995, p. 27). The treaty puts forth regional schemes to be studied and investigated. An additional 215 MCM is expected to become available to Jordan as a result of the treaty. Several storage dams on the Yarmouk and Jordan Rivers are to be constructed, and a desalination plant to treat 20 MCM of saline springs currently diverted to the Jordan River will be built to supply Jordan with 10 MCM of drinking water quality. Other regional arrangements include storing water in Lake Tiberias in winter and supplying it to Jordan in summer time (35).

Israel, Jordan and the Palestinian Authority signed a water-sharing agreement on water resources (described as a framework) in Oslo on 13 February 1996. According to a Norwegian Foreign Ministry spokesman, the agreement, which will have to be approved by the three Governments, is intended to outline principles for cooperation on existing supplies as well as new sources, such as desalination, but does not include detailed plans for water management. However, this framework is considered to be very significant because it is the first regional agreement for sharing water that has been accepted (52).

B. REGIONAL AND SUBREGIONAL GROUNDWATER BASINS

Water-related activities at the subregional and regional groundwater basins are very limited; few subregional groundwater projects are known to have been implemented during the last decade. Existing projects are described below:

1. *The Hamad Basin*

Planning for the Hamad Basin project began in 1975. This plan was based on an integrated study of both available and potential natural resources in the basin; water-resource surveys were given special attention. The four countries sharing the basin (Iraq, Jordan, Saudi Arabia and the Syrian Arab Republic) agreed to cooperate within the framework provided by this plan. In 1978, the member countries concerned agreed upon the project documents formulated by the Arab Center for the Studies of Arid Zones and Dry Lands (ACSAD). The project was begun in 1979 and lasted for four years. National follow-up projects within the Hamad Basin are currently being implemented (23).

The project area indicated by the formulated plan was originally about 100,000 square km², but was later increased to encompass entire areas belonging to the basin in the countries concerned.

Objectives for the project included: acquiring the basic information necessary for comprehensive socio-economic development of the basin; improving the living standards of the inhabitants; and evaluating the basin's natural resources, including surface, groundwater, vegetation and animal resources.

The project includes the following activities:

(a) Topographical survey using available maps and interpretations of satellite imagery, plus the preparation of a base map on a scale of 1:500,000;

- (b) Climatological studies using existing meteorological data as well as that collected during the course of the project;
- (c) Surface- and groundwater points inventory, analysis and evaluation;
- (d) Geological studies and hydrogeological correlations, as well as delineation of the main water-bearing formations and determination of their hydraulic parameters;
- (e) Collecting, compiling, recording and storing of water data;
- (f) Conducting a soil survey, plus wildlife and vegetal-cover studies.

2. *Project for shared groundwater resources in the Gulf States*

As per the request of the secretariat of the Council of Ministers of Agriculture in the Gulf States and the Arabian Peninsula, the Food and Agricultural Organization of the United Nations (FAO) carried out a shared-water project during the period April 1977 to May 1979 (11).

The aim of the project, as agreed upon between FAO (the executing agency) and the Council of Ministers, was to undertake the following:

- (a) Gather all documents which deal with the water resources of the region (project area) and evaluate them thoroughly;
- (b) Develop a conceptual hydrogeological model for the Eastern Arabian Basin, based on all available data;
- (c) Fit each country into the resulting model and determine how each shares its water resources;
- (d) Draw up a programme for future investigations aimed at better quantification of the shared resources, and prepare a pumping programme to ensure equitable sharing by the countries concerned.

To achieve the above, the FAO technical team reviewed and evaluated the available water sector data and documents relevant to the project area (1.7 million km²), including information pertaining to geological setting, geophysical surveys, hydraulic and hydroelectric-chemical parameters, and hydrogeological conditions prevailing in the project area.

Data on piezometry, water quality and well inventory were also presented on maps, and geological cross-sections were drawn. A summary of all significant hydrogeological data and the results of previous studies carried out in the area were included as well. The aquifer systems in the area under study are described as follows:

- (a) System A: the main aquifer system which recharges in inland Saudi Arabia and underflows to the east, to its eventual discharge into the Gulf;
- (b) System B: composed of discontinuous fresh-water lenses which extend from coastal Saudi Arabia across Bahrain and Qatar, and into central Abu Dhabi, United Arab Emirates. This system also includes the

shallow, unconsolidated aquifers of the eastern United Arab Emirates and inland Oman, the fresh-water aquifer in northern Kuwait, and areas in south-eastern Iraq.

A groundwater simulation model was developed, based on the data collected and a review of previous findings. The model simulated the main aquifer systems in the basin, and such features as the recharge sources and discharge areas in the different localities of the project area and water quality. The project concluded by classifying the resources according to their source aquifers, determined the hydrogeological situation and hydraulic model for each aquifer system, and established the extent of sharing which is possible within the framework of the proposed hydraulic mode; it also concluded that further studies are required in Bahrain, Kuwait and the United Arab Emirates, and recommended that a data bank and retrieval system for hydrological and hydroelectric-meteorological data be established. In addition, further interpretation of the available and future data, records, and reports should be undertaken, and the interpretations should be of a more scientific nature.

The hydrogeological conditions prevailing in the Yemeni subregion of the project area, based on available data, records and previous investigations, were studied and described. It was concluded that the largest area for the potential sharing of groundwater resources is that between Yemen and Saudi Arabia. Groundwater in the Cretaceous sandstone and Umm er Radhuma aquifers is recharged in Yemen and flows towards Saudi Arabia. The available data does not provide enough information for a precise statement on the extent of potential sharing in this area.

3. Investigation of basalt aquifer system shared by Jordan and the Syrian Arab Republic

A potential shared basalt aquifer occurs between Jordan and the Syrian Arab Republic. Intensive water withdrawal is taking place in Jordan as it furnishes one of the main water supply sources for Greater Amman, as well as in the southern Syrian Arab Republic, affecting the water quality and quantity. Both Jordan and the Syrian Arab Republic are currently engaged independently in further study of this aquifer, aiming at increasing the respective country's water supply. Additional groundwater extractions may worsen the situation. The basalt flows contain groundwater resources of regional extent and, in some areas, local perched groundwater occurs (36).

ESCWA initiated a study of this subregional basalt aquifer system, extending over an area of about 25,000 km³ and shared by Jordan and the Syrian Arab Republic, as part of its activities during the biennium 1994/1995. The study was implemented in cooperation with the appropriate authorities in both countries, namely the Water Authority (WAJ) of the Ministry of Water and Irrigation of Jordan and the Department of Irrigation and Water Resources of the Ministry of Irrigation of the Syrian Arab Republic. Subregional cooperation was substantial during the course of the investigation.

The immediate objectives of the study were: (a) to establish an information base on the hydrogeological conditions of the basalt aquifer region, which is needed for sustainable management of the groundwater resources; (b) to formulate proposals for further studies and technical measures for water resource development, management and conservation in specific areas; and (c) to introduce appropriate methods such as remote sensing and isotope hydrology for groundwater exploration and management in the basalt aquifer area.

The long-term objective of the project is to achieve optimized sustainable management of the available water resources in the basalt aquifer region.

A geological map was constructed for the area primarily comprising the basalt aquifer system shared by Jordan and the Syrian Arab Republic. Remote sensing techniques coupled with groundtruth data, and incorporating the outcome of the previous investigations, facilitated the preparation of a unified geological map which served as a major source of information on assessment and development of groundwater resources in the study area. The map presented, in addition to the surface geology, correlation of the main lithostratigraphic units, geotectonic framework and the major geologic structures that have direct control over groundwater occurrence, movement and potentials within the study area.

The study comprised an evaluation of existing data through an iterative process of data processing, digitizing of relevant features from maps, plotting of maps as working sheets and drafts and discussion with specialists of national institutions in Jordan and the Syrian Arab Republic. The main results of the study were the presentation of 15 thematic maps to be used for the purposes of water resource planning and the provision of regional information to the national institutions. The information was to a certain extent directly applicable to the planning and execution of groundwater development and management measures, such as the quantitative assessment of groundwater resources, the adequate design of irrigation schemes or the delineation of prospective groundwater exploration areas.

Data lists, documents and digital files provided by agencies in Jordan and the Syrian Arab Republic as well as information available from publications, reports and maps were stored in computer files and processed with commercial computer software. The data evaluated for the study comprised records on various parameters from boreholes and springs, groundwater quality, and isotope hydrology. Evaluation of the data resulted in the preparation of thematic maps drawn to a scale of 1:500,000 or 1:1,000,000.

The prevailing hydrogeologic conditions of the basalt aquifer system described in brief in the study include groundwater flow; depth to groundwater level; the total thickness of the basalt aquifer system; groundwater salinity; the hydroelectric-chemical water composition in aquiferous layers of the basalt as well as in underlying carbonate aquifers; and aquifer hydraulics and groundwater movement in the main basalt aquiferous horizons. No particular evaluations of groundwater balances were made in the framework of the study. A discussion of groundwater balances is therefore restricted to general considerations and an outline of information available from earlier reports.

The study also briefly surveys the hydrologic conditions in the area, covering mainly the drainage pattern, rainfall, evaporation, surface run-off and infiltration over the basaltic region within Jordan and the Syrian Arab Republic. The study concludes with follow-up actions and recommendations for integrated water resource development and management in the basaltic region within Jordan and the Syrian Arab Republic. These conclusions relate to groundwater exploration programmes, most promising areas and aquifer potentialities, water quality rehabilitation in specific areas within the basalt aquifer, surface-water impounding and artificial groundwater recharge, as well as rainfall harvesting measures. Other recommendations include: improvement of monitoring programmes on water levels, water quality and well discharges; evaluation and assessment of aquifer parameters; and establishment of a comprehensive water data base.

Finally, the study has concluded that mutual cooperation and coordination for developing and managing the shared watershed, comprising the basalt aquifer, is extremely beneficial for Jordan and the Syrian Arab Republic. The ultimate goal of shared basin development is a comprehensive plan dealing with measures to ensure rational development, utilization and conservation of water resources, taking into account the socio-economic factors prevailing in both countries. In this respect, the study recommends setting up a joint advisory steering committee responsible for coordinating, following-up and exchanging information regarding

watershed investigations. This committee may be composed of representatives of water authorities for the Governments concerned.

4. *Carbonate aquifers of the Lower Tertiary (Palaeogene) in the ESCWA region*

Mesozoic to Tertiary carbonate rocks extend over wide parts of the geological province of the Arabian shelf. The carbonate sequence, comprising predominantly limestones, dolomites, chalks, marly limestones and marls, was deposited during a long period of submersion of the Arabian shelf under the sea, which lasted from the Middle Cretaceous until the Eocene epoch. The carbonate sequence includes two important aquifer complexes:

Cretaceous limestones and dolomites with major outcrops in the sub-humid northwestern part of the ESCWA region;

Palaeogene deposits comprising primarily limestones and chalky limestones, which extend over the following areas:

- (a) Wide parts of the steppe (Badiyah) and the Hamad areas in Iraq, Jordan, north-western Saudi Arabia and the Syrian Arab Republic;
- (b) Parts of eastern Saudi Arabia, the Gulf region, southwestern Oman and south-eastern Yemen;
- (c) Parts of the semi-arid to sub-humid region in Lebanon, the Syrian Arab Republic and the occupied territories.

The Palaeogene aquiferous formations are denominated in different countries: Eocene (Middle to Upper Eocene, Lutetian), Rijam and Sallala limestone, Umm er Radhuma and Dammam, Umm er Rhaduma and Jeza.

A study of groundwater resources in Palaeogene aquifers of the ESCWA region was included in the work programme of 1996/1997 within the general scope of ESCWA activities to promote cooperation between member countries in the field of management of water resources and to provide Governments with the required information and capabilities for the management of shared water resources.

According to a preliminary evaluation of available information, the groundwater potential of the Palaeogene aquifer system in different sub-regions can be assessed as follows:

- (a) Palaeogene aquifers of limited extent occur in synclinal structures of the mountains and highlands west and east of the rift zone. The aquifers are important at least for local water supplies, such as the Jenin aquifer in the West Bank.
- (b) In the north-western part of the Syrian Arab Republic, Palaeogene chalks and limestones provide a fissure-type aquifer with generally moderate productivity. The aquifer contains the only fresh water sources in wide areas of the north-western Syrian Arab Republic. Groundwater is replenished from annual rainfall but intensive exploitation of the aquifer for irrigation and domestic supply has already led to near-depletion in some areas.

(c) In the Hamad and Wadi Sirhan areas, extending over the southern part of the Syrian Arab Republic, eastern Jordan, southwestern Iraq and northwestern Saudi Arabia, Palaeogene chalks, limestones and cherts constitute an aquifer with generally low to moderate productivity and fossil brackish groundwater. Fresh water lenses along major *wadi* systems are sustained by infiltration of wadi run-off.

(d) The Euphrates-Gulf Basin comprises an outcrop belt of Palaeogene carbonate rocks extending more than 1,500 km from southern Iraq to eastern Saudi Arabia. The carbonate rocks are partly karstified and are part of a complex aquifer system which extends from the outcrop belt eastward and northeastward until the Euphrates and the Gulf. The Palaeogene aquifer system constitutes one of the most important groundwater reservoirs of Saudi Arabia. The groundwater is, however, prevailingly fossil; present-day recharge is very limited as a result of the arid climate conditions. Fresh water lenses are sustained by recent recharge under karstic surfaces in the Gulf area, such as in Qatar and Bahrain. In Kuwait, brackish groundwater is extracted from Palaeogene aquifers for irrigation and as a mixing component for domestic supplies.

(e) In the Rub al Khali Basin, the Palaeogene is, to a large extent, covered by sand seas. On the southern fringes of the Rub al Khali in Hadramawt, Dhofar and central Oman, some present-day recharge apparently occurs in *wadis*. The groundwater of Palaeogene aquifers below the sand seas of the Rub al Khali appears to be prevailingly brackish. Groundwater movement is probably directed from the mountainous fringes of the basin towards *sabkha* areas within the desert and along the Gulf coast.

The main challenges to utilization of the water resources of Palaeogene aquifers in the ESCWA countries are:

- (a) Safe management of limited renewable fresh water resources;
- (b) Rational extraction of extensive non-renewable resources of fresh to slightly brackish groundwater;
- (c) Conservation of the quality of exploitable water resources.

The study carried out by ESCWA aims to contribute to the realization of these objectives by conducting a comparative evaluation of water resources in the region.

5. *Rum-Disi-Saq aquifer system*

The Rum-Disi-Saq aquifer system (henceforth referred to as the Rum group or Rum aquifer) is underlain by the Araba complex and basement rocks. The Khreim group, which comprises the Hiswah shale and the Dubaidib sandstone, is above the Rum group. The Khreim group is absent in the western part of the Rum group and in its place, overlying the Rum group, are younger deposits which include the Kurnub and the Ramtha formations.

The Rum group mainly comprises the Disi and Umm Sahn formations of the lower Palaeozoic. It extends at outcrop from central Saudi Arabia westwards and northwards through Tabuk, Disi, and Petra, with the most north-westerly occurrence at the eastern shores of the Dead Sea. In sub-cropping areas, this formation is known to extend northwards and eastwards underlying the whole of the Rum group. Evidence of its thickness and depth in the subcrop has been collected from borehole records. Structures such as faults, intrusions, and dikes are present in the area. Enclosed within the Rum group is the Karak-Wadi Finn fault, the Fein-Zakimat Al-Hasa fault zone, and the Siwaqa fault.

This aquifer has a generally uniform, consistent lithology over large areas and attains a thickness of over 2,000 m. The depositional environment varies from fluvial braided stream conditions to fluvial contextual conditions. The overlying Hiswah shale, which is a confining layer comprising laminated black to gray-brown micaceous silty shale and siltstone represents a post-transgression, fully marine depositional environment.

The Dubaidib and the Mudawarra formations which overlie the Hiswah shale form a leaky aquifer. In the absence of the Hiswah shale and the Dubaidib leaky aquifer, the Rum aquifer is in hydraulic connection with the younger aquifers of the Kurnub formation. As a result, the waters in these two aquifers may mix and have a common flow path. In hydrogeological system definition, it is also normal to identify the base of the system. Although of little relevance, as the thickness of the aquifer above the base is so great, it is here formed by the Araba complex and the basement, and for all intents is hydraulically insignificant. The most significant new information obtained by Haiste International and Scott Wilson Kirkpatrick (1994) is that the Rum aquifer is met at a much greater depth than previously predicted (53).

The hydraulic controls are represented by groundwater flow contours which display the piezometric head and directions of flow. These permit interpretation of rates of groundwater movement. Flow commences from beyond Tabuk, Saudi Arabia, moving broadly northwards, crossing into Jordanian territory, passing Jafer, and converges towards the Dead Sea. Generally, the new data collected by Haiste International and Scott Wilson Kirkpatrick (1994) has suggested that although the pattern of previous piezometric contour maps was correct, actual water levels are slightly deeper.

Groundwater extractions from the 1980s have changed the pattern of groundwater flow, with a significant change in the Tabuk area. High rates of extraction there for agricultural purposes have produced a very extensive cone of depression, locally diverting the natural northeasterly groundwater flow direction. The only previous piezometric contour map demonstrating this change was in the UNDP report (1991). However, the satellite image interpretations made by Haiste International and Scott Wilson Kirkpatrick (1994) have concluded that the UNDP map neglects the extractions around Tabuk town and area to the east. Lack of field data from Saudi Arabia precludes the presentation of current conditions by means of contours; nevertheless, all calculations made here include the Tabuk extractions and their impacts have been fully assessed by Haiste International and Scott Wilson Kirkpatrick (1994) (53).

Very little information on the hydraulic conditions of the leaky aquifer exists, because in Jordan its yield is low and the water quality is poor. In Tabuk, this layer was originally the water supply source, but it was exhausted by substantial pumping (United States Geological Survey, *Saudi Arabian Atlas of Water Resources*, 1980).

In Jordan, four main farming corporations are currently active: Rum, WAFA, ARABCO, and GRAMECO. The Rum farm is located in the Ed-Disi area, and the other farms are around Mudawarra. In addition, an area of small private farms has recently been established around Quweira. Estimates of extraction have been compiled for all these farms (from a combination of agricultural company records, WAJ archives, flow-meter records, and new data). The production figures for Aqaba town water supply have been taken from a combination of Howard Humphreys (1986) and WAJ data, together with additional interpolation and extrapolation.

In Saudi Arabia, the main farming corporations are the TADCO and ASTRA farms. Actual production records were obtained by Haiste International and Scott Wilson Kirkpatrick (1994) for most of the period from 1983 to 1989, while satellite imagery from 1985 and 1993 facilitated the evaluation of area under

cultivation. After correlation with measured extractions by TADCO farm during the 1983-1989 monitoring period, an assessment of extractions from both the farms around TADCO and those around Tabuk for the period 1985-1993 were made. The extractions for Tabuk town and air base were derived from 1983 municipal supply figures in Pim and Kawecki (1987).

6. Assessment of water resources in the ESCWA region using remote sensing and GIS techniques

A project promoting regional and subregional cooperation in water resource development and management among the member States was initiated by ESCWA during the biennium 1994/1995, and completed in early 1996. The project sought to improve knowledge of water resources in the ESCWA region through application of the modern techniques of remote sensing and Geographical Information Systems (GIS). The project activities included regional assessment of surface and groundwater sources and formulation of water strategies, with an emphasis on shared water resources, through interpretation and analysis of hydrological, hydrogeological and remotely sensed data. Advanced remote sensing and GIS techniques were applied within the ESCWA region to define key features of the physiography of major watersheds, surface-water bodies, regional hydrogeology and land uses (37).

The application of remote sensing techniques has contributed to further refinements of the delineation of geomorphological characteristics of twenty major drainage basins, as well as geological lineaments, areal extent of aquifers, natural vegetation cover, and irrigated areas. The use of remote sensing in combination with GIS techniques also helped to integrate hydrological and hydrogeological information leading to further refined assessments of the surface run-off and flow of rivers, characteristics of groundwater hydraulics, recharge, and development activities as well as suggestions for development and management of both surface and groundwater resources of the ESCWA region.

A detailed analysis was carried out with respect to the shared water resources, especially surface water from the major rivers: Tigris, Euphrates, Nile, Orontes and Jordan. The project also reviewed groundwater potentials of aquifers in Ordovician sandstone (Jordan and Saudi Arabia), Dammam (Bahrain, Iraq, Saudi Arabia and the United Arab Emirates) and carbonates (Iraq, Jordan, Saudi Arabia and the Syrian Arab Republic).

The project culminated in the publication of a technical report addressing three major components: (a) methodology of remote sensing and GIS techniques related to water resource assessment and hydrological analysis, including regional physiography; (b) surface and groundwater resources and suggested of water strategies for development and management of shared water resources in the ESCWA region, and (c) the development of regional hydrological and hydrogeological maps.

Maps prepared in the framework of the project include:

- (a) Regional hydrological maps to a scale of 1:2,500,000 presenting major catchment areas, drainage lines, patterns, rivers and other major water bodies, lakes, dams and rainfall distribution;
- (b) A regional hydrogeologic map 1:2,500,000;
- (c) Hydrogeologic maps to a scale of 1:1,000,000 for three major shared groundwater basins:
 - (i) Palaeozoic sandstone aquifers in Jordan and Saudi Arabia;

- (ii) The Palaeogene Dammam aquifer in Iraq, Saudi Arabia, the Syrian Arab Republic and the United Arab Emirates;
- (iii) Upper Cretaceous and Palaeogene carbonate aquifers in Iraq, Jordan, Saudi Arabia and the Syrian Arab Republic.

These maps show groundwater flow pattern, water quality, aquifer boundaries, existing development areas and potential areas for future development.

The maps were prepared using information from existing maps, as well as reports based on images from National Oceanographic and Atmospheric Administration (NOAA) meteorological satellites and Landsat Multispectral Scanner images.

V. GENERAL FEATURES OF WATER DEVELOPMENT STRATEGIES AND POLICIES IN SELECTED ESCWA MEMBER COUNTRIES WITH SHARED WATER RESOURCES

In most of the ESCWA countries it has been recognized that there is a need to formulate a national water policy within the framework of the overall economic and social policies of the country concerned. The necessary legislation must be enacted to promote an institutional set-up, and this set-up should be adequate to provide a framework on water allocation, use, quality, and health and safety concerns.

In general, efficient implementation of national water strategies is founded upon some basic concepts, including, but not limited to the following:

(a) A well-studied and achievable water policy within the framework of overall national socio-economic plans, taking into consideration what is already known about the availability, potentialities and reliability of water resources, including shared resources and future demand;

(b) The possibility of developing feasible projects within the available financial, institutional, legal and skilled manpower capabilities at national levels;

(c) The creation of alternative scenarios for well-formulated plans and programmes for the development, conservation and management of water resources.

Since the above three components are tightly interrelated, any deviation or ill-definition of any of these may raise major difficulties for adequate implementation of the strategy. On the other hand, long-term water policy and plans may not be appropriate as a permanent water strategy because projections of future water demand depend, among other considerations, on eventual changes in economical, environmental, social, political, and technological conditions.

In the ESCWA region, as in many other developing countries, the situation does not deviate much from the above, although perhaps the water situation here is more critical and faces many more challenges owing mainly to the prevalence of aridity in the Arabian peninsula in the south, and the sharing of most of the water resources with other riparian countries in the north. It is evident that the countries in the ESCWA region should give more emphasis to integrated non-structural water management and structural water development. This recommendation is based on the observation that the present trends in water resource management in the region are generally inefficient, while the potential for additional development of water resources is considerably limited in view of their scarcity, distribution and sharing. However, these two basic models, water management and water development, will continue to be indispensably intertwined, and their integration remains a must.

The following sections review major features of the national water strategies for those countries sharing water resources (surface and/or groundwater) at subregional or interregional levels:

A. EGYPT

Egypt's main water resource is the Nile, the flow of which is regulated by the Aswan High Dam. The rapidly growing population puts a strain on available water resources, as well as on the provision of sanitation services. Therefore, quite a number of water resource projects in Egypt concentrate on providing safe water and sanitation to an ever-growing population. As water becomes even more scarce, attention is also being

placed on conserving water. For example, one way of improving irrigation techniques is to reuse drainage water to increase the irrigated area, as the agricultural sector constitutes the major water consumer. However, water demand in Egypt has increased not only parallel to the agricultural expansion plan, but also in relation to industrial development and population increases. It is anticipated that the share per person will be reduced from the present prevailing rate of 950 m³/year to about 500 m³/year by the year 2025 (13).

The need for strategic planning of water resources in Egypt has long been recognized. Development of a national water master plan, which essentially began in 1977 and ended in 1980 as phase 1, was followed by a second phase that continued up to 1986. A third phase of the project was still operating in 1995. The plan deals with the period up to the year 2000. It contains a detailed statement of the water management and development needs of the country, including descriptions, reviews, analyses and plans, and recommendations for projects and programmes in all water-related sectors of the economy. It includes investment and implementation schedules, production targets, means of implementation, economic costs and benefits of projects and programmes, rural employment and demographic impacts, and surface and groundwater distribution plans. In implementing this strategy, high priority was given to planning methods while less emphasis was placed on the preparation of specific projects. Rapid changes in technology and relative economic value made it more prudent to take an appropriate decision for each new potential development than to abide by a rigid plan based on assumptions that were subject to change.

The national water master plan anticipates three development scenarios:

(a) Scenario 1 assumes that water conservation projects will be constructed. Projected growth in water demand for the non-agricultural sector would be deducted, and the water balance which could be made available for the development of new lands would then be computed;

(b) Scenario 2 assumes that there will be a high rate of growth in the agricultural sector (4.9% annually, compatible with optimistic national projections for the economy). This scenario would assign some of the projected growth to the old lands, and the balance to new lands. To find total water demand the water requirements for non-agricultural uses would be determined;

(c) Scenario 3 assumes that there will be a moderate rate of growth in the agricultural sector (3% annually). Some of this growth would be assigned to the old lands, and the balance to new lands. To find total demand, it would be necessary to determine the water requirements for the resulting increase in new lands (50,000 feddans/year) and add the water requirements for non-agricultural uses (13).

The above-mentioned three scenarios imply the provision of sufficient water supplies to satisfy the water demand for each scenario. The major options for increasing water sources are drainage re-use projects, improved water management, and water conservation projects in the Sudan, one of the upstream riparians, to reduce evaporation losses in the area known as the *sudd*, or swamps.

Much progress has been made in Egypt's use of its national water resources. Concurrent use of surface, ground, drainage and treated wastewaters has enabled Egypt to cope with both the drought conditions which lasted from 1979 to 1988 and with the problems caused by the halted water conservation projects. These projects are expected to feed the Aswan High Dam Lake (Lake Nasser) at a rate of 7,500 MCM/year in their first phase, and at a rate of 8,900 MCM/year upon completion.

The national water master plan guarantees that there will be significant amounts of water used for agriculture independent of the supply-demand balance for the Nile. These will be drawn from the

groundwater resources of the New Valley in the oasis areas, the shorelands along Lake Nasser, and treated wastewater in the Greater Cairo area.

The groundwater resources available in the eastern and western deserts and in Sinai provide about 2,700 MCM/year and are expected to increase to 4,900 MCM/year after development (12).

Treated sewage and industrial wastewater currently contribute a total volume of about 1,400 MCM/year, and the amount is expected to reach 2,200 MCM/year by the year 2000. Drainage water is likely to be available for reuse at a rate of about 3,470 MCM/year for the five-year period 1987-1992 and should reach 6,500 MCM/year by the year 2000.

The strategy of utilizing potential groundwater resources in the Nile Delta and Nile Valley, the eastern and western deserts and in the Sinai is designed primarily to achieve the following (12):

- (a) Provide domestic water supplies;
- (b) Irrigate newly reclaimed lands at the peripheries of the Nile Delta and Nile Valley;
- (c) Improve the efficiency of agricultural production and the existing irrigation networks;

Government authorities have adopted a short-term water-use policy to overcome the Nile water shortage:

(a) By using the largest possible quantities of groundwater, agricultural drainage water and sewage drainage for irrigation;

(b) By rationing water in all fields and reducing withdrawal discharges from the High Dam Lake;

(c) By making adjustments for consecutive years with continuous shortage in the Nile supply. Then the withdrawal will be as follows:

(i) When lake storage is 60-65 BCM by the end of July, withdrawal is to be reduced by 10 per cent;

(ii) When lake storage is 50 BCM or less by the end of July, withdrawal is to be reduced by 20 per cent.

In view of the critical situation of Egypt's water resources, in both quantity and quality, it was decided to implement well-defined water policy objectives and evaluation criteria to safeguard the country's water resources. Various strategy options to augment the water supply, increase water use efficiency and manage water demand were evaluated. The evaluation process was based on the following criteria:

(a) Effectiveness, efficiency and environmental impact;

(b) Equity, fiscal impact and sustainability;

(c) Administrative feasibility, political and public acceptability, regional development and international considerations.

As a result of the analysis, it was possible to develop a list of priorities for the implementation of various strategy options. Strategy options with an 'above average' overall score include (46):

- (a) Modification of the winter closure;
- (b) Implementation of conservation projects in the Upper Nile basin;
- (c) Recycling Nile aquifer water;
- (d) Recycling of drainage water;
- (e) Utilization of desert groundwater;
- (f) Crecovery based on cultivated area and type of crop;
- (g) Utilization of rainfall;
- (h) Improvement water quality;
- (i) Limitation of the rate of land reclamation;
- (j) Enhancement of public awareness.

B. IRAQ

Surface water is the main source of water supply in Iraq. These resources are abundant and can provide great potential for development in irrigation, but also cause significant problems in terms of water control. The authorities in Iraq have paid a great deal of attention to controlling floods and lessening their hazards. Appreciable efforts have been made to develop surface water resources at the national level. A number of water structures have already been constructed while work on new projects is underway. Table 4 below shows the major water structures in Iraq.

TABLE 4. DAMS AND RESERVOIRS IN IRAQ

Structure name	Planned storage (MCM)			Remarks
	Normal storage	Live storage	Reserve storage	
<u>Structures at the Tigris River</u>				
Dokan	6 800	5 500	400	Existing (1959); for power and irrigation (P+I)
Tharthar	77 600	38 500	7 800	Existing (1956); Rehabilitated (1976); for regulation
Fatha	23 300	19 300	2 700	Planned
Mosul (Saddam)	10 700	9 700	1 800	Existing (1986); (P+I)
Bakhma	8 300	7 800	600	Existing (P+I)
Badouch # 1 and # 2	Under construction
<u>Structures at the Diyala River (Tigris tributary)</u>				
Darbandi Khan	3 000	2 500	1 100	Existing (1961) (P+I)
Himrin	3 950	2 300	1 400	Existing (P+I)
<u>Structures at the Euphrates River</u>				
Hadithah (Qadisiya)	8 200	7 500	2 200	Existing; for irrigation
Fallouja	..	3 600	..	Abu Ghreeb; for irrigation
Habbaniyah	3 300	2 700	..	Existing (1956); rehabilitated (1970)
Total	145 150	99 400	1 800	

Source: United Nations Economic and Social Commission for Western Asia, *Progress Achieved in the Implementation of the Mar del Plata Action Plan in the ESCWA Region (E/ESCWA/ENR/1992/5)*; updated, p. 31.

The water resource strategy of the Government of Iraq is generally dictated by two major constraints. The first of these is flooding and poor drainage. These have been the negative attributes of the considerable floods that flow through the two major rivers (Euphrates and Tigris) and their tributaries. Approximately 65 per cent of the irrigated area in Iraq suffers from soil salinity, and flooding is a perennial hazard. Much of the effort put into hydraulic works in Iraq has been designed to manage waters so that urban and agricultural areas stay free from inundation; the provision of water for irrigation has generally been taken into account. However, there remains a large area of agricultural land that has yet to be provided with access to irrigation water.

Of the two great rivers, the Tigris provides irrigation water for some 2.2 million ha, a proportion in the valleys of the north bank tributaries. The Euphrates serves approximately 1 million ha, while the joint rivers in the Shatt al-Arab provide water for another 105,000 ha. The principal water sources for irrigation are the five great reservoirs at Dokan, Darbandi Khan, Habbaniyah, Samarra and Abu Dibbis. Together they are reported to provide 120 km³ of storage capacity. This capacity is about to increase enormously as six additional water structures are brought into use at Himrin, Bekhma, Mosul and Fatha on the Tigris, and at Hadithah and Fallouja on the Euphrates. In all, they will provide another 45 km³ of live water storage.

The second constraint is related to policy issues. The strategy of the Government in recent years has been to compensate for the construction of dams by the upstream riparians by providing over-year storage inside Iraqi territory. This process can be long and expensive in view of the lack of joint agreements on sharing waters with the Syrian Arab Republic and Turkey and the ambitious plans for new dams that are emerging in Turkey under the GAP project utilizing the twin rivers. Therefore, the establishment of a well-formulated national water strategy in Iraq depends mainly on the reliability and continuity of surface-water supplies from the Euphrates and Tigris rivers, whose estimated annual flows are approximately 49.5 BCM for the Euphrates and 28.3 BCM for the Tigris. As mentioned in earlier chapters, in the absence of any concrete agreement among the riparian States (Iraq, the Syrian Arab Republic and Turkey) the formulation of a national water policy remains impeded. In view of the prevailing status of water availability, the Government of Iraq is seeking:

(a) To reach a mutual agreement among the river-riparian countries in order to assign a specific portion of the shared water, a matter which has been under debate since 1960 and continues until the present time despite the formation of an ad-hoc committee in 1983;

(b) To continue implementing water development projects as originally planned according to whatever resources may be available, including such integrated water development and management schemes as the construction of 133 irrigation projects and various types of dams, the reclamation of deteriorating lands, the construction of a main outfall drain (MOD) with a designed capacity of about 300 m³/sec and total length of 550 km, the reformation of swampy lowlands and river-tails, and the reduction of water losses in the streams and main canals (Jonathan Crusoe, "Iraq", *Middle East Economic Development*, February 1989, p. 62). Designs have been completed for another drain, the Euphrates East Drain (EED). The 261 km section includes the Shamiya West Drain and the Najaf Collector for the Kifl-Shinafiya irrigation scheme. It will feed into the MOD at Nasiriya.

The national water policy in Iraq has also focused on electricity generation at hydroelectric stations at dam sites and on the execution of drinking water supply and sanitation projects for all urban and rural areas. A well-formulated water strategy and well-defined water policy for Iraq would fall primarily within the following parameters:

- (a) Surface water as the main source of Iraq overall water supply;
- (b) The achievement of a mutual binding agreement among the riparian States sharing the water from the Euphrates and Tigris rivers;
- (c) Surface water flood control, management and impounding as well as hydroelectric-power generation;
- (d) Land reclamation and execution of large-scale irrigation and drainage schemes;
- (e) Water resource quality control and protection;
- (f) Establishment of appropriate mechanisms, including institutional arrangements, supported by legislative authority adequate to implement the formulated water strategy, as well as the establishment of a comprehensive water data base.

C. JORDAN

Water resources in Jordan are very scarce and vary in quantity and quality over the five development areas composing the country: the Jordan Rift Valley; the northern, central, and southern regions; and the Badia region. Jordan is considered to be on the list of the very water-scarce countries, with about 160 m³ per capita per year. Most of the country's water resources have been developed, and those remaining are expensive to develop, as the costs cannot be met from the national financial resources.

Most of the industrial and municipal water supply systems in Jordan depend on groundwater and springs. Several aquifers are being over-pumped and water resources depleted. The distribution of water resources does not correspond to the areas of highest demand, particularly the densely populated urban areas. The responsible authorities in Jordan, under pressure to meet increasing municipal and industrial water requirements, have constructed a complex conveyance system. The feasibility of constructing a pipeline network linking the entire water system in northern and southern Jordan to permit integrated resource management is under study. Pressure to develop new sources has sometimes led to the selection of costly solutions. One example is the Deir Alla pumping station, completed in 1985 and designed to pump, treat and convey 45 MCM per year to the Amman area (Water is pumped from 75 m to about 1,035 m above sea level and from a distance of 65 kilometres (17)).

Great progress has been achieved in many parts of the country in applying modern irrigation techniques designed to conserve the country's water resources. In general, non-conventional and limited conventional irrigation methods are presently utilized in Jordan.

The available water resources at present are as follows (47):

- Surface-water resources 492 MCM (17)
- Groundwater resources 418 MCM
- Other sources principally as per the Jordan-Israeli Peace Treaty, treated wastewater and sea water and brackish groundwater. ..

1. *Water provided by the Peace Treaty*

The Peace Treaty is supposed to provide:

- (a) 20 MCM from Yarmouk River water in winter, stored on the Israeli side and relayed to the Jordanian side during summer;
- (b) 10 MCM from the Jordan River, released from Lake Tiberias outside the summer season for Jordan until a saline water desalination plant is constructed near Tiberias;
- (c) Storage facilities on the Yarmouk and Jordan rivers (quantities and locations are under study);
- (d) 50 MCM with drinkable standards to be allocated for Jordan through cooperation between both parties;
- (e) Groundwater in Wadi Araba (currently under study to ensure Jordanian requirements in that area).

2. *Treated wastewater*

Jordan uses around 58 MCM/year of treated wastewater in unrestricted irrigated agriculture. This forms around 25% of domestic water and is expected to increase gradually, reaching 60% to 70% of the domestic water demand by the year 2020, when the population is projected to reach 10 million, with the expectation of increased demand resulting from intensive tourism and the expansion of light industries (47).

3. *Water strategy*

The Ministry of Water and Irrigation in conjunction with the Water Authority and the Jordan Valley Authority have recently issued the Water Utility Policy which was adopted by the Cabinet in its session held on 26 July 1997. As per this policy, the main features of the water strategy are excerpted below:

... Securing a reliable supply of water, adequate in quantity and quality, is one of the most challenging issues facing Jordan today. Planning and policy formulation for the supply and utilization of water resources will be based on comprehensive and reliable data, including data on water quantity, quality, and utilization. The supplies of surface water, groundwater, and treated wastewater, and their utilization will be carefully monitored. The importance of shared surface-water supplies and groundwater aquifers demands careful and consistent assessment and monitoring of these resources. Non-conventional water resources, particularly brackish water resources, will be assessed, as desalination becomes more economically feasible.

The full potential of surface water and groundwater shall be developed based on the economic feasibility and taking into consideration the relevant social and environmental impacts. Investigation works of deep aquifers shall be conducted to support development planning. The interactive use of ground and surface water with different qualities shall be considered, and assessment of the available and potential resources shall be conducted periodically.

A Water Strategy has been formulated by the Ministry of Water and Irrigation, and was adopted by the Council of Ministers on April 26th, 1997. The strategy stresses the need for improved resource management with particular emphasis being placed on the sustainability of present and

future uses. Special care shall be given to protection against pollution, quality degradation and depletion of resources. Furthermore, the Ministry of Water and Irrigation shall continually aim at achieving the highest practical efficiency in the conveyance, distribution, application and use, and shall adopt a dual approach of demand management and supply management, with tools of advanced technology being increasingly utilized to enhance the resource management capabilities. The interactive use of multiple resources shall be targeted to maximize the usable flows, and maximize the net benefit from the use of a unit flow of water. In conjunction with this, there will be a targeting of the minimum cost of operation and maintenance with the cost of production of future industrial, commercial, tourism and agricultural projects being measured also in terms of their requirements of units of water flow. Performance efficiency of the water and wastewater systems and the management thereof shall be monitored and rated, and the improvements on performance shall be introduced with due consideration to resource economics.

The Water Strategy ensures that the rightful shares of the Kingdom's shared water resources shall be defended and protected through bilateral and multilateral contacts, negotiations, and agreements. Peace water and wastewater projects, including the scheme for the development of the Jordan Rift Valley, shall be accorded special attention for construction, operation and maintenance. Due respect will be given to the provisions of international law as applicable to water sharing, protection and conservation, and those applicable to territorial waters. Bilateral and multilateral cooperation with neighbouring states shall be pursued, and regional cooperation with appropriate mechanisms shall be advocated.

As part of the Ministry's efforts to manage the water resources more efficiently a long range plan shall be formulated for the development of the resources, and a revolving five-year plan shall be extracted from it and updated as necessary. The revolving plan shall be compatible with those formulated for the other sectors of the economy. A parallel investment plan shall accompany the development plan. ...

In view of the above policy, the Government of Jordan is planning to carry out some measures to control, manage and conserve the country's scarce water resources. In brief, these undertakings primarily deal with the following:

(a) Institutional restructuring and the introduction of private sector involvement must be supported by adequate legislation, enforcement of water laws and regulations, and human resources development, including career development (continuing education, on-the-job training and training workshops) as well as the establishment of adequate and advanced training facilities. The restructuring programme will produce an overall framework articulated by the Ministry of Water and Irrigation and supported by well-identified functions of its components, the Water Authority (WAJ) and the Jordan Valley Authority (JVA);

(b) The Government intends to involve the private sector in the management of infrastructure and services in order to improve performance and ensure the delivery of services to the public. Emphasis will be placed on the social benefits to be obtained by working in conjunction with the private sector in irrigated agriculture;

(c) The Water Strategy will consider the move towards cost-recovery by the water projects implemented through the application of water pricing policies and tariffs based on the cost of water supply, operation and maintenance;

(d) Under water resource development, the Government intends to augment water supply through the construction of storage dams, and development and management of groundwater resources;

(e) Surface-water impounding activities are progressing well in Jordan. There are plans to make use of storm run-off water, and of flood water available during the rainy season. Water impounded by dams or retention reservoirs is used for domestic, industrial, irrigation and livestock purposes. By 1980, about 15 reservoirs had been constructed, with a total capacity of about 126 MCM. A number of impounding reservoirs with a total storage capacity of about 387 MCM are located in different areas of the Kingdom: the storage capacity of these dams ranges between 2 MCM and 220 MCM (Al-Wahde Dam) (34).

The Government of Jordan has also begun to develop rain-water harvesting practices. Desert pools have been rehabilitated or constructed, and flood-water spreading is being undertaken. Artificial groundwater recharge using flood water is being practised in different localities (Shueib and Khalidiya dams) and, as of 1989, was underway in others (the Siwatge, Al-Abyed, Jurdaneh, and the Azraq and Jafer basins);

(f) Groundwater sources close to population centres in Jordan have been extensively exploited for municipal and industrial purposes. Most of these sources are currently being extracted to or beyond the limits of reliable aquifer yields. Replenishable groundwater is presently used for municipal, industrial and agricultural purposes. It is estimated that about 354 MCM of this water is currently being utilized in different localities in Jordan, resulting in the over-pumping or depletion of Jordan's main aquifers at a rate of about 94 MCM (1989 estimates). Fossil groundwater constitutes most of the stored quantity of available groundwater in Jordan. The main potential for increased production lies within the fossil aquifer of the Disi basin in southern Jordan. Abundant amounts of brackish groundwater are available in Jordan, particularly in the Rift Valley and desert areas. Brackish or slightly-to-moderately salty groundwater is present in different aquifer systems in Jordan. As per the adopted policy, the desalination of brackish groundwater resources will be undertaken.

(g) The Government intends to enforce efficiently water regulations on private sector drilling operations, drilling permits, and abstraction licenses aiming at controlling groundwater quality deterioration and reservoir depletion. Monitoring programmes and establishment of a comprehensive data base are also planned.

(h) In regard to the reuse of treated sewage effluent, the construction of sewerage facilities has rapidly increased since 1984. Following the creation of the Water Authority of Jordan, 11 treatment plants were constructed and another 22 plants were planned and designed for urban and rural areas. Approximately 84 per cent of the population was served by sewerage networks in 1990, and 88 per cent should be served by 2015. At present, about 58 MCM/a of treated effluent is being utilized in agriculture. It is estimated that the production of treated effluent which can be used for irrigation will reach 116 MCM in the year 2005 and 165 MCM in 2015 (34);

(i) Some of the measures that the water utility policy of Jordan will seek to implement in the water sector include those related to environmental impacts and improvement of water supply services. By involving non-Governmental organizations as well as the private sector, the policy will endeavour to raise public awareness about the value and scarcity of the country's water resources. The policy will also consider management of water supply and demand as well as fund-raising to implement the above-mentioned action plan to develop, utilize, manage and conserve the country's water resources.

In brief, the formulation of a water strategy in Jordan will be guided by the following parameters:

1. Jordan is a water-scarce country.
2. Water resources in Jordan do not correspond to the areas of highest demand.
3. Certain issues must be considered for the purposes of national master planning and management:
 - (a) Inadequate water data, giving rise to water data generation and synthesis;
 - (b) Groundwater mining to a certain extent;
 - (c) Use of brackish groundwater (2000-4000), and desalination;
 - (d) Treatment and reuse of wastewater;
 - (e) Modern irrigation schemes;
 - (f) Surface-water impounding and rainfall harvesting;
 - (g) Efficient water-related institutional arrangements.
4. Water conflicts continue among riparians.

D. THE SYRIAN ARAB REPUBLIC

The Syrian Arab Republic depends on surface waters as well as groundwater for the agricultural sector and mainly on groundwater (springs and wells) for domestic supply. Due to financial constraints the development of surface water has slowed down. Intensive agricultural practices depending on groundwater resources have spread rapidly in recent years resulting in water quality deterioration and/or groundwater depletion in some areas within the Syrian Arab Republic. It is reported that the Syrian Arab Republic will soon have utilized all of its national water resources, and has already exploited most of the water resources in areas such as the Damascus Basin. International shared water courses, particularly the Euphrates and Tigris rivers, will be the only option for continued development and economic growth to meet the expected needs of a fast-growing population and country-wide agricultural and industrial developments.

The country's estimated water resources are:

Surface-water resources without the Syrian Arab Republic share of the Euphrates and Tigris rivers	3.56 BCM
Total annual renewable groundwater resources	7.78 BCM
Total inland water resources, surface and groundwater, without Syria's share of Euphrates and Tigris Rivers	<hr style="width: 10%; margin: 0 auto;"/> 11.34 BCM (48)

1. *Water policy guidelines* (48)

The general policy of the Government of the Syrian Arab Republic regards water as a national resource that should be exploited in accordance with public rights and national prosperity. Three main guidelines have been established for water resource development:

- (a) Provision of good quality drinking water for all citizens of the Syrian Arab Republic is the first priority;
- (b) Food self-sufficiency;
- (c) All possible and rational use of every available source of water that falls on, crosses or originates in the country.

Supplying drinking water is a continuous task. By the year 2000, the Government aims to provide better living conditions for the people by securing a safe and adequate water supply for all citizens. Financial resources and the limited availability of good quality water in some areas have been and remain limiting factors in achieving this target.

With such a concentrated policy focus on food security and food self-sufficiency, water policies in the Syrian Arab Republic have been synonymous with expansion of irrigated area to cover local requirements for agricultural produce, to meet industrial raw material needs and to provide a surplus of produce for export. The high population growth rate has always been a major obstacle to achieving this target.

The Syrian Arab Republic has been active during the last 25 years in surface-water development. A total of 142 dams have been built countrywide, with associated irrigation networks, pumping stations, land reclamation and swamp draining, especially in the Euphrates, coastal, Orontes, Yarmouk and Al-Khabour water basins. Irrigation projects have focused on expanding irrigated areas through investment of about 70 per cent of the entire agricultural budget in constructing dams and irrigation networks. The Government has encouraged the drilling of wells all over the country through a policy of subsidization.

This large investment in irrigation resulted in a very rapid expansion of the irrigated area, and also brought with it problems of water-logging and salinity, particularly in the Euphrates River basin, as a result of improper drainage.

To increase the water supply and meet the increasing demand for water, the Government is planning to continue to construct dams and irrigation and drainage networks. Many dams are already under construction and many others are under study for the Orontes, coastal and steppe basins.

During the last three years, strengthening and modification of the existing networks has been proceeding so as to establish an acceptable network for data collection, with the use of databanking for data classification and processing, and preliminary application of remote sensing and geographical information system (GIS) technology in water sector studies, assessment and master plan preparation.

Master plans for five water basins are being elaborated, involving detailed hydrological and hydrogeological studies so as to determine the optimum safe yield of the potential groundwater resources and to make use of all possible water resources, with better allocation and optimal economic use of water resources for various sectors. This will allow prioritization of projects and enhancement of programmes. Projects under study for ongoing or future water resource development include:

- (a) Completion of the Euphrates River basin groundwater study;
- (b) Investigation of groundwater in the Al-Khabour basin;
- (c) Research into water resource utilization to make the most efficient use of available water, especially for irrigation, taking into consideration soil suitability and the irrigation technology most likely to lead to the achievement of strategic goals in agricultural policy.

2. Non-conventional water resources

Owing to the limited water resources in some densely populated areas in the Syrian Arab Republic, such as the Damascus basin, reuse of water by renovating and recycling wastewater from municipal, industrial and agricultural effluent has become a concern for the Government.

A system of sewage collectors has already been constructed in Damascus City, and a wastewater treatment plan is under construction east of the capital. Sewage system proposals are under investigation for the other big cities in the Syrian Arab Republic (Hama, Aleppo, Latakia, Sweida, Deraa and Idlep) and have been completed for Salameh and Homs.

The authorities of the Syrian Arab Republic are also considering the reuse of excess irrigation-drainage water in order to alleviate soil salinization and waterlogging as well as furnish additional water supplies, particularly for the large-scale Euphrates irrigation projects. The possibilities and benefits of developing groundwater storage by artificial recharge are being considered, especially in the desertic areas. Several dams have been constructed in these areas to make use of flash floods for groundwater recharge and/or conjunctive use of surface and groundwater resources.

As per the declared water policy, the Syrian Government intends to undertake measures within the framework of its water demand management programme. These measures include proper pricing policies, metering and subsidy, and cost recovery. Other measures relate to the application of water-saving techniques for irrigation, the improvement of water supply and sanitation services, and effective groundwater management.

3. *Critical issues (48)*

Some of the critical issues in water resource strategy formulation in the Syrian Arab Republic are given below:

(a) *International water resources*

Agreements regarding the use and development of shared water courses are always complex and difficult to achieve, but without such agreements planning and development are never satisfactory.

Based on the principles of the draft law on the Non-navigational Use of International Water Courses, as adopted by the International Law Committee (ILC), the Syrian Arab Republic's equitable and reasonable share from all international rivers represents almost 70% of available water. The agreements concluded thus far are:

- (i) An agreement between the Syrian Arab Republic and Lebanon to allocate Orontes (Al-Asi) river water, which is about $400 \times 10^6 \text{ m}^3/\text{year}$ on the border between the two countries, was signed in 1994, and friendly discussion and evaluation of shared water usage of the Al-Kabir south river is underway;
- (ii) Jordan and the Syrian Arab Republic signed an agreement in 1987 to make use of Yarmouk River flow for irrigation and power production by constructing the Unity Dam;
- (iii) The Syrian Arab Republic and Iraq reached an agreement in 1989 on the waters of the Euphrates. Under this agreement, Iraq's share will be 58% and the remaining 42% will be for the Syrian Arab Republic;
- (iv) In a protocol signed in 1987, Turkey agreed to provide a continuous flow of more than $500 \text{ m}^3/\text{sec}$ for both the Syrian Arab Republic and Iraq at the Syrian border during the filling of the reservoir of the Attaturk Dam. However, when Turkey began filling this reservoir on 14 January 1990, the

flow of the Euphrates River into the Syrian Arab Republic and Iraq was reduced to a trickle for 30 days;

- (v) Iraq, the Syrian Arab Republic and Turkey, the three countries sharing the waters of the Euphrates River, have already constructed several hydraulic structures on the river to regulate floods, provide power, and supply water for irrigation. These projects were executed at national levels to satisfy each country's objectives.

Return flow from irrigated areas in Turkey may bring added pollution to the Euphrates, making the water less suitable for re-use downstream.

Increased salinity in the water of the Euphrates, already up from 400 ppm of TDS in 1989 to 1,360 ppm of TDS in 1990, would lay waste to 40% of the agricultural land in the Euphrates basin and also damage industrial installations and water treatment plants for domestic uses.

Because of the severe economic damage which could result from altered flow, both in quality and quantity, in the Euphrates, the water issue is one of extreme immediate concern to all parties, and it is therefore urgent for them to continue with efforts to achieve the necessary agreements on the use and development of international rivers and supplies of water. A peaceful, concerted effort is necessary in order to reach an agreement on an equitable and reasonable formula for sharing among riparian countries.

(b) *Increasing demand and water scarcity*

Actual annual water use for irrigation increased from 7.2 BCM in 1980 to 11.13 BCM in 1995. If all planned projects had been completed, with current irrigation technologies, the volume of water needed to meet all agricultural demand for the people in the same year (1995) would have reached 15.9 BCM. The total demand for all purposes would have reached 16.95 BCM.

Actual water use in 1995 for all purposes was 12.36 BCM, of which 11.13 BCM was for irrigation, 0.95 BCM, for domestic use, and 0.28 BCM for industrial consumption. Had the water resource been fully used, there would have been a shortfall in water to meet the planned demand from the different sectors; the areas slated for irrigation would have been without water, and part of the population would have been left with insufficient drinking water.

(c) *Water quality degradation*

The water quality of rivers is suffering from major pollution problems arising from the disposal of different wastes (industrial effluent, sewage discharge) directly into the water courses without any treatment. As mentioned earlier, the effects on the quality of water in the Euphrates river due to flow decrease and drainage water effluent upstream are causing serious concern within the river basin in the Syrian Arab Republic and have already affected agricultural crops, soil salinity, industrial and water purification plants. Problems of surface-water degradation exist in the area of Damascus (Barada River), Homs and Hama (Orontes River) and Aleppo (Quiq River). The water of the Barada River is seriously polluted due to the inflow of industrial and domestic wastewater.

(d) *Water use efficiency*

Irrigation is not only the largest water user in the Syrian Arab Republic, but is also the least efficient compared to other uses, and has been highly subsidized by the State. At the same time, the scarcity of water resources is the main obstacle to achieving the future goals of the agricultural sector, which include self-

sufficiency in food and industrial crops, and even a surplus of agricultural production for export. Furthermore, in some regions, the annual renewable water resources are already completely utilized and possibilities for increasing water supplies are exhausted. The only option is to increase the efficiency of irrigation and other uses.

4. *Strategic options*

As quoted from the Syrian case study on national water policy reform, the main features of the Syrian water strategy read as follows (48):

Syrian Government policy is to make efficient use of every drop of available water: from rainfall, rivers, groundwater and international courses.

Domestic water supply and water for drinking purposes has first priority for use, for the welfare and well-being of the country's people.

The policy of food self-sufficiency, which is essential for the independence of the country, will face difficulties in the near future if no immediate measures are undertaken to redress the increasing imbalance between water demand and supply.

Economic growth is causing increasing competition for water among different sectors, with growing scarcity of water in some regions. Balance between supply and demand is becoming critical in some areas (Damascus, Aleppo, ... etc.) and water will be one of the main constraints on future economic development of the country.

Treating water as an economic good requires careful consideration of the legal, institutional and regulatory implications.

Pricing policy to reflect strength of demand for water and to orient consumption of water towards those placing the highest value on it and to actively manage the demand of water within the country would be a successful instrument for water-saving and conservation and to meet the cost of construction and the services of transportation and operation and maintenance within water projects, since implementation of such projects is mainly constrained and delayed by lack of funding.

Introducing incentives to change agricultural practices and domestic water misuse, stopping the illegal use of water, water pollution, deterioration of groundwater in quantity and quality, and reaching agreement about shared water with riparian countries on the Euphrates and Tigris rivers are all critical, immediate targets, occupying a position of high concern on the Government's agenda. Without these agreements, water policy and strategic choices will face many difficulties.

Stricter legislation is required to enforce obligations to conserve groundwater in quantity and quality. This situation has led the authorities in the Syrian Arab Republic to take specific legal measures to prevent abuse of groundwater assets and govern their exploration, withdrawal and use. The most important consideration in terms of national development is how much is achieved and how much will be achieved in the coming future before the problem of water in the country becomes dangerously critical.

Strict penalties should be applied to conserve surface water and prevent pollution. Industrial units should be obliged to treat water before recharging it into rivers and lakes, and charges should be paid by polluters to meet the treatment costs and other consequences of contamination.

The conservation of water resources and efficient planning and management should be major strategies. National-level, appropriate institutions are required to deal with political and technical coordination, as well as with administration of water resources.

The Agricultural Cooperative Bank encourages farmers to drill wells and to buy pumps. If this policy of subsidy is to be continued, it should be changed in form and value. Transferring subsidies from well drilling to the application of new methods of irrigation (drip, sprinkler, ... etc.) and for adoption of new water-saving technologies, especially in areas where groundwater is overexploited, become essential changes.

Increasing water tariffs on drinking water and water for irrigation has been discussed, and MOI is proposing a new water charge system to cope with water scarcity. Application of charges on the basis of unit of land irrigated rather than on the volume of water consumed is not conducive to developing a water-efficiency attitude in users. It is better to levy charges for irrigated crops on the basis of volume of water consumed, thus providing an incentive to users to save water, and simultaneously protecting soil from the waterlogging, salinity and groundwater aquifer fluctuations that can render areas potentially unusable.

Strategy formulation will face many obstacles owing to the current situation of water resources in the Syrian Arab Republic. Main obstacles are:

- The absence of comprehensive studies on groundwater availability in some basins (Al-Khabour, Euphrates, the desert, the coast) and general shortage of data and information for integrated surface and groundwater management;
- Countrywide uncontrolled and unmetered water use, mainly in the agricultural sector.
- The absence of agreement on international shared water, especially Euphrates and Tigris;
- The absence of comprehensive socio-economic studies related to water resources;
- The absence of clear population growth policy.

Water resources are in critical situation, and scarcity is an urgent and growing problem, causing conflict between different sectors. Water resources should be managed in an integrated manner to meet social, economic and environmental targets of the country, and such integration should be accompanied by comprehensive legal and institutional reform.

The main target of the recommended national water policy in the Syrian Arab Republic is to achieve a situation of adequate and good quality water for all sectors and the fiscal capability for continuing O&M [operation and maintenance].

E. THE GULF COOPERATION COUNCIL MEMBER STATES

Because of their limited water resources and an overdraft situation which has resulted in reduced quantity and quality, many of the GCC member countries have turned to the sea for their freshwater supply. Considerable progress in desalination activities has been made in recent years.

The Gulf States are generally considered world leaders in non-conventional water resource production, particularly in desalinating sea water and/or brackish groundwater. Since the United Nations Water Conference (1977), substantial progress has been made in desalination techniques and in improving skilled manpower capabilities to maintain and operate desalination plants. The cost of desalination per unit volume of water produced has been progressively reduced. In addition, treated sewage effluent reuse is widely practiced in the Gulf States for restricted irrigation or public gardening.

Non-conventional water resources production in the GCC member States has contributed substantially to meeting the countries' domestic, industrial and, to a certain extent, irrigation water requirements. National water resources (primarily groundwater) in some member States are no longer potable and can hardly even be used to irrigate certain saline water-tolerant crops, owing to excessive water quality deterioration and sea water intrusion into the coastal aquifers. Treated sewage effluent, which normally provides about 60 to 70 per cent of domestic water supply, has helped maintain agricultural production in some areas in the Gulf States.

For the purpose of water strategy formulation in the Gulf States, Government authorities have considered, among other things, the following:

- (a) Construction of additional desalination plants to meet growing water demand;
- (b) Promotion of surface-water impounding to make use of flash floods for storage and/or artificial groundwater recharge;
- (c) Enhancement of wastewater reuse for restricted agriculture;
- (d) Implementation of groundwater exploration, management and conservation projects;
- (e) Modernization of irrigation schemes, as well as efficient operation, maintenance and development of conventional or traditional (*aflag* and springs) irrigation schemes;
- (f) Achievement of mutual agreements among the riparian States sharing the potential subregional aquifers particularly, the Damman/Umm er Rhaduma aquifer systems.

VI. A CONCEPTUAL FRAMEWORK FOR THE MANAGEMENT OF SHARED WATER RESOURCES IN THE ESCWA REGION

A. GENERAL CONSIDERATIONS

Water problems in the ESCWA region are diverse and changing as the gap between supply and demand is widening. Water issues are linked to scarcity, maldistribution, and sharing. When these three features of water as a resource are combined, one outstanding implication emerges: the great need for cooperation among national riparian States, and even among groups within nation States, and the correspondingly great risk of potential conflict.

The development and management of regional water resources in the ESCWA region present a challenge for water managers and experts. The need for a sustainable and comprehensive methodology or model to develop and manage regional water resources in the ESCWA region is evident. The rationale for the formulation of this methodology (model) stems from the fact that future options for water management in the region may include transfer of water across boundaries and regional groundwater development.¹ Two case studies are presented in this chapter to illustrate the opportunities that may lead to collaborative action in the management of shared water resources. The first case-study addresses water sharing along the Euphrates River.

The Euphrates river flows from Turkey through two downstream ESCWA member countries, Iraq and the Syrian Arab Republic. Turkey is rich in water resources while both the Syrian Arab Republic and Iraq are generally poor in water resources. The Euphrates River and the River Tigris account for almost the same flow of fresh water (measured at the source) in the ESCWA region as does the Nile: the Euphrates, 32,700 MCM/year, Tigris 49,200 MCM/year; total flow, 81,900 MCM/year; the Nile, 83,600 MCM/year.

The second case-study addresses the management of shared ground water resources between Saudi Arabia and Jordan, the Rum-Disi-Saq aquifer. The Euphrates and Tigris rivers differ from the Nile in that they rise and flow entirely within the Middle East. Thus, they offer a regional opportunity either for water agreement or for conflict over the allocation of water resources. Turkey encompasses 28 per cent of the Euphrates basin but accounts for 98 per cent of the stream's run-off. The Syrian Arab Republic has 17 per cent of the basin within its borders but provides only 2 per cent of the total run-off. The other 55 per cent of the basin (40 per cent Iraq, 15 per cent Saudi Arabia) contributes almost nothing to the flow of the Euphrates.

It is not the intent of this study to come up with specific figures for the amount of water to be shared among riparian States; rather, it aims to develop guidelines and principles within a framework that will help riparian States to reach agreement on the management of shared water resources.

B. APPROACHES AND METHODOLOGIES FOR EVALUATING AND MANAGING SHARED WATER RESOURCES

The allocation and management of shared water resources is a field which encompasses various disciplines, ranging from economics to politics, to the law, and reflecting trends in areas as diverse as

¹ Odeh Al-Jayyousi, "Evaluating potential water conflict in the Middle East: strategies for cooperation", Ph.D. thesis, University of Illinois at Chicago (Chicago, Illinois, 1993), p. 2, para. 1.

engineering and the environment. Each discipline offers possible theories, mechanisms, and principles for the allocation and management of shared water resources.

This overview is intended to cover only economic approaches, political theory, water law, and planning theory. These bodies of knowledge represent the conventional alternative methodologies employed by policy analysts to deal with resource-allocation conflicts.

1. *Economic methodologies*

With reference to economics, the concepts of scarcity, demand, and the “tragedy of commons” (see below) are introduced to help us define the terminology for our problem statement. Ciriacy-Wantrup (1952)² established the basic concepts of conservation economics, distinguishing between renewable and nonrenewable resources. Moreover, he introduced special problems of critical zone resources. A critical zone resource is one that can be replenished until a threshold of irreversible depletion has been reached. Beyond that level, it may be lost forever.

Ciriacy-Wantrup emphasized the importance of technological change in overcoming problems of nonrenewable resources and the crucial role of institutions as safeguards against inefficient use of flow resources or irreversible depletion of critical zone resources. He also introduced the concept of the safe minimum standard for dealing with critical zone renewable resources.

A considerable body of literature exists on the economic theory of common-property resources (Hardin and Baden 1977).³ According to this theory, much of the environmental quality problem can be attributed to the tragedy of commons. As elaborated by Gordon, maximum economic sustained yield requires the equating of marginal product and the marginal cost of effort. When average product exceeds marginal product, this leads to over-exploitation. Cost-benefit analysis for evaluating shared water depends heavily on the choice of the discount rate. However, concern for the intergenerational irrationality is raised since discounting and effects on welfare are evaluated from the point of view of present consumers.

Optimization models fail to consider the environment itself as a depletable resource (Smith and Krutilla 1979).⁴ There is a need to incorporate environmental elements such as residuals management, including recycling and resource recovery, in resource depletion models. Optimal control theory searches for the equilibrium-optimal sustained yield.

2. *Political and institutional methodologies*

In political theory, the formation of institutions was introduced as a solution for the tragedy of commons. Economics helped us identify the problem of scarcity and the tragedy of commons. Political and institutional theory developed frameworks to address these problems. One of these frameworks, proposed by Vincent and Elinor Ostrom (Butrico and others 1971),⁵ is known as the institutional analysis of common pool resources.

² Ibid., p. 16.

³ Ibid., p. 25.

⁴ Ibid., p. 28.

⁵ Ibid., p. 32.

Wildlife, fish, groundwater, lakes, streams, and the atmosphere are all examples of common pool resources. Under the Ostroms' approach, particular problems occur in the utilization and management of these kinds of resources (in this study reference is made to water) whenever the following conditions are present: 1) ownership of the resource is held in common; 2) a large number of users have independent rights to use of the resource; 3) no one user can control the activities of other users or, conversely, voluntary agreement or willing consent of every user is required in joint action involving the community of users; and 4) total use or demand upon the resource exceeds the supply. As soon as these conditions prevail, efforts of any one user to increase his supply of the resource from a limited common pool leads to an adverse effect on others. Any one user, following the economic principles outlined above, will attempt to increase his utilization of the resource until his marginal costs equal his marginal benefits, without taking into account the spillover costs he creates for other users. Some spillover costs will be felt by others who wish to utilize the common supply for the same purpose and must now pay higher costs to do so. Other spillover costs will be felt by users who wish to utilize the common supply for different purposes and may now be excluded from doing so or may have to pay higher individual costs to do so.

Since spillover costs may be extensive, each user may be led to adopt strategies which produce high costs for others while acting in relation only to his own private costs and private benefits. Intense competition for the limited supply will result unless institutional arrangements require all users to take spillover costs, as well as their own individual costs, into account when making decisions regarding the utilization of the common resource. Such competition may force some users out of existence and may produce extraordinarily high costs in the continued utilization of the resource.

A consequence of utilizing the rule of willing consent in the development of a common pool resource will be the relative lack of attention to investment in projects which would provide a common benefit. Even though total benefits exceed total costs, the specific benefit to any single user will rarely exceed the total costs. Thus, the single user is not likely to invest in projects of common benefit without some arrangement requiring other benefited individuals to contribute their share. Consequently, many potential spillover benefits will not be realized. Therefore, sole reliance upon the rule of willing consent in the development of a common pool resource may lead to over-investment in facilities for private use and benefit.

Once a competitive common pool situation develops, users relying upon the rule of willing consent to make their basic decisions, and following the above economic principles, will be led to accelerate their competitive race with one another for the limited supply. Individual users may be led to adopt any or all of the following patterns of conduct: 1) to conceal or to minimize access to essential information on resources; 2) to ignore adverse effects on the resource in the conduct of his own enterprise; and/or 3) to follow a hold-out strategy in relation to other parties drawing upon the same resource pool.

Since information about how much of the resource any one individual is using may lead others to try to limit his activities, an individual may attempt to conceal information about his own use. Furthermore, an individual may ignore the general consequences of his personal actions. If individuals who are adversely affected by spillover costs in their utilization of a common shared resource cannot find an appropriate solution available among existing public jurisdictions, they may then contemplate forming a new collective or public enterprise.

The above is an example applying an institutional analysis framework to common pool resources. However, political theory provides numerous models to enhance understanding of management of shared water resources and water conflicts. Models can be found to portray the origins, processes, and outcomes

of conflict. It is convenient to characterize these models of conflict and cooperation according to the phase of the conflict/cooperation phenomenon that they portray.

One outcome-modeling approach that has sometimes been applied to water crises is game theory. In a scenario described by Frey (1993),⁶ riparians are assumed to be playing a non-cooperative game in which they know the strategies and payoffs of all other parties and try to determine a rational, cost-benefit strategy for themselves, assuming the others are committed to their respective choices. Game theory suggests the likely outcomes under such conditions. Other models for shared water resources utilize game theory to examine whether there exists a stable equilibrium for the particular game examined. That equilibrium is commonly defined as a system of players' strategies, under the approaches introduced in Section 1 (above), in which players cannot change tactics and improve their payoffs; given the strategies of the others, each player has no better move than the one chosen.

Modeling of transboundary river situations in terms of optimal environmental analysis also has been suggested (Dorfman 1972).⁷ These models use the fundamental economic notion of optimality to establish criteria for solutions to water conflicts. It assumes that each riparian can identify its own benefits under any strategy or plan, and that each nation is trying to maximize those net benefits. Any plan that, compared with some other plan, does not reduce any nations' net benefits and increases at least some nation's net benefits, is superior. A plan is optimal if there is no other plan that is superior to it.

Another set of models that can be applied to transboundary river basin conflicts relates to negotiation and conflict management. These models, such as Alternative Dispute Resolution (ADR) and Process of International Negotiation (PIN), portray constructive approaches to negotiation, serving as a template for negotiating success rather than as a predictive model of actual conflict processes or outcomes (Potapchuk, 1990).⁸ They concentrate on identifying the interests (values and goals) of each party to the conflict and use a collaborative search to find a solution that maximally satisfies each actor's interests.

A related approach to resolving conflicts over transboundary water resources employs the systematic evaluation of alternatives. Used by the Department of the Interior in the United States, this approach is known as the Multi-Attribute Tradeoff System (MATS); however, other similar computer packages exist (Smith 1990).⁹ Under MATS water proposals are evaluated in terms of key factors such as (1) yield (the net quantity of water added), (2) feasibility (the prospect of implementation), (3) dependability (how positively the plan will produce the designated results), and (4) political impact (the socio-political consequences).

The following section presents the third methodology, international law, as a means of managing shared water resources.

3. International law

Water policy is more likely to be influenced by a country's upstream or downstream position within a basin than by international law. For most riparians the only constraints imposed on national water policy

⁶ Ibid., p. 41.

⁷ Ibid., p. 42.

⁸ Ibid., p. 43.

⁹ Ibid.

are the fear of setting unfavorable precedents in further dealings with neighboring countries and the disapproval of the international community.

Traditionally, four theories governing the use of international rivers exist in the literature (Utton and Teclaff, 1978, p. 154):¹⁰

(a) The Harmon Doctrine, which advocates absolute sovereignty for upper riparian States.

(b) Absolute Territorial Integrity, which guarantees to the lower riparian the use of the river in an unaltered State.

(c) Drainage Basin Development, or the Community Theory, which stresses mutual development of a river's waters by all riparian States.

(d) The Restricted Territorial Sovereignty or Equitable Utilization Theory, which permits use of a river's waters to the extent of doing no harm to other riparian countries.

The last theory has become the most widely advocated by the international legal community (Utton and Teclaff 1978).¹¹ In reality we have only four alternative principles which govern the use of waters flowing through more than one State:

(a) The principle of absolute territorial sovereignty, by virtue of which a State can dispose freely of the waters actually flowing through its territory, but has no right to demand the continued free flow from other countries;

(b) The principle of absolute territorial integrity, by virtue of which a State has the right to demand the continuation of the natural flow of waters coming from other countries, but may not for its part restrict the natural flow of waters flowing through its territory into other countries;

(c) The principle of community in the waters, by virtue of which rights are either vested in the collective body of riparian States or are divided proportionally;

(d) A restriction of the free usage of the waters which does not extend as far as the principle of a community in the waters but which restricts the principle of absolute territorial integrity.

For detailed arguments of each principle one can refer to Berber (1959). However, it is argued that the conceptual legal framework, "which exists in theory, might serve the purpose. But we have seen that on water issues, particularly international water issues, the law is not inclusive" (Naff and Matson 1984, pp. 8-9).

The concept of equity as applied to shared water resources must be defined to reflect the competing arguments in the principles of international law. In international law, though appeal is often made to considerations of equity, the definition of the term remains elusive (Moore 1992, p. 16) argues that in the realm of international water law, there is no universally accepted definition of equity in the division of waters

¹⁰ Ibid., p. 44.

¹¹ Ibid., p. 45.

between users. Rather than attempt a definition, the Helsinki Rules on the Uses of the Water of International Rivers (International Law Association 1966) identify several factors thought to have a bearing upon equity and that, consequently, should be taken into account when determining a reasonable share of basin waters for each basin State.

Due to the specific characteristics of each international river and the regional aquifers in terms of the hydrologic, hydrogeologic, institutional and legal aspects, it is not realistic to draw up rules and regulations of universal applicability unless they are kept broad and flexible.

Historically, the elaboration of such a set of principles has undergone an evolutionary process. The International Law Association (ILA) formulated the Helsinki Rules in 1966. Since 1971, the International Law Commission (ILC) of the United Nations has been working on comprehensive principles, currently in the form of 36 draft articles, on the law of the non-navigational uses of international watercourses. A framework convention was held by the United Nations 6th Committee to refine the draft articles. The General Assembly has already adopted the convention articles listed in annex 1.

The ILC draft articles deal only with ground water that is part of a river system. Groundwater not associated with rivers is not included. The main concepts and principles included in the ILC draft articles may be summarized as follows:

(a) As reported by Flint (1995), the articles aimed to achieve a balance between the “equitable and reasonable” utilization of an international river (Article 5) on the one hand, and the desirability of avoiding “significant harm” to the other riparians that are already using the river (Article 7), or might want to use it in the future, on the other hand. However, the ILC made it clear that it regards “equitable and reasonable” as the guiding criteria;

(b) Relevant factors are to be considered in determining whether any use of the river is “equitable and reasonable”. However, no attempt was made to order these factors in terms of priority owing to the variation in relative importance of these factors from one country to another;

(c) The articles stress the riparian States’ obligation to protect international rivers and associated ecosystems (Articles 5, 8, 20, 21);

(d) The articles oblige riparian States to cooperate in the optimal utilization and protection of the rivers which they share (Article 8);

(e) The articles recognize that agreements between riparian States may cover the entire river basin, or only part of it (Article 3). In the latter case, however, the agreement should not adversely affect, “to a significant extent”, other riparian States’ use of the waters in the basin.

The management of shared water resources should take into consideration many factors which include current laws, institutional settings, and present and future water resources and uses. Specifically, the following are some factors to be considered in managing shared water resources:

1. Climatic conditions and water availability in the planning basin or region.
2. Available and utilizable water resources in the present and future.
3. Present and projected water requirements for all uses.
4. Water cost from different sources and users’ ability to pay.

5. Existing legal and institutional frameworks.

C. METHODOLOGY

From the above review of approaches and methodologies, it can be noted that economics lacks a model for measuring social welfare; individual, group, and regional income distribution receive little attention. Another problem regarding such economic techniques as willingness to pay or tradeoff analysis is that people may not be able to think in terms of complete trade-offs and contingencies. Moreover, another basic element missing from economic approaches is intergenerational equity, since all effects on social welfare are evaluated from the point of view of present consumers.

Political theory was useful in dealing with the tragedy of commons by proposing a collective public enterprise. According to the theory of institutional analysis of common pool resources, if individuals adversely affected by spillover costs in their utilization of a common pool resource cannot find an appropriate solution available among existing public jurisdictions, they may then contemplate forming a new collective or public enterprise. However, political theory does not offer specific strategies to achieve cooperation.

To address these methodological limitations, a new methodology for managing shared water resources is proposed. This methodology is based on the combination of both international law and decision support systems. A sound methodology should be practical and consider the political realities of the "here and now". In other words, it is not merely a technical or a theoretical exercise; rather, it should consider qualitative aspects, interaction effects among actors, trust-building, and the exchange of information among riparian States. It should be mentioned that the proposed conceptual framework for managing shared water resources will focus on principles, guidelines and processes rather than specific numbers on "who gets what and how much".

In order to devise a methodology or conceptual model to better deal with the allocation of water resources in a general setting and to propose new institutional mechanisms to address regional water resources management and allocation issues, the study aims to develop a methodology which is based on a combination of international law principles and decision theory using the Analytical Hierarchy Process (AHP). An essential component for this conceptual framework is to build consensus on the management of regional water through group decision-making and collaborative problem-solving. International law helps establish principles and rules for allocation of shared water resources. The rules to be adopted in the proposed methodology are the Helsinki Rules. They represent equitable standards or criteria for the allocation and management of shared water resources. Utilizing AHP, it is possible to set weights for the various factors in the Helsinki Rules and to set priorities for the development and management of regional water resources. AHP is a multi-criterion decision-making tool which utilizes judgement, knowledge, and intuition to set priorities and to evaluate policies, strategies, and scenarios.

A description of the two components and the linkages between international law and the decision support system is presented below:

1. *International law and the reasonable share*

In international law, there is no accepted definition of equity. However, the Helsinki Rules on the Uses of the Water of International Rivers identify several factors thought to have bearing upon equity. These factors should be taken into account when determining a reasonable share of basin waters for each basin State. These factors include:

- (a) The geography of the basin, including in particular the extent of the drainage area in the territory of each basin State;
- (b) The hydrology of the basin, including in particular the contribution of water by each basin State;
- (c) The climate affecting the basin;
- (d) The past utilization of the waters of the basin, in particular the existing utilization;
- (e) The economic and social needs of each basin State;
- (f) The population dependent on the waters of the basin in each basin State;
- (g) The comparative costs of alternative means of satisfying the economic and social needs of each basin State;
- (h) The availability of other resources;
- (i) The avoidance of unnecessary waste in the utilization of waters of the basin;
- (j) The practicability of compensation to one or more of the co-basin (riparian) States as a means of adjusting conflicts among uses;
- (k) The degree to which the needs of a basin State may be satisfied, without causing substantial injury to a co-basin State.

Under the Helsinki Rules, there is no one factor upon which an allocation regime should be based; indeed, the Helsinki approach specifies that weighted consideration must be given to all relevant factors.

However, the weight to be given to each factor is to be determined by its importance in comparison with that of other relevant factors. In determining what is a reasonable and equitable share, all relevant factors are to be determined together and a conclusion reached on the basis of the whole.

This implies that factors identified by the Helsinki Rules must be operationalized or represented in a quantifiable manner. Moreover, an effort should be made to translate these legal provisions into practical allocation regimes in order to be able to develop criteria or standards for the allocation of shared water resources between riparian States.

Through synthesis of the above factors stated for the determination of a reasonable share of waters among riparian States four equity standards, or criteria, are derived for the analysis of shared water resources. These include:

- Existing utilization
- Natural flow
- Recharge area
- Population

These standards will be incorporated (as inputs) in the decision support system using the Analytical Hierarchy Process (AHP).

2. *Decision support system: Analytical Hierarchy Process (AHP)*

AHP is a multi-criterion decision-making tool which utilizes judgement and knowledge to set priorities and to evaluate alternative strategies, policies, and scenarios. A hierarchy will be constructed in light of the issues and characteristics of each riparian State. The outcome of AHP will be a payoff matrix for each country. The above proposed methodology, as shown in figure V, is a version of the rational planning model.

The Analytical Hierarchy Process (AHP) enables us to deal with complex problems which involve conflicting criteria and several alternatives which require intuition and judgement. Each factor and alternative in the hierarchy tree is identified and evaluated with respect to other related factors. AHP, as described by Aziz (1992),¹² is basically intended to capture the perceptions of people closely involved with certain pertinent issues via a procedure designed to arrive at a scale of preferences among sets of alternatives; it could therefore be considered as a multiobjective-multicriteria model.

To apply the approach, a complex unstructured problem needs to be first broken down into its component parts. After arranging these parts into a hierarchical order, numerical values representing subjective judgments on the relative importance of each part are assigned. To come up with the final outcomes, those judgements are then synthesized (by means of weighting) to determine which variables have the highest priority. A description of the AHP along with a numerical example is presented in annex 2.

D. CASE-STUDY NO. 1: MANAGEMENT OF SHARED WATER ALONG THE EUPHRATES

1. *Historical background*

The intent of this case study is to present the main issues, constraints, and opportunities which normally exist in the management of shared water resources. This historical background outlines the developments in water plans for the three riparian States. This section is based on the work of Naff and Matson (1984) and Kolars (1991).

Beginning in the early decades of this century, Turkey, the Syrian Arab Republic and Iraq all formulated plans and implemented projects to achieve flood control on the Euphrates and to use its waters for hydroelectric generation and large scale irrigation. Planning was largely on a country-by-country basis, though there have been technical consultations among the three States since the early 1960's. Throughout the period 1909 to 1974, neither the absence of integrated planning for the entire basin nor the failure to reach agreement on water resource sharing led to serious international conflict among the riparian States. Projects implemented in this period did not result in significant adverse ecological consequences and demand for water did not exceed supply.

During the 1960s, as their plans for the use of the Euphrates developed, Iraq, Turkey, and the Syrian Arab Republic held a number of discussions concerning the division of the river's waters. Little is known of the content of these discussions since, except on one occasion in 1975, all three countries seem to have kept their talks off the public record (Naff and Matson 1984, p. 93).

¹² Ibid., p. 93.

During a tripartite meeting in Baghdad in September 1965, Iraq is said to have demanded 18,000 MCM/year of Euphrates water, the Syrian Arab Republic 13,000 MCM/year, and Turkey 14,000 MCM/year. This is total of 45,000 MCM/year, or 1.4 times the Euphrates mean annual discharge of 32,000 MCM/year at Hit, Iraq. Both the Syrian Arab Republic and Iraq are dependent on agriculture.

Although the Joint Technical Committee on Regional Waters was formed in 1980, the only formal agreement relevant to the Euphrates waters is the 29 March 1946 Iraq-Turkey friendship treaty which obligates Turkey to inform Iraq of plans for conservation works on the Tigris and Euphrates and to adapt projects “as far as possible” to the interests of both States (United Nations Treaty Series, vol. 37, p. 226).¹³ The three riparian States had not reached any further formal agreement by the time the Keban and Tabqa dams began to fill in the winter of 1973-1974, although there is some evidence that Iraq and the Syrian Arab Republic reached a provisional accord in the early 1970s and may have agreed to Soviet arbitration of water disputes between them.

Two arguments are presented by the Syrian Arab Republic and Iraq in terms of equity and the criteria for “who gets what and why”. Iraq’s argument is based on its established right to the water of the Euphrates river according to international law. The Syrian argument is based on what they refer to as their rightful share of the water flowing in their territory. The rationale for establishing the Syrian Arab Republic’s rightful share is based mainly on the criterion of “items”, which claims that whoever has more water should give to those who have less water. The criteria by which equity is to be judged are a critical issue in planning and policy analysis as noted by Deborah A. Stone (1988, p. 41), who discussed the equity issue and the many interpretations it may entail. She pointed out that equity may be viewed differently based on the dimension or unit of measurement. Equity may be judged by the criteria of process or by the criteria of recipients and items. She stated: “Most policy issues can be seen as a question of whether and how the ‘haves’ should give to the ‘have nots’. Even if it is not the primary conflict in policy issues, the distributive component is always there. Should polluters pay river users for damage to water quality?”

Whether distributions should be judged by criteria of process or by criteria of recipients and items thus represents one of the major divides in the great debate about equity. It is argued that a distribution is fair if it came about by a voluntary and fair process. It is just if all the holdings in it—what people have—were acquired fairly.

(a) *Description of the Greater Anatolia Project (GAP)*

This section presents an overview of the Greater Anatolia Project (GAP). It is very critical to understand the GAP in order to assess the value of this study. The GAP will affect the development of the Tigris-Euphrates, one of the world’s great river systems, harnessing its waters and the potential water resources for Iraq, the Syrian Arab Republic and Turkey.

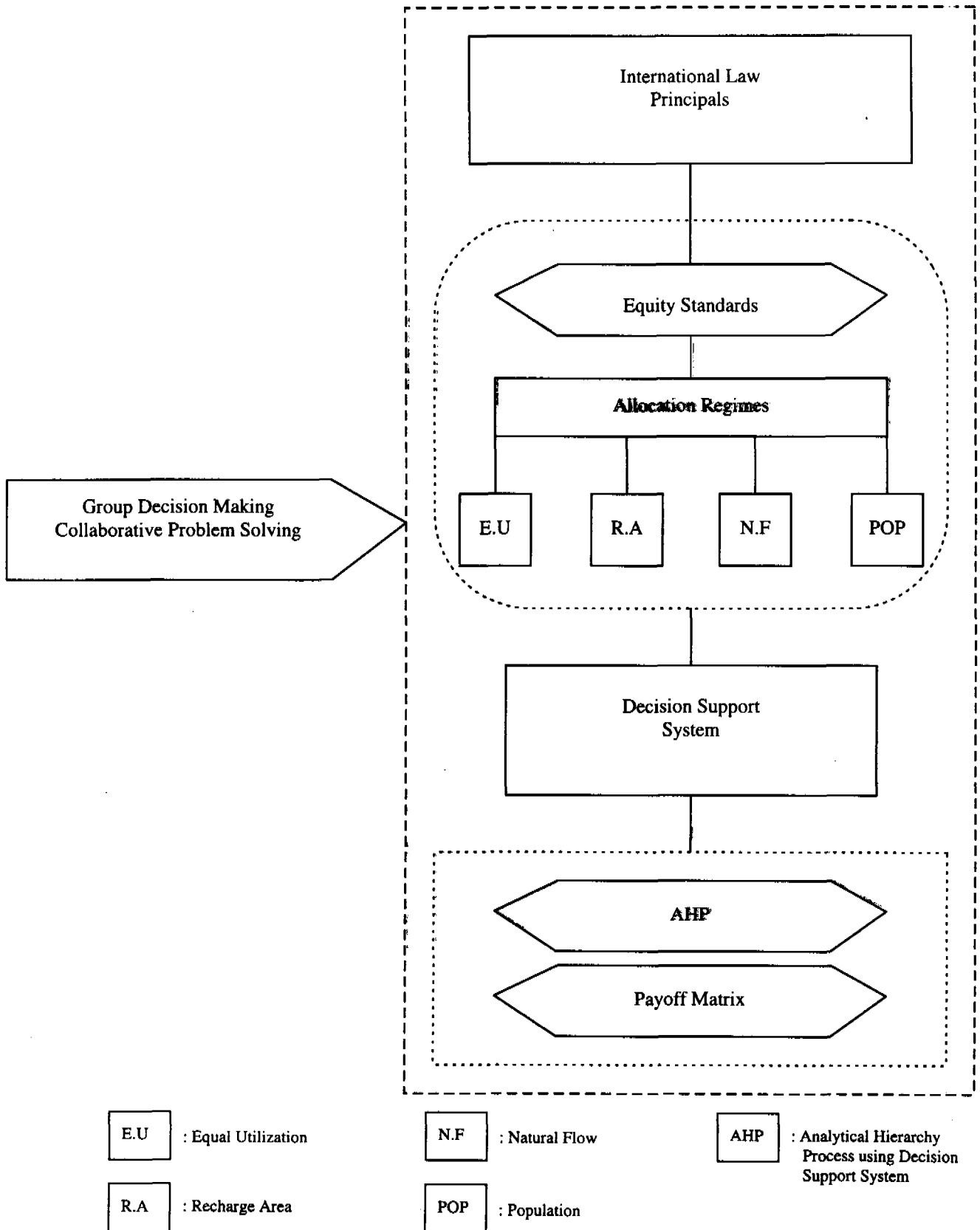
Given that GAP will create economic, social and spatial changes in the entire region, once energy and irrigation schemes come on line, the Turkish Government views the project as a comprehensive “integrated regional development project” (Kolars and Mitchell 1991, p. 19).¹⁴ The entire project of both the Tigris and Euphrates river basins is scheduled for completion by the year 2013. Kolars (1991)¹⁵ presents a

¹³ Ibid., p. 111.

¹⁴ Ibid., p. 143.

¹⁵ Ibid., p. 145.

Figure V. Proposed methodology for managing shared water resources



thorough historical overview of the GAP. In 1987 GAP included an area of 74,000 km² lying between the Anti-Taurus Mountains and the Syrian border. At the time approximately 42,000 ha were irrigated with surface and underground waters in both the Euphrates and Tigris basins. The Karakaya Dam was nearly completed and already producing electricity. In the eastern part of GAP, the Cagcag and Botan hydroelectric stations had a combined operating capacity of 16 MW.

Protocols concerning the Euphrates and Tigris rivers date back to 1946 when Iraq and Turkey agreed that their control and management depend in great part upon the regulation of flow in Turkish source areas. At that time, Turkey agreed to begin monitoring the two streams and share related data with Iraq. In 1980 Turkey and Iraq further specified the nature of the earlier protocol by establishing the Joint Technical Committee on Regional Waters. After a bilateral meeting in 1982, the Syrian Arab Republic joined the committee, which subsequently held meetings in Ankara, Damascus, and Baghdad (Waterbury 1990, p. 23).¹⁶

Upon completion of the Keban Dam in 1974 Turkey began filling its reservoir; at the same time, the Syrian Arab Republic began filling Lake Assad behind the Tabqa Dam. This coincided with a major regional drought which is referred to as the 1973-74 water crisis. In January and February of 1990, Turkey reduced the flow of the Euphrates when it closed the spillways on the Ataturk Dam in order to complete construction on the river bed in front of the dam as well as to begin filling its reservoir.

The importance of the GAP to Turkey goes beyond hydro-power or foreign exchange. Given the underdevelopment of the south-eastern region, it reflects a desire on the part of the Government to improve significantly the population's level of living. In other words, the GAP project offers an integrated socio-economic development plan at the national level.

The project's objectives are to be met through the plan's development strategies (Master Plan, vol. 1, pp. 2,3):

- (i) To develop and manage water and related land resources for irrigation, urban and industrial uses;
- (ii) To improve land use by managing cropping patterns and establishing better farming practices and farm management;
- (iii) To promote the manufacturing industry with emphasis on agro-industries and those based on indigenous resources;
- (iv) To provide better social services to meet the requirements of local people and to attract technical and administrative staff to stay in the region.

It should be noted that hydro-power development is not specifically cited in these general objectives. Nevertheless, it continues to play an important part in development planning, as shown by the three alternative scenarios suggested by the Master Plan in order to achieve the goals stated above. The first posits that all irrigation areas in the original plan be completed by 2005; the second, that power generation be maximized "subject to the implementation of priority irrigation schemes"; the third, that "only priority irrigation and hydropower schemes will be implemented by 2005" (Master Plan, vol. 1, p. 9). In view of the difficulties surrounding the first two scenarios, the Master Plan recommends the third scenario. This third scenario was raised because of Turkey's need to increase its agricultural productivity, using the Euphrates

¹⁶ Ibid., p. 150.

River waters after they have been stored behind the Ataturk, Keban and Karakaya dams, in addition to the water stored in the Kralk, Dicle and Batman dams on the Tigris River.

As mentioned above, there are many large dams on the Tigris and Euphrates rivers and others are planned or under construction in Turkey. All three countries (especially the Syrian Arab Republic and Turkey) plan to increase water withdrawals commensurate with their urban development, population growth, and increased irrigation development and hydro-power.

In 1991, a preliminary study by the U.S. Army Corps of Engineers entitled "Water in the Sand", commented as follows:

- (i) Many future projections for withdrawals show substantial depletion, especially in the Euphrates; full development of the Greater Anatolia Project (GAP Turkey) and modest development of Syria's plans indicate that Iraq will be hard pressed to meet its own irrigation needs on the Euphrates;
- (ii) It is likely that neither the Syrian Arab Republic nor Iraq will be able to meet its needs during low flow years, unless upstream reservoir carryover storage is released;
- (iii) Approximately 10% of the Euphrates' annual flows will be lost via evaporation from Turkish reservoirs alone; Euphrates basin irrigation in Turkey may consume another 30 to 40% when all projects come on line;
- (iv) While the full impact of water quantity depletion may not be felt for some time, the impact on water quality is likely to be close at hand; in the future, total agricultural return flows may account for more than one-half of the flows to Iraq via the Euphrates;
- (v) Iraq's problem with water that is already salty will only be further exacerbated, as Iraq has incurred considerable expenditure to increase its irrigated agricultural production by developing drainage systems.

In general, all three countries have programmes that call for increased water utilization and all the recent efforts (1980-1996) to resolve the conflict ended without any consensus (draft, "Water in the Sand", U.S. Army Corps of Engineers, 1994).

(b) *Application of the proposed methodology*

The following section utilizes international law principles and the Analytical Hierarchy Process (AHP) to analyze the allocation of shared water along the Euphrates. The intent of this analysis is to illustrate how the the proposed conceptual framework may be applied by riparian States who share water resources. However, the application of the methodology will only focus on the process of reaching agreement and building consensus among riparian States. It does intend to support one riparian over another. Moreover, it does not aim to come up with specific figures of the amount of water each riparian has to share. It aims to develop a methodology for the equitable and reasonable management of shared water resources which is based on collaborative problem-solving and group decision-making.

(i) *International law principles*

In light of the Helsinki Rules and the factors outlined for the determination of a reasonable share of waters among riparian States, four equity standards can be derived for the analysis of shared water resources. This means that the allocation of shared water resources will be based on four criteria. These include:

1. Existing utilization
2. Recharge area
3. Natural flow
4. Population

These criteria will be incorporated (as inputs) in the decision support system using the Analytical Hierarchy Process (AHP) as shown in figure VI. This process consists of goals, actors, objectives and strategies. The weights for the above four criteria will be reflected in the weights assigned to each actor in the hierarchy, which will in turn be compared to objectives and strategies.

It should be mentioned that the above criteria are not exhaustive; riparian States may agree on other standards or criteria. This should be done through a communicative process where data is shared and concerns and arguments are raised in a collaborative problem-solving environment. The goal is to reach agreement on the criteria on the issues regarding “who gets what and why” through group decision-making by the riparian States concerned.

(ii) *Decision theory: the decision support system*

After developing the criteria for water allocation, the methodology involves the application of AHP to devise and rank objectives and strategies for each riparian State. To apply AHP, the analyst (through group decision-making) should construct the hierarchy of the problem to be analyzed and then perform an analysis of the problem, as presented in annex II.

Constructing the Hierarchy

The overall hierarchy of the problem consists of four levels as shown in Figure VI. These levels are:

- Level 1: Goal
- Level 2: Actors
- Level 3: Objectives
- Level 4: Strategies

The goal or the focus for each country is to maximize its share of the waters of the Euphrates River. The weights are derived from a pairwise comparison using AHP with respect to a scale ranging from “Extremely Important” to “Less Important”.

The actors in this problem are:

- Actor 1: Turkey
- Actor 2: The Syrian Arab Republic
- Actor 3: Iraq

The descriptions below will help establish for each actor the objectives and strategies to be applied in the Analytical Hierarchy Process (AHP).

The first actor: Turkey

Turkey is the upstream riparian and enjoys the most favorable situation. Turkey is characterized as water-rich. Although agriculture constitutes only about one-fifth of Turkey's gross domestic product (GDP), it is still a crucial sector of the economy; it provides over 55 per cent of the jobs, most raw materials for industry, and 25 per cent of Turkey's exports. Considering the average annual rainfall, water per capita in Turkey is estimated at 10,000 m³/year (Gleik 1991).¹⁷

The second actor: The Syrian Arab Republic

The Syrian Arab Republic, as the second riparian user, occupies the most uncertain situation *vis-à-vis* the role of the Euphrates in its national economy. Water poor, if not destitute, it has neither the ample rainfall of Turkey, nor a second major stream such as the Tigris. It is poor as well in hydro-power.

The third actor: Iraq

Iraq, the third actor, is a downstream riparian that is likely to be adversely affected by the water structures and water resource development projects in the upstream countries. Iraq relies on the Euphrates-Tigris waters for its overall socio-economic development on a country-wide scale.

Description of objectives, strategies and scenarios

Identification and definition of objectives and strategies for each riparian State may be extracted from each country's national plan through document analysis. However, it is recommended that this task be carried out through group decision-making in order to build understanding and trust among riparian States. In an attempt to explore future prospects for sharing water resources, two scenarios are suggested, although other scenarios may be developed through group decision-making. These scenarios include:

Scenario 1: Upper riparian control, in which the upstream riparian State exercises the relative advantage of having the power to control water;

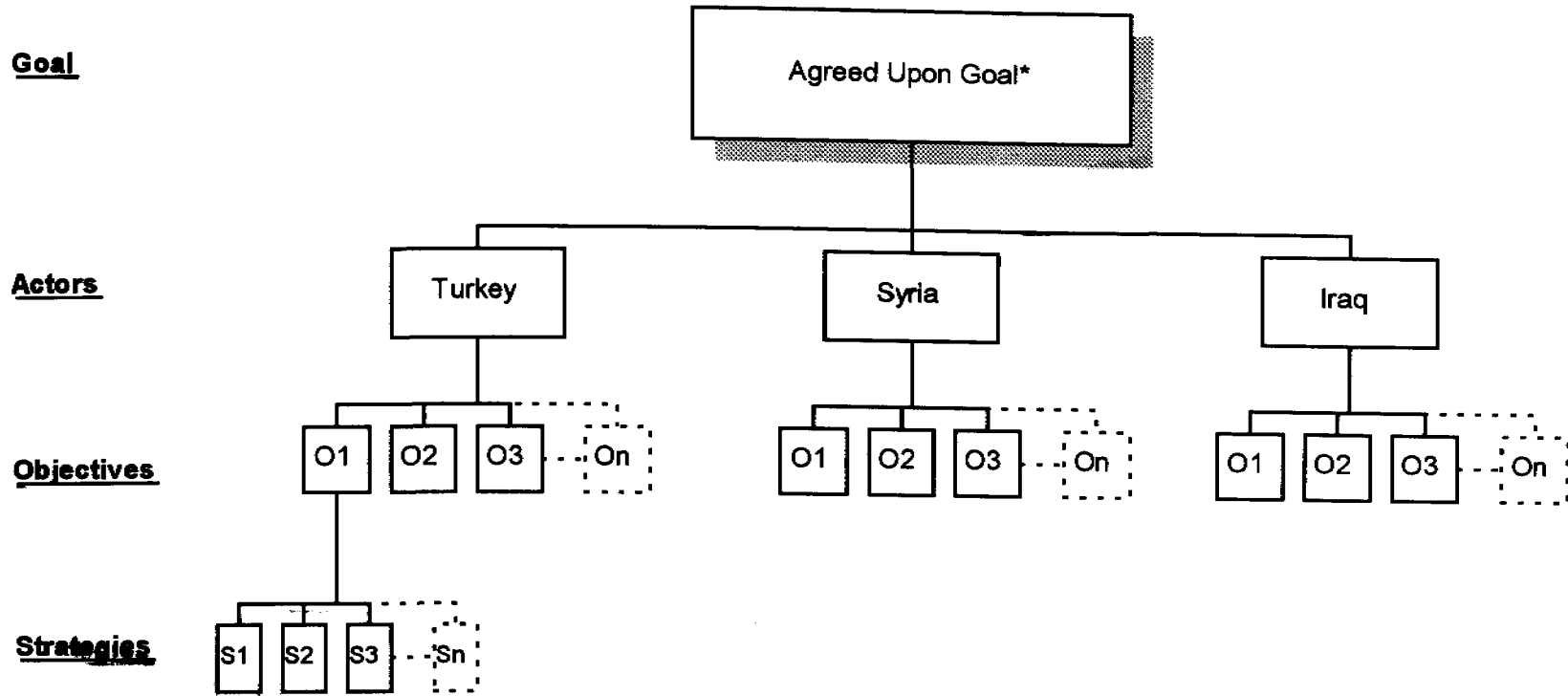
Scenario 2: River basin planning, where all three riparian States coordinate their plans in a cooperative manner.

(iii) *Group decision-making (collaborative problem-solving)*

An integral part of the proposed methodology or conceptual framework is to employ group decision-making and collaborative problem-solving approaches at all phases of the problem in order to reach agreement and build consensus among riparian States. Group decision-making and collaborative problem solving should be employed at the stage where criteria (or principles) for allocation regimes are determined and at other phases which involve constructing the hierarchy and its components, the objectives and strategies, as illustrated in figure V.

¹⁷ Ibid., p. 2.

Figure VI. General structure of the Analytical Hierarchy Process



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Legend: O1.....n Objectives ranked 1.....n
 S1.....n Strategies ranked 1.....n

Source: Thomas L. Saaty, *Decision-making for Leaders: The Analytical Hierarchy Process for Decisions in a Complex World* (Pittsburgh, University of Pittsburgh, RWS Publications, 1988).

* A common goal agreed upon through a group decision-making process.

The outcome of such a process, which is expected to be open and transparent, is likely to be strategies and action plans, agreed upon and sustainable, for the development and management of shared water resources.

In light of the relevant document analysis for each actor (Iraq, the Syrian Arab Republic and Turkey), objectives and strategies have been devised. These objectives and strategies were extracted from each country's development plans.

Objectives and strategies identified for each actor are outlined below:

Actor 1: Turkey

Objectives:

1. Increase hydro-electrical power;
2. Increase agricultural output;
3. Increase social welfare in south-east Anatolia.

Strategies:

1. Enhance economic development in south-east Anatolia;
2. Achieve land reclamation;
3. Encourage urbanization of south-east Anatolia.

Actor 2: Syrian Arab Republic

Objectives:

1. Increase agricultural output;
2. Establish an industrial base;
3. Increase energy supply.

Strategies:

1. Achieve land reclamation;
2. Develop agro-industrial base;
3. Activate surface-water impoundings.

Actor 3: Iraq

Objectives:

1. Increase exports;
2. Establish industrial base;
3. Increase agricultural output.

Strategies:

1. Develop industries;

2. Achieve land reclamation;
3. Develop water resources.

By synthesizing the above objectives and strategies for each actor in the proposed methodology, AHP, we can anticipate the relative weights (or rankings) of the combinations of strategies among actors that are likely to lead to intra-regional cooperation through communicative action, collaborative problem-solving, and group decision-making.

For the first case study, the application of the proposed methodology may result in cooperative strategies by adopting river basin planning.

E. CASE-STUDY NO. 2: GROUNDWATER IN THE RUM-DISI-SAQ AQUIFER SYSTEM*

The area of shared groundwater resources in this case study is the Rum-Disi-Saq aquifer system in southern Jordan, including that part of Saudi Arabia where the aquifer is being utilized and where such utilization is likely to impact on Jordan both now and in the future. It stretches 400 km from beyond Tabuk, Saudi Arabia in the south and south-east to the northern tip of the Dead Sea.

A description of the geographical and hydrological features of the area is presented below.

The geopolitical and hydrological situation in which Jordan finds itself makes it very difficult to achieve this objective in the short- or even medium-term. Nevertheless, the exploitation of fossil water in this aquifer system amounts drawing on "capital" and it would be prudent to manage carefully the rate and duration of this exploitation and to work towards alternative, long-term, and sustainable resource development. This is particularly important as the issue of sustainable development is further complicated by the substantial exploitation of the same water resources in the Tabuk area of Saudi Arabia. The impact of various scenarios for future exploitation has been considered thoroughly by the authorities concerned in both member countries. As a result of the exploitation of groundwater capital, now and in the future, development design horizons and possible phasing of development should be put in this context.

1. *Geographical extent*

The areal extent of the aquifer system is some 74,000 km² from Tabuk in Saudi Arabia to the northern tip of the Dead Sea. The western limit is the geological boundary of the Rum group, and the eastern limit, a groundwater flow line as discussed below under Rum aquifer. Underlying this large area, water resources are enclosed within a hydrogeological unit, from which both Jordan and Saudi Arabia extract water. The principal rock matrix is known in Jordan as the Rum-Disi aquifer. Apart from the Rum-Disi aquifer, a secondary rock matrix is present in much of Jordan and a large part of western Saudi Arabia, where it is known as the Saq Aquifer. Although this secondary aquifer contains substantial water, it is considered irrelevant to this case-study because it forms other hydraulic units which can not easily make a contribution to Jordan's needs.

The Rum-Disi-Saq aquifer system, as a self-contained hydrogeological unit, has been selected because within it a rational balance of inflows, outflows, extractions and their impacts can be made by means of

* Rum-Disi-Saq aquifer, Rum group and Rum-Disi aquifer, wherever mentioned in the text, are interchangeable.

mathematical modeling and hydrochemical analysis. Working with such a unit minimizes the possibility of random errors and misconceptions.

2. *Water demand*

The normal concept of relating reliable yield to the annual replenishment from recharge can not be applied in the case of the Rum aquifer system. Alternative concepts can be used such as that of reliably withdrawing the water until some pre-set criteria are met. These criteria might include economic criteria, such as the cost-benefit of development, or other arbitrary criteria, such as the physical lift capability of a pumping plant or a pre-set depth to which future regional water levels would decline.

The original demands and planning horizons for the Rum aquifer, dating from the 1970s, were related to local needs, such as agricultural requirements and municipal demand for Aqaba, Ed-Disi, and the neighboring region. In recent years, however this water resource has taken on national significance and the intention now is to assess its strategic resource availability for supply to Amman and northern Jordan. Various consultants' reports on national water resource management options refer to the expected yield from the Rum aquifer as a means of meeting the growing demand. These reports are briefly reviewed by Haiste International and Scott Wilson Kirkpatrick (1995) as follows:

“In a review of water demands, *A Water Management Study of Jordan* (PRIDE Report 1982) quotes the Disi water estimated storage capacity of 3,000 MCM as being available for 23.4 years. This is assumed to relate to the part of the aquifer in the so-called Ed-Disi basin”.

Some studies view the Rum aquifer as an economic resource that can provide additional water supply to Greater Amman. In their evaluation of alternative sources to meet long-term national demand, the Thames Water Report (1988) identified 50-70 MCM/year as the Rum aquifer's annual yield. They indicated that for municipal needs, the only two new competing sources were the Al-Wehdah (Unity) dam and Ed-Disi-Mudawarra well fields. They concluded that in terms of present value, the sum of capital, replacement and annual pumping, and associated treatment costs, the Rum aquifer would be slightly cheaper than the Al-Wehdah dam for capacities in the range 50-75 MCM/year.

Other studies approach the required yield of the Rum aquifer from a resource balance point of view, indicating that the 100-year safe yield (European Commission Study, reported by Salzgitter 1993) would be 110 MCM/year. Allowing for the current committed extraction, reported to be 65.5 MCM/year in 1991, this would permit a further 45 MCM/year for development.

A UNDP study (1990) suggested that 125 MCM/year could be sustained for 50 years, provided that the Tabuk extraction remained at 250 MCM/year. This report concluded that “present knowledge of the aquifer is deemed to be sufficient to enable development without the need for further detailed and lengthy investigation”. The Thames Water Report (1988), however, concluded that realistic aquifer data were lacking and that before this source is exploited for supply to Amman an investigation programme consisting of test and observation boreholes is required, as exploitability could only be assessed on such a basis.

Howard Humphreys (1986) extended and reran their previous mathematical model for a 200-year simulation for extraction of 200 MCM/year from Jordan. Although suggesting a staged programme, they concluded that 110 MCM/year could be extracted.

The Thames Water Report (1988) indicated that to supply 100 MCM/year approximately 70 wells would be required (at 1.7 MCM/year, equivalent to 55 l/s from each well), of which 20% would serve as a standby or as a means of meeting peak demand.

From the above information, it can be seen that the estimated storage capacity varies from about 3,000 MCM, being depleted in about 24 years, to an annual extraction of 110 MCM/year for 100 years, and 110 MCM/year for 200 years, although the latter estimate includes a staged approach to extraction.

Conventional demand forecasting is based on population, industrial development, agriculture and other similar growth indicators, which are usually reliable for 15- to 30-year forecasts. The intention of the Haiste International and Scott Wilson Kirkpatrick study (1995), however, was to assess much longer periods, specifically 200 years. Furthermore, the population and demand centers to be served from this source are yet to be confirmed. As a result, the conventional approach could not be used in the interim report stage; rather, the historical production rates of all existing sources and expected production rates of planned sources were extrapolated.

The approach adopted by Haiste International and Scott Wilson Kirkpatrick (1995) for aquifer yield estimation is to define demands for a planning horizon and assess whether the aquifer could reliably produce the yield. One of the criteria which defines the reliability of the estimate is that pumping lifts may not exceed 250m. On the basis of the above model projecting a 200-year period, four planning horizons of 50-year blocks have been adopted by this study for demand forecast.

In Jordan, municipal demands are increasing in Disi village and the neighboring hamlets, including many new small settlements and recently developed small farms and communities in the Quweira area. Although some of the present Quweira extraction is from Wadi Yutum gravels overlying the basement, once established these farms will require a reliable supply to enable them to continue to operate and to support the small population. Long-term water supply to these areas will have to be provided from the Rum aquifer, as there is no other source.

Production in Saudi Arabia can be sub-divided into five geographical sub-groups, as determined from the satellite imagery (TADCO, TADCO extension, farms around TADCO, farms around Tabuk, and Tabuk town). Apart from Tabuk town, all the extractions are for agricultural developments. The five groups have been lumped into one for forecasting purposes in order to apply a single growth rate. Attempting to apply individual growth rates would not produce a better estimate. It should be noted that the recent annual growth in extractions appears to be declining from 14% per year in 1990 to 10% per year in 1993 (Haiste International and Scott Wilson Kirkpatrick, 1995).

The following information has been obtained from agricultural sources in Tabuk, Saudi Arabia in order to assess the future of the Saudi Arabian Authorities' plans. The Fifth Development Plan (1990-1995) states that important objectives are to reduce water consumption by agriculture without targeting growth rates by switching agricultural production away from highly water-intensive cropping. The granting of new wheat licenses was terminated in 1985; thus, it is assumed that the phenomenal expansion noted on the satellite images between the years 1985 and 1993 is from the licenses granted before the embargo. Payments of subsidies to farmers were considerably delayed in 1992, and the wheat cropping of that year was also delayed. In 1993, the Saudi government decreed that only 45% of the wheat acreage would be subsidized and it is expected that as a result much farmed land was converted to orchards and alternate crops such as barley and alfalfa. In 1994, wheat cropping was further reduced to 25% of its acreage, as the national grain silos were unable to accept further wheat. There is a growing acceptance in the scientific-technical community that fossil aquifer reserves should not be utilized for agriculture.

3. Future developments

In the estimation of long-term (up to 200-year) growth rates, a range of 3 values has been adopted for each grouping of the extractions, the values being assessed qualitatively as low, medium, and high. A different rate is applicable to each of the groupings presented below:

(a) *Jordan agricultural sources*

As the life of the initial contract for farms is 25 years, their growth rate will be directly related to their planned cultivated area, up to their licensed maximum. During this period, extraction may increase at a high compound rate of 5% per year from the 1993 levels. Government intervention, resulting from the increasing realization that wheat cultivation is uneconomical, might hold the farms' present production to the constant amount as pumped in 1993 until the end of their contract. The conditions offered may not be acceptable to the farms, in which case, with modifications in the cropping patterns their extraction may rise at 1% per year inclusive.

(b) *Existing municipal sources*

Production from the existing well field supplying Aqaba and the neighboring region (Ed-Disi, Quweira, and small neighbouring communities) would increase at a high rate of 2% per year if rapid development took place, reaching over 20 MCM/year in 50 years. If this rate continued, the 150-year demand would reach 89 MCM/year, but a 1% increase (the medium rate) would halve this high demand. Government policies and economic constraints might also determine that the present rate of demand for Aqaba and the region remain constant.

After the year 2000, production for this field may decline for the following reasons: the value of crops grown does not justify continued expansion; the use of high-quality fossil reserves for agriculture is recognized as uneconomical; and the physical properties of the aquifer preclude continued expansion. An intergovernmental agreement should be reached between Jordan and Saudi Arabia to jointly manage the aquifer so as to maintain the level of water in the aquifer within economic reach.

If the above circumstances were to come about, the production rates could decline gradually by 1 to 5% per year. In terms of aquifer yield, the most stressful to the aquifer system is the scenario in which total production in Jordan is held at 156 MCM/year and production in Saudi Arabia remains at 977 MCM/year.

(c) *Application of the proposed methodology*

The intent of this analysis is to illustrate how the proposed conceptual framework may be applied by riparian States who share water resources. However, the application of the methodology will only focus on the process of reaching agreement and building consensus among riparian States. It intends to come up with specific figures of the amount of water each riparian has to share. The proposed methodology may be applied in the same manner as it was applied in the first case study by using group decision-making and collaborative problem-solving.

(i) *International law principles*

Equity standards or criteria are derived from the principles of international law for the analysis of shared water resources. This means that the allocation of shared water resources will be based on seven criteria. These include:

1. Existing utilization
2. Recharge area
3. Natural flow
4. Population
5. Safe yield
6. Water use efficiency
7. Sustainability

These criteria will be incorporated in the Analytical Hierarchy Process (AHP) as shown in figure VI. The weights for the above seven criteria will be reflected in the weights assigned to each actor in the hierarchy which will in turn be compared to objectives and strategies.

It should be mentioned that the above criteria are not exhaustive; riparian States may agree on other standards or criteria. This should be done through a communicative process where data is shared and concerns and arguments are raised in a collaborative problem-solving environment. The goal is to reach consensus on the criteria regarding the issues of “who gets what and why” through group decision-making by the concerned riparian States.

(ii) *Decision theory*

After developing the criteria for water allocation, the methodology involves the application of AHP to devise and rank objectives and strategies for each riparian State. To apply AHP, the analyst (through group decision-making) should construct the hierarchy of the problem to be analyzed and then perform an analysis of the problem as presented in annex I.

Constructing the hierarchy

The overall hierarchy of the problem consists of four levels as shown in figure VI. These levels are:

- Level 1: Goal
- Level 2: Actors
- Level 3: Objectives
- Level 4: Strategies

In this case-study the goal or the focus for each country is to maximize its share of water. The actors in this problem are referred to by the following notation:

- Actor 1: Saudi Arabia
- Actor 2: Jordan

Group decision-making and collaborative problem-solving should be employed at the stage where criteria (or principles) for allocation regimes are determined and at other phases which involve constructing the hierarchy and its components (objectives and strategies).

The outcome of such a process, which is expected to be open and transparent, is likely to be agreed upon and sustainable strategies and action plans for the development and management of shared water resources.

In applying this methodology to the Rum aquifer, shared by actor 1 and actor 2, data from the constant rate and the step drawdown pumping tests were analyzed by a number of investigators in order to determine the hydraulic characteristics of the aquifer and the level of sustainable aquifer exploitation. The following data, used as inputs in formulating the recommendations for this model, need to be validated by both actors:

Rum-Disi aquifer: The parameters of prime concern are the horizontal hydraulic conductivity and the storage coefficient. The former varies from 1 m/d to 2 m/d, and the latter between 0.002 and 0.005. When applied to a regional system, this range of values may give significantly differing design parameters for a well field that is expected to operate over a long period of time.

Confining Layer: The data set for this feature are severely limited, as tests to evaluate the confining layer have never been carried out in Jordan. The values obtained from the pumping tests may be particularly unreliable because of borehole construction factors, but the vertical hydraulic conductivity value obtained suggests that it may be 0.04 m/d. The confining layer is not considered to have any storage in it.

Leaky Aquifer: Data suggest that horizontal hydraulic conductivity may be 0.01 to 0.1 m/d but borehole construction factors affect reliability, as with the confining layer.

Rum aquifer: The core plugs analyzed in the laboratory suggest that the hydraulic conductivity varies from 0.3 to 5 m/d, and the total porosity varies from 15 to 25%. Such a range of variation is normal in plug analysis as it is based on point samples that reflect the natural variation in formations.

Enhancements to the mathematical model that has been constructed for the Rum aquifer have led to the development of a calibrated transient model in which there is a good degree of confidence. This applies particularly to those areas of the aquifer in Jordan where national well fields are located, and to a certain extent in Saudi Arabia.

Applying the same methodology as in case-study No. 1, the outcome may be represented as combinations of cooperative strategies between Jordan and Saudi Arabia for optimal sharing of the groundwater in the Rum aquifer. A synthesis of some broad objectives and strategies identified and evaluated is outlined below:

Actor 1: Jordan

Objectives:

1. Satisfy water demand for all uses;
2. Improve water productivity (return of 1 m³ to GNP).

Strategies:

1. Transfer Rum water to Amman (domestic uses);
2. Enhance water use efficiency.

Actor 2: Saudi Arabia

Objectives:

1. Achieve food self-sufficiency (or security);
2. Improve water productivity (return of 1 m³ to GNP).

Strategies:

1. Limit irrigation from non-renewable groundwater (sustainability);

2. Import crops.

The anticipated outcome of a cooperative approach to managing shared groundwater in the Rum aquifer is that actor 1 and actor 2 agree on strategies that assign priority to the satisfaction of domestic water demands as well as emphasize the need for sustainability.

However, this methodology can be validated in the ESCWA region by involving the actors in a communicative process. Within this framework, the coriparians would be encouraged to apply group decision-making and collaborative problem-solving approaches in order to arrive at a mutually acceptable plan of action.

VII. CONCLUSIONS AND RECOMMENDATIONS

A. BACKGROUND

Most of the water which flows across the boundaries in the ESCWA region is not regulated by comprehensive international agreements signed by all the riparian States. The region is characterized by wide variations in the riparian countries' relative economic and political power. The limited number of agreements on international rivers in the region necessitates the adoption of sound principles of international law to ensure the allocation of shared water in an equitable and reasonable manner. Sharing water equitably is only one part of the challenge of transnational water courses; using and managing the water optimally and protecting the ecological integrity of the river systems or regional aquifers are other key prerequisites for sustainable development in the region.

Water issues occupy a central concern in the national agenda of all ESCWA member States who want to be assured of a sufficient quantity of water to cope with the progressive water demands for all sectors and to achieve socio-economic development associated with more urbanization, relatively high population growth rate, high rate of industrialization, and greater productivity in agriculture on the one hand and the scarcity and sharing of water resources with other riparians on the other.

International law has two main components: (1) treaties and other international agreements; and (2) the general principles of international law. Due to the specific characteristics of each international river in terms of the hydrologic, institutional and legal aspects, it is not realistic to draw up rules and regulations of universal applicability unless they are kept broad and flexible.

Historically, the elaboration of a set of principles related to water issues has undergone an evolutionary process. The International Law Association (ILA) formulated the Helsinki Rules in 1966. Since 1971, the International Law Commission (ILC) of the United Nations has been working on comprehensive principles which are in the form of 36 draft articles on the law of the non-navigational uses of international watercourses. A framework convention was held by the UN's 6th Committee to refine the draft articles, which were recently adopted by the United Nations General Assembly (annex I).

The ILC draft articles deal only with groundwater that is part of a river system. Groundwater not associated with rivers is not included. The main concepts and principles included in the ILC draft articles may be summarized as follows:*

The articles aimed to achieve a balance between 'equitable and reasonable' utilization of an international river (Article 5) on the one hand, and the desirability of avoiding 'significant harm' to the other riparians that are already using the river (Article 7), or might want to use it in the future, on the other hand. However, the ILC made it clear that it regards 'equitable and reasonable' as the guiding criterion. Relevant factors are to be considered in determining whether any use of the river is 'equitable and reasonable'. However, no attempt was made to order these factors in terms of priority due to the relative importance of these factors from one country to another. The articles stress the riparian States' obligation to protect international rivers and associated ecosystems (Articles 5,8,20,21). The articles oblige riparian States to cooperate in the optimal utilization and protection of the rivers which they share (Article 8). The articles recognize

* Odeh Al-Jayyousi, "International law and shared rivers", paper presented at the Expert Group Meeting on Water Legislation, Amman. 24-26 November 1996 (E/ESCWA/ENR/1996/WG.1/WP.5).

that agreements between riparian States may cover the entire river basin, or only part of it (Article 3). In the latter case, however, the agreement should not 'adversely affect', to a significant extent, other riparian States' use of the waters in the basin.

B. CONCLUSIONS

Based on the material presented throughout this document, the following main conclusions may be drawn:

1. In general, it can be concluded that good regional progress has been made in water resources management, institutional arrangements and water legislation at the national level, though very limited progress *vis-à-vis* managing and developing shared water resources at the subregional and regional levels has been made. Moreover, progress in national water resource projects has been hampered because of the increased political instability in the region and the resultant general trends of diverting technical and financial aid to more pressing needs.
2. A lack of cooperation for managing and developing the major shared water resources is common in the region. Despite years of effort, no formal protocols yet exist among the riparians of the Nile, Yarmouk, Jordan, Orontes, Al-Kabir, Tigris, Euphrates and Shatt Al-Arab rivers. If current circumstances continue, most of the downstream riparians will experience a severe quantity and/or quality deficit in water resources. Under even the best circumstances, most of the end-user countries will be unable to generate sufficient capital to finance critically needed water-storage and management projects without massive assistance from donor nations and lending institutions.
3. The existing shared water commissions in the region (The UNDOGO¹⁸ Group and the Permanent Joint Technical Commission for the Nile, the Technical Committee for the Yarmouk, and the Trilateral Commission for the Euphrates and Tigris rivers) proved unable to meet periodically and defuse the water conflicts among the riparians.
4. Such conflict resolution cannot be attained without the formulation of joint comprehensive water resource management plans. The plans should include explicit agreements on water allocation among the riparians concerned for each river basin, and/or exploitation rights for the major aquifers within the region. Given the lack of regional cooperation in the water sector among the ESCWA member States, it is remarkable that so few open conflicts over water have erupted. However, this state of affairs is changing rapidly. The closer each riparian State comes to depletion of its water resources, the greater the likelihood of conflict.
5. There should be relevant agreements between the countries sharing river basins and groundwater basins to ensure that each country can safely obtain its fair share of water. Upper river basin countries should not make any changes in the basin without studying carefully the effects on the other countries within the river basin. Countries that share groundwater basins, especially those not subject to water replenishment or with a limited amount of water replacement, should work towards formulating agreements on development plans which would not seriously affect the efficiency of the groundwater basin. It cannot easily be assumed that aquifers will be consistently treated in the same way as surface water. The legal rules for groundwater are still in the process of formulation, and the issue of aquifer is already under discussion.

¹⁸ The group of East African countries sharing the Nile River water.

6. Agreements among riparian States can be reached with the assistance of United Nations agencies or regional organizations representing countries with shared water basins.
7. Water use strategies and action plans for development of the shared water basins in the region can also be discussed in meetings or in ad hoc group discussions.
8. Existing international law for international watersheds does not provide precise rules capable of application in each and every instance. The substantive rules and principles that create rights and obligations for riparians are of a broad and flexible nature, qualified only by a number of non-legal variables. Riparian States are responsible for reaching agreements regarding appropriate regulation of the management and utilization of a particular watercourse. Likewise, as per the Helsinki Rules of 1966, the principle of equitable utilization as well as the obligation of riparians not to cause appreciable harm are general in nature and flexible and not precisely defined. However, the formulation of an appropriate legal mechanism, on the basis of which riparians can harmonize competing interests and cooperate in the management and utilization of a common water resource, poses a challenging problem when applied to a particular international watercourse.
9. In the absence of precise substantive rules, the procedural obligations of cooperation, negotiation and mutual consultation and the requirements for the exchange of information among watercourse States play an important role. They provide the foundations upon which riparian States can proceed towards an agreement.
10. One may conclude that the execution of unilateral water development plans as well as utilization practices for shared river and regional, interregional and groundwater basins have resulted in a significant impact on the usability and availability of water and, to a certain extent, on human health conditions. Such plans and practices also impact negatively on the environment, although this concern is not the focus of the current publication.
11. Inter-basin water transference and detouring and/or capturing significant volumes of waters from international or transboundary river systems have caused serious problems such as lowering the level of the Dead Sea, and deterioration of water quality in Jordan and Euphrates rivers, particularly in the lower reaches of the river systems.
12. Domestic, industrial and agricultural effluents flowing into the shared water resources may cause water quality to deteriorate within river systems, as in the case of the Orontes waters. The execution of huge irrigation schemes by the riparians utilizing shared waters may contribute heavily to salinization, soil degradation and water-logging as a result of poor irrigation-drainage networks or the utilization of deteriorated waters in some shared river systems. In the case of the Nile River basin, the stoppage of the Upper Nile Water Conservation Projects owing to the absence of multilateral agreement deprived the riparians, particularly the Sudan and Egypt, from additional volumes of water.
13. The withdrawal of groundwater within national territory can no longer be viewed as isolated from its effects on groundwater reservoirs in neighbouring territories, including salinization of surface waters and aquifers.
14. Cooperation and coordination in the development and management of the shared watersheds and river basins (briefly presented in the document), would be extremely beneficial. The ultimate goal of shared basin development is the execution of a comprehensive and multi-faceted plan dealing with measures to ensure rational development, utilization and conservation of water resources, taking into account the socio-economic factors prevailing in the ESCWA member countries concerned.

15. In order to reach an agreement on joint actions for shared basin development, negotiations should be conducted. In these discussions, the upstream country may seem to be in a very strong negotiating position, but one must consider the whole field of relations among the countries involved; if one country abuses its water position, it may well suffer in its relations with the neighbouring countries in another field such as trade affairs. It is clearly vital that the negotiations be conducted in a spirit of regional cooperation, possibly resorting to a neutral country and/or a knowledgeable team of experts to suggest what would be equitable and beneficial for all countries concerned.

C. RECOMMENDATIONS

Considering the points listed above, it is recommended that the following measures be considered by the member countries involved to develop their shared surface- and/or ground-water resources:

1. Establishment of joint advisory steering committees responsible for the coordination, follow-up and exchange of information regarding watershed investigations. These committees would be composed of representatives of the Governments concerned.

2.(a) Development of an integrated management mechanism to standardize and harmonize basic technical data on all relevant watershed parameters. Representatives from national teams designated by their Governments should be members of the steering committees mentioned above. This mechanism would be expected to perform the following:

- (i) Formulation of joint monitoring programmes for basic data collection, inventory and publications, required mapping, appraisal of existing projects, training requirements and facilities, research and its execution, basin development and management, and the design and execution of relevant pilot projects of common interest;
- (ii) Sponsorship of necessary studies and research, with the help of international agencies and other bodies as appropriate, to compare and analyse the institutions currently managing and developing the shared basins;
- (iii) Formulation of subregional plans and designs, including alternative water resource development schemes and allocation policies;

OR

(b) Direction of efforts towards the establishment of a joint river basin-wide authority for the major river basins in the region as appropriate and in full agreement with the concerned member Governments. This kind of authority has proven to be very efficient in other regions. It would provide the basis for cooperation, coordination and monitoring of all areas related to water resource development in a sound and comprehensive manner for the benefit of all countries involved;

3. Implementation of the main duties of this proposed authority, which at least in the initial stages, would be concerned with all basic data collection, processing, analysis, interpretation, evaluation and fact-finding.

4. Based on the conceptual framework proposed in the document, development of a linkage between international law principles and hydrological considerations, using the Decision Support System for the management of shared water resources, both surface and groundwater.

A regional institutional framework should be developed to serve as a platform for facilitation, mediation, and conflict resolution for shared water resources. Other conditions viewed as necessary for the conceptual framework to be viable include:

- (a) Availability and access to water-related information;
- (b) Improved communication among policy makers in the water sector.

Operationalizing the principles of international law is essential to defining criteria (or equity standards) for equitable and reasonable allocation of shared water resources. The four criteria proposed (existing utilization, recharge area, natural flow and population) should be validated in real situations in the ESCWA region.

The document recommends the establishment of a regional institutional framework as a forum for sharing data, group decision-making, collaborative problem-solving and consensus-building among riparian States.

5. In order to be able to develop integrated management mechanisms for dealing with questions or implementing shared water resource policies, the existing literature emphasizes that there is a need for organizations (Vlachos 1994):

- (a) That are sufficiently comprehensive to encompass the problems under attack;
- (b) That facilitate coordination of all related efforts;
- (c) That are adaptable to the dynamics of environmental change and to progressive stin the solution of environmental problems (operational flexibility);
- (d) That are capable of obtaining, evaluating and applying the appropriate science and technologies to a variety of resource problems.

6. The following are the major shared aquifers occurring in the region.

- (a) The Palaeozoic-Mesozoic sandstone aquifer, best represented in Bahrain, Jordan, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen;
- (b) The carbonate rock aquifer, which comprises three different groups:
 - (i) The Dammam/Umm er Radhuma limestone complex (Palaeocene-Eocene Tertiary) occurs in Bahrain, Kuwait, Oman, Qatar, Saudi Arabia, the United Arab Emirates and Yemen;
 - (ii) Carbonate rock aquifers belong to the Upper Cretaceous-Palaeocene time period and occur in the Hamad Basin in Jordan, Saudi Arabia, Iraq and the Syrian Arab Republic;
 - (iii) Jurassic-Cretaceous-karstic limestone and dolomite aquifers occur mainly in Lebanon, the Syrian Arab Republic and Jordan, in the highlands (the uplifted blocks) that border the Rift Valley system on both sides. The aquifer is of great importance for all sharing member countries as it feeds most of the large springs occurring in the area, with generally regular flows.

It is recommended that mutual action plans be worked out and agreed upon among riparian States to investigate the above-mentioned shared major aquifers in order:

(a) To delineate each aquifer's areal extent, potential, storage capacity and its dependability *vis-à-vis* space, time and quality;

(b) To study the possibility of trapping or capturing the water flowing into the sea, to waste, from some of the aquifers mentioned above. The Dammam/Umm er Rhaduma aquifer complex is experiencing a high rate of waste and quality deterioration through submarine flow into the Gulf area. Mesozoic karstic carbonate in Lebanon and the Syrian Arab Republic aquifer have proven to have similar waste as well as submarine flows into the Mediterranean sea. The same aquifer is experiencing quality deterioration and/or drainage by subsurface flow into the brackish groundwater reservoir in the Jordan Valley depression;

(c) To formulate and execute plans of action to develop potential water resources in the shared aquifers, from which more than one member country can benefit through fairly planned joint development schemes;

(d) To make consistent the status of hydrogeological investigations carried out on those aquifers and to fill in the gaps in these studies;

(e) To initiate plans and programmes for joint future monitoring, data updating and development of these aquifers.

Annex I

LIST OF ARTICLES FROM THE INTERNATIONAL LAW COMMISSION RULES ON THE NON-NAVIGATIONAL USES OF INTERNATIONAL WATER COURSES

Part I: Introduction

- Articles 1: Scope of the present convention
- Articles 2: Use of terms
- Article 3: Watercourse agreements
- Article 4: Parties to watercourse agreements

Part II: General Principles

- Article 5: Equitable and reasonable utilization and participation
- Article 6: Factors relevant to equitable and reasonable utilization
- Article 7: Obligation not to cause significant harm
- Article 8: General obligation to cooperate
- Article 9: Regular exchange of data and information
- Article 10: Relationship between different kinds of uses

Part III. Planned Measures

- Article 11: Information concerning planned measures
- Article 12: Notification concerning planned measures with possible adverse effects
- Article 13: Period for reply to notification
- Article 14: Obligations of the notifying State during the period for reply
- Article 15: Reply to notification
- Article 16: Absence of reply to notification
- Article 17: Consultations and negotiations concerning planned measures
- Article 18: Procedures in the absence of notification
- Article 19: Urgent implementation of planned measures

Part IV: Protection, Preservation and Management

- Article 20: Protection and preservation of ecosystems
- Article 21: Prevention, reduction and control of pollution
- Article 22: Introduction of alien or new species
- Article 24: Management
- Article 25: Regulation
- Article 26: Installations

Part V: Harmful Conditions and Emergency Situations

- Article 27: Prevention and mitigation of harmful conditions
- Article 28: Emergency situations

Part V: Miscellaneous Provisions

- Article 29: International watercourses and installations in time of armed conflict
- Article 30: Indirect procedures
- Article 31: Data and information vital to national defence or security
- Article 32: Non-discrimination
- Article 33: Settlement of disputes

Part VII: Final Clauses

- Article 34: Signature
- Article 35: Ratification, acceptance, approval or accession
- Article 36: Entry into force

Annex II

THE ANALYTICAL HIERARCHY PROCESS (AHP) AS A METHODOLOGY FOR EVALUATING ALTERNATIVES

A brief description of AHP as a methodology for evaluating alternatives is outlined below, based on Saaty 1988.

1. The first step involves the composition or structuring of a hierarchy of the components of the problem or issue to be analyzed. This phase may involve group decision-making to explore the various perspectives of the problem. In this paper, the hierarchy was composed of the following levels (from top to bottom): Goals, Technologies, Criteria and Users. However, these components are by no means exhaustive; other levels may be incorporated into the hierarchy such as Strategies, Scenarios, and/or Actors.

2. The second step is to make pairwise comparisons; that is, to compare the elements of a hierarchy in pairs (as will be shown in the numerical example below) against a given goal or criterion. To perform pairwise comparisons, a matrix is used to compare different variables. This is done as follows:

(a) Start at the top of the hierarchy to select the criterion (C), or property, that will be used for making the first comparison. Then, from the level immediately below, take the elements to be compared for example, $A_1, A_2, A_3, \dots, A_N$, considering that we have N elements;

(b) Arrange these elements in a matrix as shown in table A-1 below.

TABLE A-1. SAMPLE MATRIX FOR PAIRWISE COMPARISON

C	A ₁	A ₂	...	A _N
A ₁	1			
A ₁		1		
.			1	
A _N				1

(c) In this matrix compare the element A₁ in the column on the left with A₁, A₂, A₃, and so on in the row on the top with respect to property C in the upper left-hand corner. To compare elements, one should ask: "How much more strongly does this element possess or contribute to influence, satisfy, or benefit the property than does the element with which it is being compared?"

(d) To fill the matrix of pairwise comparisons, we may use the numerical values 1 through 9 presented in table A-2. When comparing one element in a matrix with itself, the comparison must give unity (1) which represents the values in the diagonal of the matrix.

Table A-2 below describes the ranks and their definitions.

TABLE A-2. THE SAATY RANKING SYSTEM

Intensity of importance	Definition	Explanation
1	Equal importance	Two activities contribute equally to the objective
3	Weak of importance of one over another	Experience and judgement slightly favour one activity over another
5	Essential or strong	Experience and judgement strongly favour one activity over another
7	Very strong or demonstrated	An activity is favoured in importance strongly over another; its dominance demonstrated in practice
9	Absolute importance	The evidence favouring one activity over another is of highest possible order of the affirmation

(e) To illustrate how to form a normalized matrix and to come up with relative weights in a generalized form, the following numerical example is presented:

Suppose that the outcome of pairwise comparison was made for three elements A_1 , A_2 , and A_3 with respect to criterion C as shown in table A-3:

TABLE A-3. SIMPLE MATRIX COMPARING THREE ELEMENTS FOR CRITERION C

C	A_1	A_2	A_3
A_1	1	1/2	1/4
A_2	2	1	1/2
A_3	4	2	1
column total	7	3.5	1.75

To synthesize our judgments so as to get relative weights, the following steps are to be taken:

(a) Add values in each column; then divide each entry in each column by the total of that column to obtain the normalized matrix as shown in table A-4;

TABLE A-4. NORMALIZED MATRIX

C	A_1	A_2	A_3	Average of rows
A_1	1/7	1/7	1/7	0.14
A_2	2/7	2/7	2/7	0.29
A_3	4/7	4/7	4/7	0.57

(b) Average the rows in each row of the normalized matrix; this yields the percentages of overall relative priorities of the elements A_1 , A_2 , and A_3 . Hence, we can make deductions with reference to relative weights as calculated above.

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