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REPORT ON MISSION TO THE ENVIRONMENTAL RESEARCH AND WILDLIFE DEVELOPMENT AGENCY ABU DHABI – UNITED ARAB EMIRATES

STRATEGY DEVELOPMENT FOR WATER RESOURCES MANAGEMENT IN ABU DHABI (PHASE I)

20-27 April 2001

by

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Note: The views expressed are those of the regional adviser and do not necessarily reflect the views of ESCWA.

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ملخص تنفيذي

طلبت هيئة أبحاث البيئة والحياة الفطرية وتنميتها في إمارة أبو ظبي في دولة الإمارات العربية المتحدة مساعدة الاسكوا، في تطوير استراتيجية لإدارة مصادر المياه في الإدارة، وذلك عن طريق الخدمات الاستشارية التي تقدمها الاسكوا للدول الأعضاء. وقد نفذ المستشار الإقليمي المهمة خلال شهر نيسان ٢٠٠١. ويمثل هذا التقرير المرحلة الأولى نحو تطوير الاستراتيجية المطلوبة ليتسنى مراجعته من الجهات المعنية في الإمارة قبل إعداد الاستراتيجية النهائية. وقد استلزم تطوير الاستراتيجية إعداد رؤيا مستقبلية لتطوير وإدارة مصادر المياه كخطوة أولى نحو إعداد الاستراتيجية. وقد أمكن من خلال إعداد الرؤيا المستقبلية تحديد المشاكل الحالية والمحتملة لمصادر المياه، وكذلك المحددات والفرص المتاحة مستقبلاً. كما أمكن من تحديد البدائل والمسارات المختلفة والمحتملة لتطوير وإدارة مصادر المياه في المستقبل، وتحديد الأهداف الاستراتيجية وكذلك قواعد تنفيذ هذه الاستراتيجية.

كما تم إعداد الإطار العام لخطة العمل اللازمة، وسوف يتم تفاصيل هذه الخطة فيما بعد في المرحلة الثانية من العمل، وتحديد الأدوار لمختلف الهيئات العامة العاملة في قطاع المياه لتقوم كل منها بتنفيذ الأعمال المتاحة بها.

ومن الجدير بالذكر ان مصادر المياه الحالية في الإمارة تشمل المياه الجوفية ومياه التحلية ومياه الصرف الصحي المعالجة. وتستعمل المياه الجوفية لكافة الأغراض تقريباً، بينما تستعمل مياه التحلية للأغراض المنزلية مباشرة او بعد خلطها بالمياه الجوفية. كما تستعمل مياه الصرف الصحي المعالجة لري الحدائق والأحزمة الخضراء بشكل خاص. وقد بلغ استعمال المياه من كافة هذه المصادر عام ١٩٩٥ حوالي ٦٢٠ مليون متر مكعب (م م م)، حوالي ٥٧% منها استعملت لأغراض الري والباقي للأغراض المنزلية. وبلغت مساهمة المياه الجوفية في كامل مصادر المياه حوالي ٥ر٤٨%، بينما بلغت مساهمة مياه التحلية حوالي ٣٦%، والباقي من مياه الصرف الصحي.

وتعاني مصادر المياه الجوفية من استنزاف للمخزون الجوفي نتيجة للضخ السنوي بمعدل يفوق عدة مرات معدل التغذية السنوية لها من مياه الأمطار والفيضانات وخلال العشرين سنة الأخيرة. كما تعاني من تدهور مستمر في نوعيتها، والمتمثل في زيادة ملوحة المياه فيها. ويهدد استمرار الاستنزاف بالمعدل والنمط

الحالي استدامة هذه المصادر في مواقع الاستثمار الحالية، وكذلك التنمية الاقتصادية والاجتماعية المعتمدة عليها. ويزيد من ندرة المياه تزايد الطلب عليها لمختلف أنشطة التنمية الاقتصادية والاجتماعية، وخاصة في المجال الزراعي المعتمد كلياً على المياه الجوفية والذي قد يتضاعف حتى عام ٢٠٢٥ اذا لم يتم ضبط التوسع في المساحات الزراعية.

ويعتبر تزايد ندرة مصادر المياه، وخاصة الجوفية منها، مع تزايد الاحتياجات من أهم التحديات في المستقبل، والتي لا بد من إيجاد الحلول المناسبة لها. ومن أهم هذه الحلول تحقيق الإدارة المتكاملة لمصادر المياه المختلفة، والتوزيع الأمثل لحصص المياه لمختلف القطاعات وتدعيم مصادر المياه الجوفية بمصادر مياه إضافية من تحلية مياه البحر وتطوير مصادر مياه الصرف الصحي، خاصة للزراعة. كما ان وضع استراتيجية مناسبة لإدارة مصادر المياه الجوفية تضمن حمايتها من الاستنزاف والتدهور النوعي، وتضمن استدامتها، يعتبر من أهم الخطوات التي يجب تحقيقها. ومن أهم مكونات هذه الاستراتيجية: اختيار الأهداف المناسبة والعملية، تحديد قواعد العمل والتنفيذ، ووضع خطة عمل مناسبة مع برنامج عمل زمني محدد، وتوزيع للأدوار بين المؤسسات ذات العلاقة. كما ان من مستلزمات تنفيذ الاستراتيجية إنشاء قاعدة بيانات ونظام معلومات متكامل للمياه، وتطوير مؤشرات لأهم قضايا المياه مثل التدهور النوعي والاستنزاف والحالة البيئية ذات العلاقة بالمياه العذبة.

ومن أهم أهداف الاستراتيجية المقترحة ما يلي:

١- ضمان استدامة مصادر المياه بالكمية والنوعية المناسبتين، وفي المكان والزمان المناسبين أيضاً.
٢- ضمان استدامة نواحي التنمية الاقتصادية والاجتماعية المختلفة والمعتمدة على المياه.
٣- ضمان التوزيع العادل والمتكافئ والأمثل لمصادر المياه بين القطاعات التنموية المختلفة.
٤- حماية الصحة العامة للإنسان ورفع مستوى معيشته.
٥- حماية البيئة والأنظمة الحيوية ذات العلاقة بالمياه العذبة.

هذا وسوف يتم تحديث هذه الاستراتيجية بعد مراجعتها من الجهات المعنية في إمارة أبو ظبي، وكذلك بعد توفير البيانات المطلوبة والتي سبق تقديمها للهيئة. وقد طلبت الهيئة إعداد الصيغة النهائية باللغة العربية.

EXECUTIVE SUMMARY

The Mission: An advisory mission was implemented during the period 20-27April, 2001, to the Environmental Research and Wildlife Development Agency (ERWDA) in Abu Dhabi, U.A.E., upon their request, to assist in developing a strategy for managing the fresh water resources in the Emirate, which would help achieve the socio-economic development goals, sustain the fresh water resources, healthy environment and healthy ecosystems in the Emirate.

This report represents the first draft/step for developing the needed strategy. The report includes an assessment of the current and future water situations, development of a strategic future water vision as a base for developing the required strategy, selection of appropriate practical goals, identification of the main water issues relevant to Abu Dhabi, setting the main strategy principles for implementation, and highlighting the main components of the action plan.

Water policies and strategies are readiness and preparedness for the future so that we will not be surprised with problems and consequences without organizing and planning. Developing a vision for the future provides diagnosis and identification of future conditions of water resources and water demand, and the expected problems that may be encountered, and their possible solutions. A future vision for water also lays down the various alternatives and scenarios that are expected and which are seen most practical and favorable The selection of the most favorable scenario dictates the course of action to be followed, namely, the policies and strategies required to implement the selected scenario and achieve its goals. Therefore a vision is a pre-requisite to the formulation of future water policies and strategies. A vision is also a justification for actions and routes to be undertaken and followed. On the basis of the future vision, the future goals, objectives and relevant water issues can be identified and selected. These goals form the pillars of the water policy and strategy which would be the reference and guide for all our future actions.

In view of the above it has been found necessary to develop in order to assist developing the required water management strategy.

Current Water Resources And Water Use: Groundwater in the Emirate of Abu Dhabi is the most important natural fresh water source. It has been providing almost all the water supply needed for municipal, industrial and irrigation purposes since the very early days.

Relatively fresh and renewable groundwater occurs in the relatively shallow alluvial deposits, and these constitute the best groundwater reservoirs, in terms of quantity and quality. This groundwater has been exploited at much higher rate than the average annual recharge resulting in progressive water level decline, and salinity build up. These shallow aquifers are highly vulnerable to depletion and quality deterioration

Brackish non-renewable saline groundwater occurs in deeper geological formations of sand stone and limestone, as well as at shallow depth in the sabkha and coastal areas. The salinity is expected to be high to very high, and the already performed exploratory work for these deep aquifers is not sufficient to make a scientific final assessment of the potential of the deep aquifer(s), both

quantitatively and qualitatively. The initial estimates of the groundwater resources have proved to be overestimated.

Groundwater resource assessment should be a continuous process during development, and should be based on an appropriate data collection and monitoring program, and the use of appropriate simulation models. Initial estimates were based on scanty information.

At the current stage of groundwater resource development, it is believed that the current groundwater resource management, in terms of resource sustainability is neither adequate nor satisfactory. Efforts have been concentrated on groundwater development, and very little has been done to alleviate the effects of over pumping. However even with full development of the total potential of the groundwater resources, the deficit in the water balance equation will remain high.

Surface water in the Emirate of Abu Dhabi is of little importance for direct utilization. However it is the main source of recharge for the intensively utilized fresh groundwater resources, particularly in Al Ain and Liwa areas.

The current desalination installed capacity in Abu Dhabi is 245 gpd, the practical capacity is 184 mgd, and the actual annual production of desalinated water amounts to 136 mgd. All this water is being used for domestic water supply.

With the increasing water demand to 376 & 415 MCM in the years 2020 & 2025 respectively, and the already stressed groundwater resources, **The production capacity of desalinated seawater for domestic water supplies needs to be increased to cope with the increasing demand.**

The total water use in the Emirate in 1995 amounted to about 620 MCM. About 85 % of the groundwater use is for agriculture, and the remaining is for municipal and industrial uses. About 36 % of the total water use comes from desalination of seawater mainly for municipal purposes. In addition, about 55 MCM/yr of treated wastewater is being used for irrigating parks and green belts.

The total municipal water use in 1997 was about 266 MCM. Out of which 16 % came from groundwater sources and the remaining came from seawater desalination.

Future Water Demand: Population growth implies increase in water demand as well as in food production, agriculture and industries. Urbanization and the rising income and standard of living would also raise the daily water consumption per person.

The Municipal Future Water Demand would increase from 161 to 415 MCM from 1995 till the year 2025.

The industrial water demand in the Emirate has been estimated at 10% of the municipal water demand. Therefore it will be as follows in MCM/yr.:

The Irrigation Water Demand the gross irrigation water abstraction from groundwater increased from 57 to 384 MCM from1982 till the year 2000 respectively. The future irrigation water demand depends on the government agricultural and water policies. The estimated demand would

range from a low of 516; to a high of 1892 MCM/yr. in 2020 with a moderate estimate of 762 MCM in 2020.

The future vision for water resources management would include the favorable scenes: sustainable water resources and socio-economic development, sustainable and equitable water supplies for the various uses, proper and equitable water resources allocation, integrated water resources development and management, and better human health and healthy environment.

Need For Augmenting The Existing Groundwater Resources: It is clear that the groundwater resources are not, and will not be sufficient to meet the current and future water demands. In addition, with the difficulties facing effective water management, particularly in the area of controlling groundwater abstraction, augmenting the existing limited water resources, by additional conventional and non-conventional water resources, and integration of the use of all the available water resources, become essential and important for maintaining sustainable water resources and socio-economic development. **The various possible options may include the following:**

- *Water Resources Management:*
- *Demand Management:*
- *Supply Management:*
- *Sea Water Desalination:*
- *Waste Water Utilization Potential:*
- *Utilization Of Brackish Groundwater:*

These options constitute the main components of the various possible scenarios for domestic, industrial, and irrigation water supplies in the future.

Water Resources Management: In addition, applying sound water resources management concepts and practices are essential for achieving sustainable water resources and socio-economic development. The most important of these are the following:

- Integrating the total water resources to meet the various water demands, and
- Increasing the water use efficiencies particularly in agriculture, and
  Applying the various means of water supply and demand management.
- Gradual reduction of the annual groundwater abstraction for irrigation, to approach a reasonably acceptable and sustainable level. The most effective way would be through increasing the irrigation efficiency, applying economic feasibility assessment for agriculture activities, and reducing the cultivated areas.

Strategy Development: Based on the developed vision, the water resources management strategy has been developed in terms of its main components: the strategic objectives, the strategy principles, and the action plan. In addition, the key challenges, the linkages of the water resources to the environment, the strategy characteristics, and the requirements for implementation have been identified. A methodology for developing the strategy has also been proposed.

As stated in ERWDA environmental strategy, the water resources management strategy needs to be designed and directed according to the following steps:

1. Develop management strategy for water resources.
2. Establishing a water resources databases.
3. Development of indicators for critical water issues (resource depletion, degradation and sustainability).
4. Developing a monitoring program.
5. Implement management and enforcement.
6. Conduct recovery and rehabilitation.

Strategy Objectives: The main strategy objectives have been defined as follows:

1. To support the sustainable development of the water resources and other related socio-economic developments:
   a. Proceed towards the integrated management approach, which would consider the conjunctive utilization of all available water resources and all other environmental and socio-economic conditions and activities.
   b. Maintain adequate water supplies for all uses in the required quantity, quality, time and space, and according to pre-established priorities for water allocation.
   c. Achievement of a water resources and socio-economic development, particularly for agricultural, which is technically, socially, economically, financially, and environmentally balanced and viable.
   d. To ensure equitable and fair water resources allocation and exploitation, with emphasis on the low-income sector of the society and the rights of the future generations.
2. To enhance human health and well being.
3. To protect the environment and ensure sustainable and healthy ecosystems.

Strategic Action Plan: Once the goals, objectives and the principles for action are well defined, an appropriate, comprehensive, and flexible action plan has been developed. The action plan included programs, means and tools for implementation, and a general implementation schedule. This action plan will be detailed in the second phase of the project when the detailed activities, and the responsibility of implementation will be identified in cooperation with ERWDA.

Recommendations: It is recommended that his document be updated upon its review by a national team or committee, and after the collection of the additionally required data as requested from ERWDA during this mission.

The action plan will be detailed during the next phase to show the activities needed, and a detailed time schedule with distribution of work among concerned organization .

At a latter stage, the required database will be identified, a monitoring program and special indicators for the various water issues will be developed. The need for special groundwater rehabilitation program will also be identified and recommended.

PART - 1

STRATEGIC VISION
FOR WATER RESOURCES DEVELOPMENT AND MANAGEMENT
In The
EMIRATE of ABU DHABI

INTRODUCTION

Water policies and strategies are readiness and preparedness for the future so that we will not be surprised with problems and consequences without organizing and planning. A vision for the future provides diagnosis and identification of future conditions of water resources and water demand, and the expected problems that may be encountered, and their possible solutions. A future vision for water also lays down the various alternatives and scenarios that are expected and which are seen most practical and favorable. Therefore a vision is a pre-requisite to the formulation of future water policies and strategies. A vision is also a justification for actions and routes to be undertaken and followed.

On the basis of the future vision, the future goals and objectives can be identified and selected. These objectives should be realistic and achievable. They form the pillars of water policy and strategy. Such policy would be the reference and guidance for all our future actions. Then the strategies would come to achieve specific favorable scenarios, as it is supposed to answer the question of what we should do to achieve the policy objectives. Therefore, a vision is so important, and should be realistic and up to our ambitions in the future.

A vision should be based on two important aspects:

1: An in-depth knowledge of the present water status in the country, and
2: Realistic insight for the future

The first aspect also includes knowledge of other water-based socio-economic activities and sectors.

In view of the above it has been found necessary to assess the present water resources and water uses, as well as to project the future conditions and requirements. Then, future scenarios have been tested for various water resources availability and water demand options. The selection of the most favorable scenario dictates the course of action to be followed, namely, the policies and strategies required to implement the selected scenario and achieve its goals.

A vision for water resources development and management in the Emirate of Abu Dhabi has been prepared in the light of the above concept and approach, and using the data provided during the last mission to the Environmental Research and Wildlife Development Agency (ERWDA),Abu Dhabi, U.A.E. during April 2001. Should new and additional data and information is made available calculations and projections, for water supply and demand as well as water balances can be updated. The developed vision may be considered a base for the development of water-resources development and management strategy.

CURRENT SITUATION

SURFACE WATER RESOURCES

Surface water in the Emirate of Abu Dhabi is of little importance for direct utilization. However it is the main source of recharge for the intensively utilized fresh groundwater resources, particularly in Al Ain and Liwa areas. In Al Ain area the wadies drain the relatively high rainfall mountain areas in Oman. Floodwater in these wadies infiltrate to the groundwater in the alluvial sediments.

Rainfall over the Emirate is the main source of both surface and groundwater. It can be described as erratic and sporadic due to its high variability in time and space. Rainstorms are mostly of short durations but of moderate to high intensities, resulting in flash floods with relatively short flow durations but high peaks. Part of the floodwater infiltrates through the sandy gravelly beds of the stream channels to recharge the groundwater. However the short flood durations, the low frequency and the relatively small quantities of floods do not justify the direct use of floodwater for irrigation or other purposes.

GROUNDWATER RESOURCES

General Features:

Groundwater in the Emirate of Abu Dhabi is the most important natural fresh water source. It has been providing almost all the water supply needed for municipal, industrial and irrigation purposes since the very early days.

Relatively fresh groundwater occurs in the relatively shallow alluvial deposits, while brackish and saline groundwater occurs in deeper geological formations of sand stone and limestone, as well as at shallow depth in the sabkha and coastal areas.

It can be stated that the shallow groundwater occurring in the alluvial deposits is renewable to a certain degree. However recharge may occur only once every 1-5 year. Only rainstorms generating floods are expected to contribute to groundwater recharge. Replenishment for the groundwater generates from the floodwater by infiltration through the highly permeable alluvial deposits within the stream channels and at the outwash areas of the wadies (indirect recharge). Direct recharge from rainwater also occurs but in smaller quantity. Therefore, the best groundwater reservoirs, in terms of quantity and quality, are found at the outwash areas of the major wadies.

This groundwater has been exploited at much higher rate than the average annual recharge resulting in progressive water level decline, and salinity build up.

The deep groundwater, on the other hand, is considered non-renewable. The exploitable storage is not known, and the practical annual mining yield has not been determined. Moreover, its salinity is expected to be high to very high.

Based on literature review and discussions with local water experts and managers, it can be concluded that the already performed exploratory work for the deep aquifer(s) is not sufficient to make a scientific final assessment of the potential of the deep aquifer(s), both quantitatively and qualitatively.

Although the storage capacity of the alluvial aquifer is high, the limited aquifer thickness and Arial extent constraint the total storage volume of fresh water. Moreover, the adjacent seawater, which also extends landward below fresher groundwater to some distance, and is in hydraulic equilibrium with the groundwater, creates additional boundary for the groundwater reservoir. In addition, the absence of impermeable boundaries between seawater and the fresh water aquifer, and the low hydraulic gradient of the groundwater system, render the aquifer highly vulnerable to salt water intrusion upon man-made interference by pumping.

Under natural undisturbed conditions, the aquifer was in a hydraulic balance under steady state conditions with the seawater. However, man interference by intensified pumping, at a rate much greater than the annual rate of replenishment, has disturbed such natural balance. After the recent intensive over pumping, seawater and saline groundwater invaded the fresh water aquifer laterally and vertically.

GROUNDWATER ASSESSMENT:

Concept and Approach:

It has been a general practice for the previous studies to assess the ground water recharge as 10% of the annual average rainfall, and the groundwater storage based on the volume of water that can be stored in the interstices (pore space) in a bulk volume of the aquifer, which was taken as 10% of the total rock volume. No actual tests or measurements of neither the percent of rainfall that infiltrates to recharge the aquifer nor an appropriate assessment of the exploitable groundwater storage have been made. Such approximations may be accepted at the early stage of resource assessment and development and for general planning purpose. However, for the later stage of resource management, more detailed studies using well designed pumping tests and mathematical models are needed to assess the actual response of the aquifer to development, and to study further future development potentials and the various development options.

Assessment should be a continuous process during development, and should be based on an appropriate data collection and monitoring program. The accuracy of assessment is dependent on the availability, accuracy and consistency of such data. Continuous monitoring and assessment are needed for continuously changing conditions, and for periodical evaluation of development impacts particularly when problems arise.

The point now is that we are at a late stage of groundwater resource development and what has been done in resource management in terms of assessment of the practical safe and sustainable rate of groundwater yield is not sufficient. Efforts have been concentrated on groundwater development, and very little has been done to alleviate the effects of over pumping. However even with full development of the total potential of the groundwater resources, the deficit in the water balance equation will remain high.

WATER USE:

General:

It has been an official policy and a general practice that the groundwater resources in Abu Dhabi are used for irrigation, municipal and industrial purposes. The total water use in the Emirate in 1995 amounted to about 620 MCM. The distribution of this amount for the different uses and from the different water sources is shown in table and figure (1). About 85 % of the groundwater use is for agriculture, and the remaining is for municipal and industrial uses. About 36 % of the total water use comes from desalination of seawater mainly for municipal purposes. (1995)

Municipal:

The average production for municipal water use in 1995 was 162 million gallons per day.The total municipal water use in 1997 was about 266 MCM. Out of which 16 % came from groundwater sources, tables and figures (1,2), and the remaining came from seawater desalination.

Irrigation Water Use:

Historical groundwater pumping for irrigation is given in table and figure (3). It increased from 57 MCM in 1982 to 384 MCM in the year 2000. About 95 MCM of treated wastewater were used for recreational agriculture in 1995.

The total number of wells in the Emirate until 1995 was 36386 wells, of which 31893, (87.75) were still in operation, while 4493 wells were abandoned.

The total farms' and cultivated areas in the Emirate were given as 47816 and 39044 hectares respectively in 1995. The total number of farms was 10281 farms, giving an average area of 4.65 hectares per farm. (Table & figure 3.)

Industrial Water Use:

Data on this issue was requested during the mission.

PROBLEM ANALYSIS:

The principle of cause and effect applies very well to groundwater problem analysis in order to identify the problems, the causes, and the effects.

FUTURE SITUATION

WATER DEMAND:

General:

There are several factors which dictate increasing water demand in the future for all water uses. Population growth is the first natural factor. Population growth implies increase in water demand as well as in food production, agriculture and industries. The rising income and standard of living would also raise the daily water demand per person. Other factors, which raise water demand, include increased urbanization, increasing the percentage of population served by piped water, the introduction of sewerage system, and changing priorities among water users.

On the other hand there are factors which would decrease water demand such as: appropriate pricing and tariff system, increased public awareness to avoid misuse of water, and increasing the efficiency of operation and maintenance of the water storage and distribution networks.

The absence of efficient pricing and charging system would have a reverse effect. Free water distribution will encourage waste and misuse. Similarly, lack of public awareness of the value of water and of its scarcity in our region would have a negative effect.

Municipal Future Water Demand:

A general look at the historical municipal water production in the U.A.E., table and figure (2), indicates an observed rise around the year 1992/93 to almost doable the rate for the previous years since 1984. Generally for the period 1984-1996, the water production has increased to slightly more than double.

On the other hand, demand projections have been made based on the increase rate of municipal water demand during the past 20 years, and assuming future demand would increase at the same rate. The demand would increase from 161 to 415 MCM from 1995 till the year 2025. The total future water demand is given in table and figure (5).

Industrial Water Demand:

The industrial water demand in the Emirate has been estimated at 10% of the municipal water demand. Therefore it will be as follows in MCM/yr.:

	1995	2000	2010	2025
Municipal demand	162	197	277	415
Industrial demand	16.2	19.7	27.7	41.5

Irrigation Water Demand:

The gross irrigation water abstraction from groundwater increased from 57 to 384 MCM from1982 till the year 2000 respectively. The future irrigation water demand depends on the government agricultural and water policies. Three estimates have been made: high, moderate and low estimates. The estimated demand would range from 516 (high), to1892 (low) MCM/yr. in 2020. A moderate estimate is calculated as 762 MCM in 2020. (Table and figure 6). The abstraction figures have been calculated based on the yearly cultivated areas, (figure 2), and an average irrigation water requirement of 3400 mm./yr, and applying an overall irrigation efficiency of 50%.

Table & Figure (1)
Water Use in Abu Dhabi Emirate In 1995, By Water Source & Type of Use

A : (million Gallons per Day)

Water Source (mg/d)	Type Of Use		Total
	Municipal	Irrigation	
Groundwater	26	157	183
Desalinated Water	136		136
Treated Waste Water		58	58
Total	162	215	377

B : (Million Cubic Meters /Yr) (MCM/Yr)

Water Source (mg/d)	Type Of Use		Total
	Municipal	Irrigation	
Groundwater	43	258	301
Desalinated Water	224	0	224
Treated Waste Water	0	95	95
Total	266	353	620

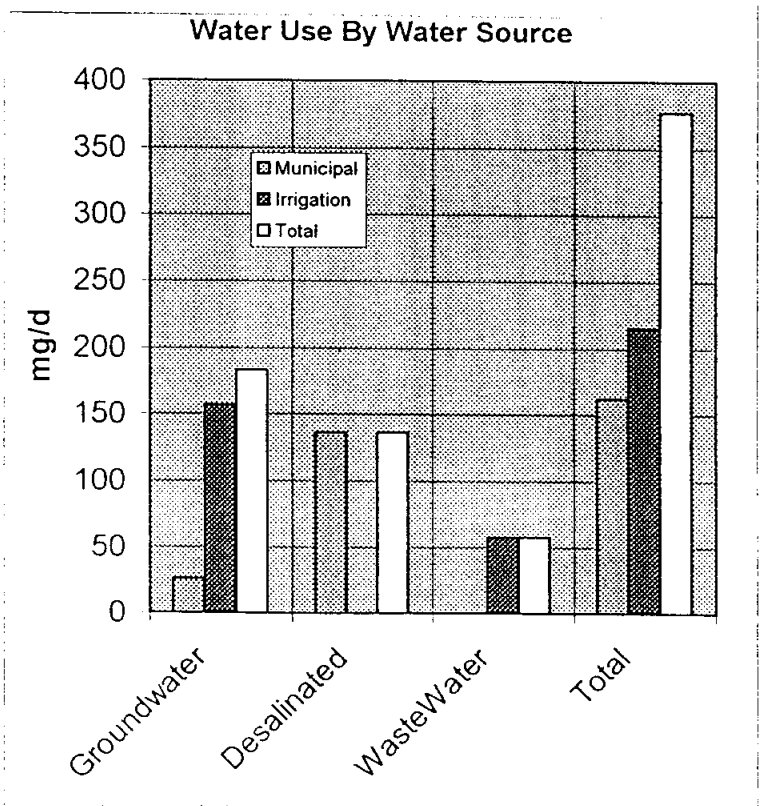


Table & Figure (2)
Development & Projections of FRESH Water Domestic Supplies in Abu Dhabi (mg/day)

(Groundwater & Desalinated Water)

	Year	Annual production Rate mg/d	Annual Grawth Rate %
	1980	51	
	1981	55	8.5
	1982	61	10.9
	1983	64	4.9
	1984	73	14.1
	1985	77	5.5
	1986	86	11.7
	1987	93	8.1
	1988	118	26.9
	1989	131	11.0
	1990	134	2.3
	1991	138	3.0
	1992	150	8.7
	1993	155	3.3
	1994	160	3.2
	1995	162	1.3
	2000	192	3.5
P	2005	229	3.5
R	2010	270	3.4
O	2015	316	3.2
J	2020	367	3
E	2025	405	2
C	2050	519	1
TIONS			

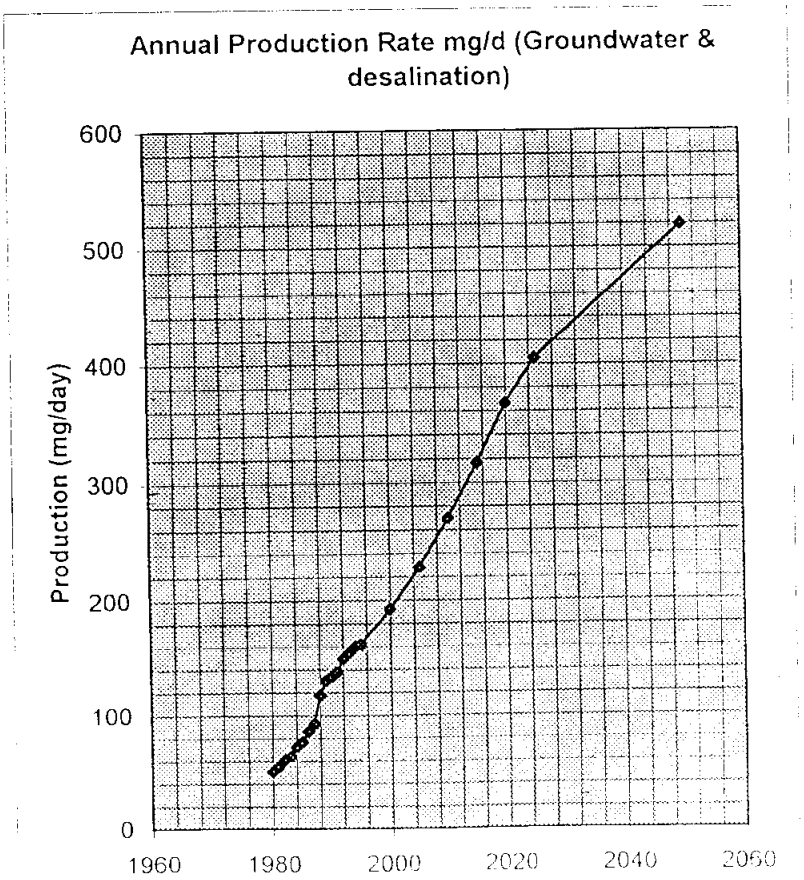
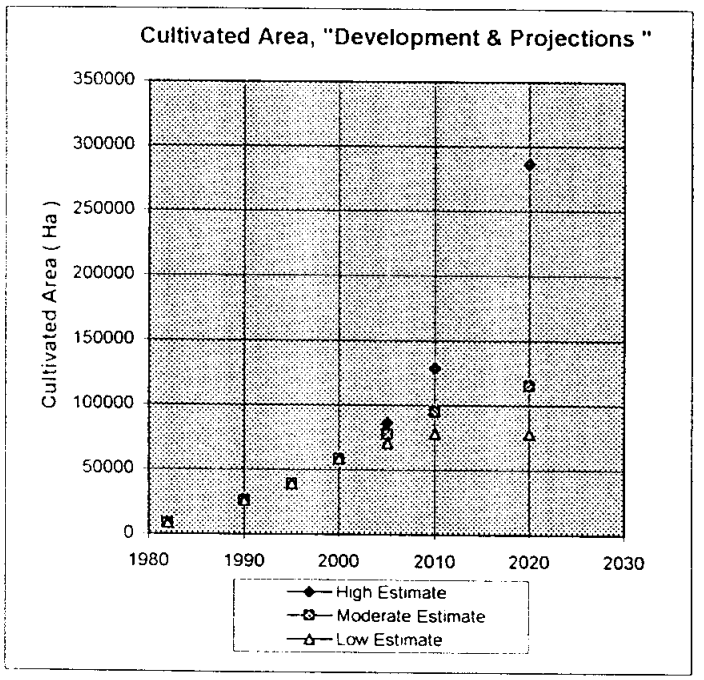


Table & Figure (3)

Past, Current, And Projected Growth In Cultivated Area And Grounwater Pumping In Abu Dhabi

Year	High Estimate			Moderate Estimate			Low Estimate		
	Gr.Rate	Area (ha)	Annual Pumping Rate (MCM)	Gr.Rate	Area (ha)	Annual Pumping Rate (MCM)	Gr.Rate	Area (ha)	Annual Pumping Rate (MCM)
1982		8567	57		8567	57		8567	57
	15			15			15		
1990		26207	173		26207	173		26207	173
	8.3			8.3			8.3		
1995		39044	258		39044	258		39044	258
	8.3			8.3			8.3		
2000		58170	384		58170	384		58170	384
	8.3			6			4		
2005		86664	572		77844	514		70772	467
	8.3			4			2		
2010		129116	852		94709	625		78138	516
	8.3			2			0		
2020		286593	1892		115450	762		78138	516



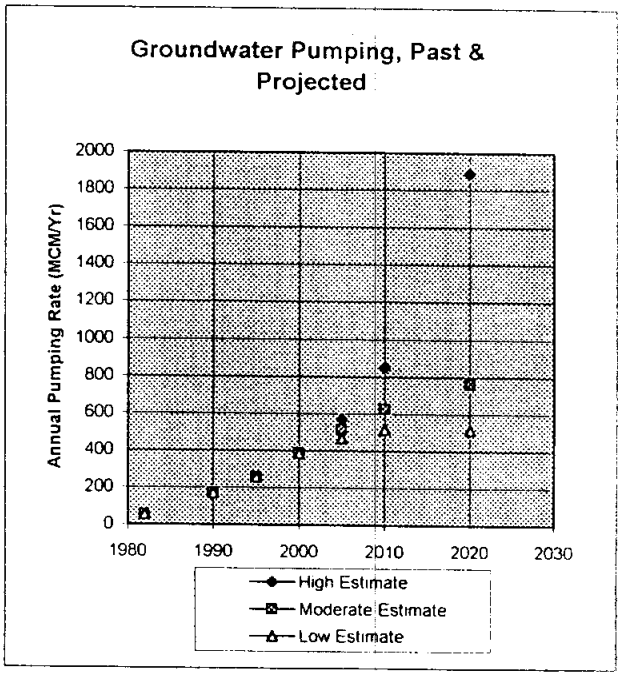
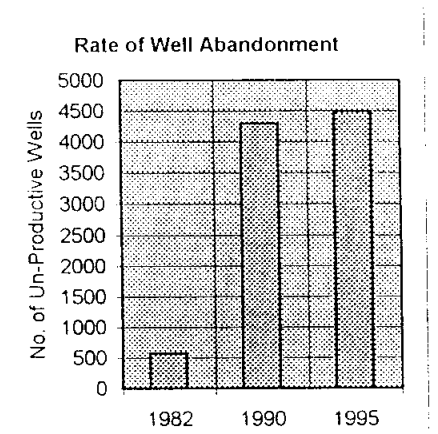


Table & Figure (4)
Histrical Development of Irrigation Wells in Abu Dhabi

	YEAR			
	1982	1990	1995	2000
Total Number of Wells:	5667	14076	36386	
Productive:				
Number	5085	11584	31893	
%	89.7	82.3	87.7	
Un-Productive * :				
Number	572	4292	4493	
%	10.1	30.5	12.3	



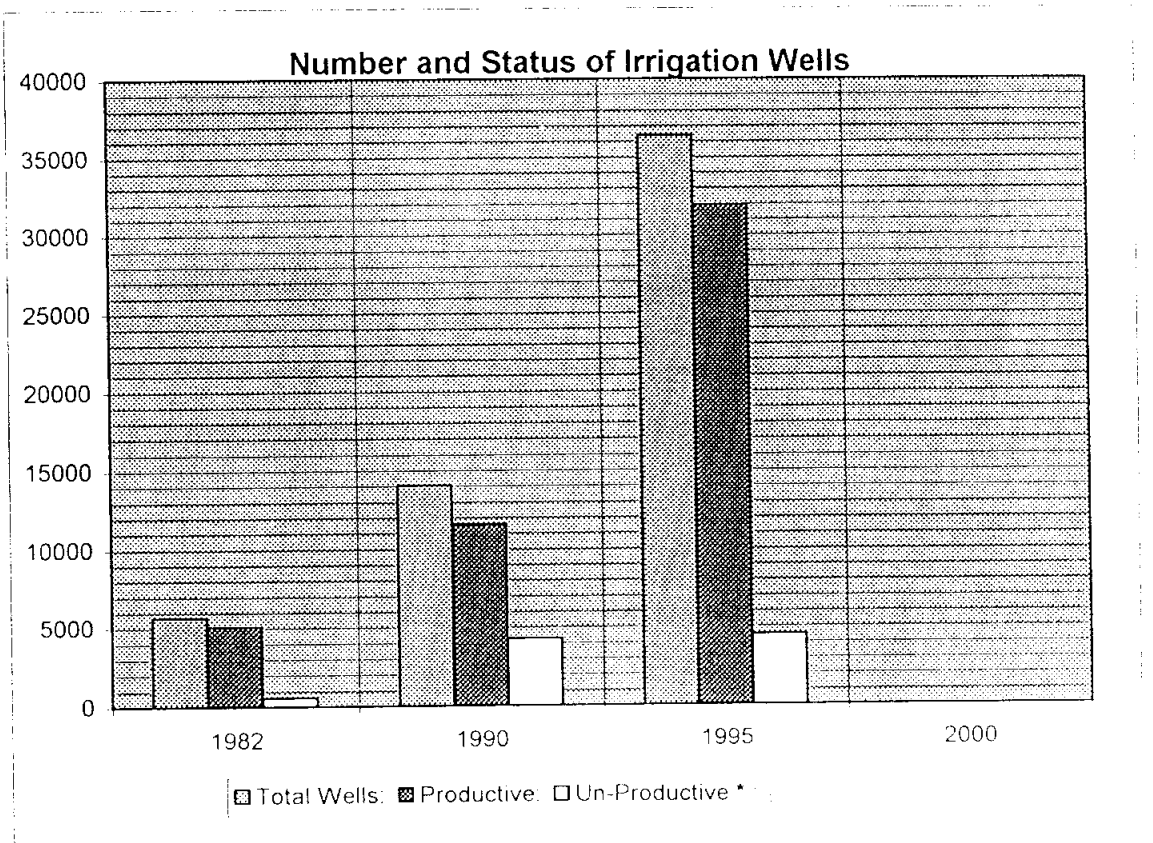


Table & Figure (5)
Future Desalination Requirements For Domestic Supply

Year	Installed Capacity mg/d	Projected Actual Prodution Capacity as % of insalled	Practical Projected Production Capacity mg/d	Assumed Sustainable Groundwater Supply of 26 mg/d	Total Available Supplies mg/d	Domestic Demand mg/d	Additional desalination Requirement mg/d	Total Future Desalination Requirement mg/d *	Additional Installed Capacity Required mg/d at 75%	Total Future Installed Capacity mg/d
1995	245	75	184	26	210	162				
2000		70	172	26	198	197	-1	171	-1	244
2005		65	159	26	185	234	49	208	65	310
2010		60	147	26	173	277	104	251	139	384
2015		55	135	26	161	324	163	298	218	463
2020		50	123	26	149	376	228	350	303	548
2025		45	110	26	136	415	279	389	372	617

Notes

* Installed capacity in 1995 was 245 mg/d.
* Production rate in 1995 was 136 mg/d.
* Groundwater production rate in 1995 was 26 mg/d.
* Total fresh water production for municipal use was 162 mg/d.
* The current actual production capacity is assumed to be 75%.
* The installed capacity would decrease by 1% per year due to depreciation

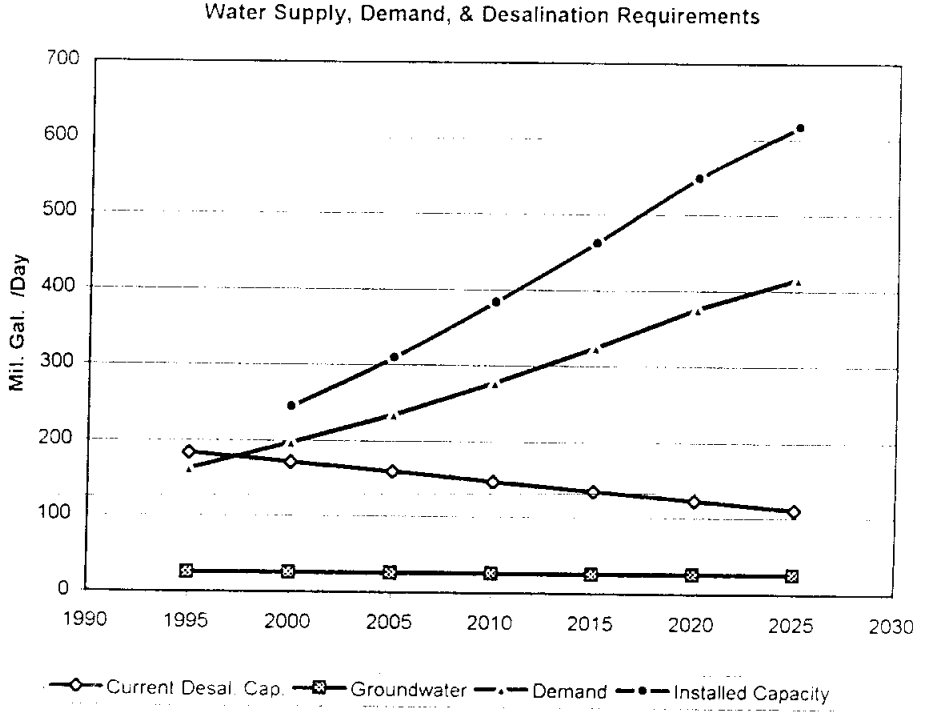


Table & Figure (6)

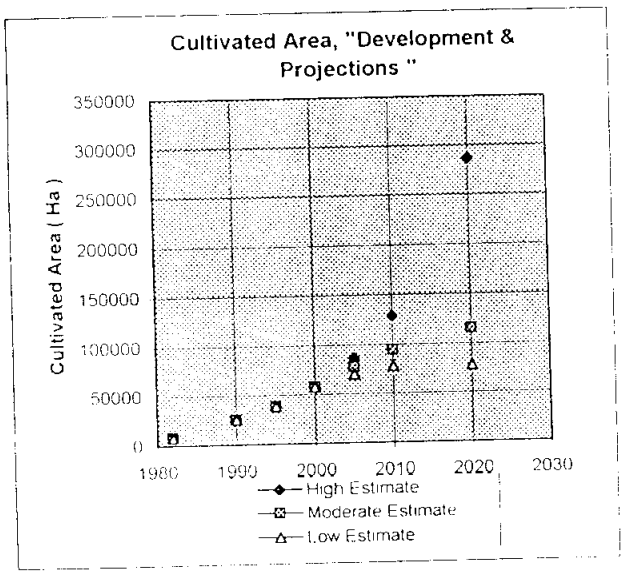
Past, Current, And Projected Growth In Cultivated Area And Grounwater Pumping In Abu Dhabi

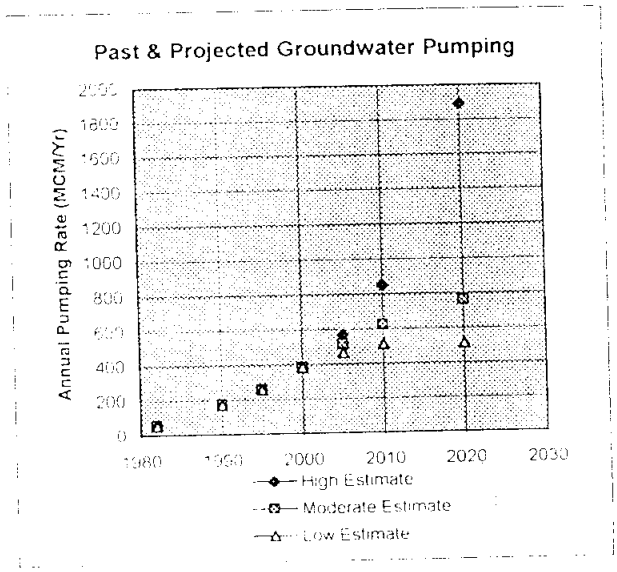
Cultivated Area (hectar)

	High Estimate	Moderate Estimate	Low Estimate
1982	8567	8567	8567
1990	26207	26207	26207
1995	39044	39044	39044
2000	58170	58170	58170
2005	86664	77844	70772
2010	129116	94709	78138
2020	286593	115450	78138

Annual Groundwater Pumping (MCM/Yr.

	High Estimate	Moderate Estimate	Low Estimate
1982	57	57	57
1990	173	173	173
1995	258	258	258
2000	384	384	384
2005	572	514	467
2010	852	625	516
2020	1892	762	516





OPTIONS FOR AUGMENTING THE EXISTING GROUNDWATER RESOURCES

With the difficulties facing effective water management, particularly in the area of controlling groundwater abstraction, augmenting the existing limited water resources, by additional conventional and non-conventional water resources, becomes essential and important for maintaining sustainable water resources and socio-economic development.

Two approaches for dealing with such situation are needed side-by-side: Engineering solutions / resource development, also called structural measures, and management approach / non-structural measures.

The structural measures emphasize on developing new water resources such as: recharge dams; water harvesting projects; collection, treatment, distribution and re-use of municipal wastewater and seawater desalination.

The non-structural measures would include the following management aspects:

- Water resources management (discussed earlier) to try rehabilitate and restore the seriously depleted aquifers:
  - Deep brackish groundwater,
  - Treated waste water,
  - Desalinated seawater.
- Water supply management which includes improving the efficiency of the water supply system/network, to detect and prevent leak, and reduce the unaccounted for water.
- Demand Management using appropriate water conservation programs, water saving devices, and the adoption of adequate pricing policy.
- Adoption of socially and economically appropriate water allocation policy, particularly for the water use in irrigation.

Comparing the future total water demand in the year 2020 (1134 MCM/year), with the current water supplies (646 MCM/year), additional 488 MCM will be needed. The following additional quantities, from new water supply options may be considered:

Potential Water Source	Targeted use	Quantity MCM/yr.
• Waste water collection and Treatment AT 35 % of the supply	Recreation	132
• Desalinated seawater (additional)	Domestic	227
• Savings from raising the Irrigation efficiency by 20%	Agriculture	103
• Savings from reduction of leaks From the distribution system By 8 % of municipal water use	Domestic	30
• Increase in groundwater pumping	Agriculture Irrigation.	132
Total		**624**

These options for augmenting the groundwater supplies indicate the potential strategic directions and tracts that can be followed in the future to meet the water demands for the various socio-economic development activities. It is clear that if these additional water sources can be developed, a surplus of 136 MCM will be available however: this surplus is expected to be directed towards domestic and urban recreational uses and not to irrigated agriculture. Therefore, there would be an increase in groundwater pumping for irrigation by an amount of 132 MCM, as a minimum in 2020,considering the low estimate of the irrigation future demand. Any Wastewater diverted for agriculture would definitely reduce some pressure from the already over-developed groundwater resources.

WATER RESOURCES MANAGEMENT:

We are, and we will be facing a two-fold water problem during the coming few decades. An increasing water demand, and in the meantime a decreasing fresh water supply. The increasing water demand, with population is normal, and can be planned for if financial resources are made available. The problematic issue is the decreasing availability of fresh water resources for the different water uses. Water scarcity and over-pumping are the major cause for this problem. Indirect causes include lack of control and adequate management of the development process of groundwater and agricultural activities.

Because of the constraints and limitations of the groundwater resources in the Emirate of Abu Dhabi as described earlier, and the little practical value for direct use of the limited surface water resources, the groundwater resources should be managed in an integrated and conjunctive manner with the other available non-conventional resources, namely sea water desalination and treated municipal waste water.

As these non-conventional water resources are pretty well under control, and they are not expected to be seriously affected by human activities, emphasis should be concentrated on the management of the groundwater resources, which are the major water sources for all uses, particularly for agriculture, and they already suffer most from depletion and water quality deterioration problems as a result of human interference and activities.

The management approach for a newly developed natural resource, like water, usually differs from that for an already over-developed resource. The approach also differs for a renewable and non-renewable groundwater resource. It also differs with the type and severity of the problems encountered, that dictate the management criteria to be adopted: water levels, water quality, storage volume or recharge rate, as well as the level of attention needed.

Presently, we are faced with a situation where the aquifer has been over pumped, several times greater than the annual rate of recharge, and for about 20 years. The situation is considered super critical, particularly in Al Ain area, and to a less extent in Liwa area, and requires intensive care and attention. Under such circumstances huge efforts are needed to improve the conditions of the groundwater reservoir. If the current level and pattern of development is continued, it would constitute a real threat to the resource sustainability, that will then require a large-scale aquifer restoration and

rehabilitation program would. Such a program would be costly, and its success depends on several factors, most importantly are the following:

1. **The will of the Government to stop deterioration, start reversing the situation in order to protect such valuable water resource, and pave the road for a new start towards sustainable water resources and socio-economic development.**
2. **The support and alternatives the government would provide to implement such a program**, as it is not expected that the farmers would be left alone to bear the consequences. Financial and technical support are needed to increase the irrigation efficiency and agricultural productively so that farmers can produce more with one unit of water, and thus maintain their level of income. In some cases partial or complete compensation may be required for water rights.
3. The government policy: whether full mining of the groundwater resource will be allowed, or to maintain a sustainable development.
4. The acceptance of the farmers of the plan: This depends on their awareness of the present problems and future consequences including the possibility of loosing their agricultural investments in few years, as well as the amount of support the government is willing to provide.

The program is expected to include various protective and corrective measures, at different levels for the different areas, depending on the level of water resource deterioration in each area. The program can be only implemented on gradual basis starting with the most critical areas. Flexibility of the plan to deal with various conditions and requirements should be maintained without sacrifying the goal.

The program would include two main streams: improve the management and control of the existing groundwater resources, and/or develop new water sources to augment the existing one. The two alternatives aim at protecting, rehabilitating, and rest orating the existing water resources. They include:

- Issuance and enforcement of adequate legislations to have better management and administration of water resources. This requires strengthening the institutional capability to act and implement what is required.
- Increase the irrigation efficiency, by enforcing and supporting the conversion to the modern water-saving irrigation methods.
- Improve the farming practices, including the cropping pattern, crop selection, and the application of appropriate crop water requirement.
- Reduce irrigation water abstraction by reducing the irrigated area, stop licensing new farms, and issuance of annual extraction permits.

The resource development option, on the other hand, includes development of new water resources to augment groundwater, such as:

1. Extend sewerage collection and treatment systems to the major population centers, even in the rural areas, and build adequate treatment facilities to treat the collected wastewater so that it can be reused for irrigation. The option for the

natural treatment techniques through infiltration basins should be considered as it proved its technical and economic viability in different countries.

2. Increase the desalination capacity of seawater for municipal purposes so that the groundwater may be released for other uses, or just to reduce abstraction.

   We may start abstraction reduction at a rate of 10-20% annually in the most critical areas. The target for this reduction may be decided at a later stage based on the monitoring results of the aquifer response.

DEMAND MANAGEMENT:

As water is involved in many activities in our life, and if full cost pricing is considered inappropriate to be adopted for social and political reasons, screening and evaluation of water-using projects and activities become necessary. Particularly in countries or regions where water is a scarce resource like U.A.E.

No one can argue the fact that free water supply will encourage overuse and misuse of water. If people know that they will pay the water bill at the end of the month, they will make sure that they waste no water, and they would try to rationalize their water uses. However, the people response to water pricing differs from one country to another, and within the various water users in the same country, the rich and the poor, the rural and urban population, as well as domestic, industrial and touristic water users.

Since water industry has become a common practice in this region through desalination and water bottling industries, then water has been accepted to be like any of the commercial commodities. The government spends millions of Dirhams in the water industry. Full-scale or partial costing of water use seems justifiable to conserve such water and maintain and operate such important services and expensive water facilities and make these resources and services self-supporting as a step towards achieving their sustainability.

In addition, different water uses require a wide range of water quality, ranging from high purity requirement for drinking purposes to less pure water for irrigation and industry. Therefore water allocation and water pricing should consider the level of purity required and supplied for each specific water users category.

Water pricing should also distinguish between the values of the products of water use, particularly irrigation and industry. Charges for irrigation water may be accrued indirectly through taxes on the cultivated areas or through an annual groundwater extraction permit, which sets the allowable area to be irrigated. Charging irrigation water according to water quantity requires installing water meters, which is not an easy process. The idea of taxes on cultivated areas or fixed fees per unit irrigated area seems more favorable.

Water pricing system, if designed properly, could be an effective tool for water saving. This is particularly true if increasing prices are given for increasing quantities of used water. Such a pricing policy should be effective in reducing water consumption by the rich, and in the mean time protect the

benefit and welfare of the poor, for whom a minimum water requirement may be given free or at a low price.

The best way to implement water pricing is through installation and maintenance of a system of water meters for each house connection. This procedure is superior to other systems based on the type and size of the residence.

Sectors like hotels and industries with high value return and products should be charged higher prices.

High water-consuming industries, and those which produces highly polluted wastewater effluents, should be discouraged or charged high water cost; while low water consuming industries with high value products should be encouraged. Brackish and treated municipal wastewater may be used for cooling in some industries. Recycling within factories should be encouraged.

SUPPLY MANAGEMENT:

The main thrust under supply management would be to reduce the system losses, particularly from the municipal water supply systems by detecting and fixing leaks, as well as to prevent pollution of the water within the network.

SEA WATER DESALINATION:

The current desalination installed capacity in Abu Dhabi is 245 gpd, the practical capacity is 184 mgd, and the actual annual production of desalinated water amounts to 136 mgd. All this water was used for domestic water supply.

With the increasing water demand to 376 & 415 MCM in the years 2020 & 2025 respectively, and the already stressed groundwater resources, it will be impossible to provide the additional demand from groundwater resources. Further more, the groundwater salinity is expected to increase leading to further reduction in the availability of fresh groundwater supply all over the Emirate. **Therefore increasing the production capacity of desalinated seawater for domestic water supplies seems inevitable in the future.**

Expansion in seawater desalination will have a number of beneficial impacts. The following are the most important:

1) It will alleviate the stress on the groundwater resources, giving it a chance to recover.
2) It can free more groundwater for other purposes particularly for irrigation, and therefore reducing the risk for more abandonment of farms.
3) It will ensure that the obligation of the Government to maintain the supply of good quality water and in sufficient quantity for domestic purpose can be better satisfied.

4) The produced desalinated water will be added to the terrestrial water cycle through wastewater reuse. The salinity of the produced wastewater will remain acceptable for reuse for irrigation.

WASTE WATER UTILIZATION POTENTIAL:

Wastewater treatment in water-rich countries is mainly done for health and environmental protection purposes. **However, in arid and semi arid areas, and in water-short areas, it should have an additional role, which is to provide a new water source to satisfy recreational water demands, and the possibility of expanding its use for agricultural production to substitute for some groundwater, and alleviate the pressure on these over exploited resources.**

An average 80% of the domestic water supply can be collected by a sewerage system. However, considering a leakage loss, within the system, of 20%, would give about 60% of the total domestic water supply that would reach a wastewater treatment plant. This amount of water can be used for irrigation after appropriate treatment.

As the domestic water supply increases with time, the wastewater production will increase. And as most of the domestic water supply is fresh water, the salinity of the produced wastewater would be relatively fresh, and may still be better than many of the groundwater resources presently used for irrigation.

Therefore, municipal wastewater collection, treatment, and reuse in arid and semi arid zones, like the U.A.E., should be considered as a new non-conventional and growing water source. Successful examples in Abu Dhabi, Dubai, Sharjah and Al-Ain are clear evidences

An alternative treatment method to the conventional mechanical, biological treatment method is the natural treatment using sand and gravel infiltration beds, and basins. These beds could be naturally or artificially laid materials. This method has proven technically and economically variable and feasible in different countries. The topographical and hydro geological conditions in various parts of Abu Dhabi seem favorable for the construction of such facilities.

The infiltrating water would recharge the aquifer to can serve as a storage and conveyance media. A recovery well system can be constructed around/down stream the infiltration basins to pump water for direct use. Experience gained elsewhere has proven that the movement of such wastewater for few hundreds meters in appropriate sandy, gravelly material is sufficient to achieve advanced water treatment up to the tertiary level. A complete removal of bacteria and viruses can be achieved. In addition a high percentage of removal of most of the heavy metals such as Boron and Cadmium can be achieved. This method achieves two purposes: water treatment and groundwater recharge at a much lower coast than the conventional, single-purpose, and mechanical/biological treatment method.

An important aspect for selecting the appropriate site of such a natural treatment and recharge facilities, is the hydrogeology of the area and the site. The site may be selected so that the infiltrating water would not flow towards water supply well fields. In addition appropriate design of the recovery wells, their distribution and spacing around the site can ensure that interference with other wells can be easily prevented.

Recycling of industrial water may take place within factories for a number of times before the water is discharged.

UTILIZATION OF BRAKISH GROUNDWATER:

Generally, in a region with limited fresh and brackish water resources, the utilization of brackish groundwater for appropriate purposes should be well planned, taking into consideration the socio-economic as well as the hydrological aspects, the soil conditions and crop salt tolerance.

The brackish groundwater storage could also be reserved for municipal water supply in emergency caces, for some or all domestic water uses, with appropriate water treatment as needed. An emergency plan can be formulated for this purpose which should include: assessment of the resource potential, sitting, drilling and completion of production wells, and may include storage and desalination process and conveyance facilities.

Another type of use for such water could be by desalination for small fresh water supply using small to medium size reverse osmosis units (RO), particularly for rural areas. Beach wells can also be drilled to produce brackish and/or saline water for desalination purposes.

Finally brackish groundwater could be used for irrigation and landscaping in public, recreational, and touristic areas and facilities, directly or after mixing with treated wastewater and street drainage water.

FUTURE SCENARIOS AND THE STRATEGIC VISION

Based on the previous assessment of the present water situation, and the projections for the future water demand and potential supply options, the main features of the future vision can be identified.

The various possible scenarios for managing the future water supply and demand can be laid down to form the basis for selecting the most realistic and favorable scenario. As a first step for the evaluation of these scenarios, a water balance is calculated to show the amount of water deficit for each one.

The deficit in the case of meeting the domestic water supply is assumed to be provided from additional seawater desalination plants, and this will be a measure for comparison between the different scenarios.

On the other hand, the deficit in the agricultural water supply will be a measure of groundwater depletion, and will be used for comparing the different scenarios for the agricultural water supply.

Further evaluation would be needed to test the technical, economic and financial feasibilities in the future before implementation.

The scenarios for domestic water supply are based on providing additional water from the following water supply options:

1) Groundwater, (at the current rate of 26 MCM/yr, or nothing),
2) Desalinated sea water, (equal to the total deficit in the domestic water supply),
3) Savings from reducing water losses from the water supply system(s) by 5 %,
4) Savings from applying a water-demand management program by 10 %.

The following table gives the details of these scenarios.

Table ( ) : **Future scenarios for domestic water supply (MCM/yr)**

	Scenario "1"	Scenario "2"	Scenario "3"	Scenario "4"
Water demand, 2020	376	376	376	376
Water resources:				
Groundwater	26	26	0	0
Desalination, 2000	172	172	172	172
Savings: System Efficiency, at 5%	0	19	0	19
Savings: Demand Management, at 10 %	0	38	0	38
Total resources	198	255	172	229
Deficit/ Desalination requirement	178	121	204	147

On the other hand, the scenarios for irrigation water supply are based on the following sources:

1) Increasing groundwater pumping,
2) Increasing irrigation efficiency by 20 %,
3) And possibly diverting the newly developed treated wastewater for agricultural production to substitute some of the groundwater, and thus alleviating the stress on these resources.

In addition, scenarios for the agricultural sector assumed the following three alternatives:

1) Expansion of the cultivated area at the current rate, about 8 % per year,
2) Gradual reduction of the cultivated area to zero growth rate by the year 2010,
3) Fixing the cultivated areas at the 2000 level, or

The results of all the scenarios are compared in terms of the remaining water deficit, which is the overdraft from the groundwater reservoir in the agricultural sector. Table , gives the results of this comparison.

Table ( ) : Scenarios For irrigation water demand (MCM / yr)

Scenarios	Water demand	Water resource	Water resource	Water Resource	
		Waste water	Savings by increased efficiency by 10%	Groundwater	Annual groundwater depletion rate
1	1892	50	378	1464	1464
2	1892	0	378	1514	1514
3	516	50	103	363	363
4	516	0	103	413	413
5	384	50	77	257	257
6	384	0	77	307	307

However with all these options the deficit and the overdraft would remain. This water deficit cannot be completely eliminated, but it can be reduced to an accepted level, which can be considered sustainable for a planned period of time by further curtailing the agricultural activities, and reducing the irrigated areas. For all the scenarios, measures such as improving the farming practices, and managing the cropping pattern are assumed to be applied.

Comparing the water deficits of the various scenarios, with the water deficit as the main criteria, indicates that the second and the forth scenarios for the domestic water supply are the best. On the other hand, the fifth and sixth scenarios for agriculture are the best. All these favorable scenarios combine the largest number of water supply options, together with the efficiency options.

Finally we may conclude that applying sound water resources management concepts and practices are essential for achieving the future goals of sustainable water resources and socio-economic development. The most important of these are the following:

- Integrating the total water resources to meet the various water demands, and
- Increasing the water use efficiencies particularly in agriculture, and
- Applying the various means of water supply and demand management.
- Gradually, start reducing the annual groundwater abstraction, particularly in agriculture, to approach a reasonably acceptable and sustainable level. The most effective of all the possible ways would be by curtailing the agricultural development (by reducing the cultivated areas).

HIGHLIGHTS OF THE FUTURE VISION

Based on the above discussion, we may be able to identify the general features and highlights of the future vision for the water resources scenes, particularly; the unfavorable scenes which we would like to reverse or convert into favorable scenes. This process will be the venue for identifying the main strategic water issues, and setting our future strategic objectives. These **un-favorable** future scenes, which need to be changed or reversed, are identified as follows:

- Continuous and progressive depletion of both the renewable and the non-renewable groundwater resources thus threatening the sustainability of these scarce and valuable water resources, and the related socio-economic developments, particularly in the agricultural sector.

- Continuous and progressive water quality deterioration and salinity build up that will threaten the suitability of these water resources for the various water uses.

- Decreasing fresh water availability, while increasing water scarcity, and consequently, increased suffering from water shortages.

- Increased competition on our scarce water resources among the various water users and uses, with the possible urgency for reviewing the water allocation policy under anew set of priorities.

- Increasing reliance on the more costly non-conventional water resources.

- Consequently, there will be a continuous threat to the natural environment, particularly the eco systems.

The favorable future scenes would be the opposites of these unfavorable scenes, namely, sustainable water resources and socio-economic development, sustainable and equitable water supplies for the various uses, proper and equitable water resources allocation, integrated water resources development and management, and better human health and healthy environment.

THE MAIN WATER POLICY ISSUES IN ABU DHABI

The following water issues have been identified and selected from a longer of list issues, as they are believed to be most relevant to the water situation in Abu Dhabi in general, and to the management of water resources in particular. The selection is based on the outcome and requirements as revealed by the developed vision, the results of discussions with water experts and mangers in U.A.E. during the previous missions, and on review of the available study reports. The selection is also based on the available knowledge on the current water situation and the possible future situation.

The selected issues constitute the core and the main elements of the required strategy. Each issue needs to be described and assessed in terms of its current status, bases for action, objectives, stakeholders, gaps and needs, and inter-linkages with other issues. On the bases of such brief profile for each issue a policy statement, a strategy, and an action plan can be formulated, discussed with interested parties and individuals, adopted and applied by the concerned parties.

The issues may be grouped under the following main areas:

- Water Resources assessment, vulnerability, and monitoring.
- Resource planning and development.
- Resource management.

The issues are related to the natural water resources, which is mainly groundwater, as well as to the non-conventional water resources, desalination and wastewater.

In more specific terms the main issues include the following:

1. Exploration and assessment of the deep groundwater resources.
2. Planning, development and management for:
    a) Renewable groundwater.
    b) Non-renewable groundwater.
3. Water desalination, management and environmental impacts.
4. Wastewater management, reuse, and environmental impacts.
5. The use of non-renewable groundwater in desert irrigation and agricultural production.
6. Groundwater mining and depletion.
7. Groundwater quality deterioration and pollution.
8. Groundwater protection and rehabilitation.
9. Demand management including: water conservation, efficiency of water supply systems, and water use efficiency, particularly in agriculture.
10. Environmental aspects of groundwater development and management.
11. Socio-economic aspects of groundwater development and management.
12. Groundwater resources scarcity and vulnerability.
13. Institutional and capacity building.
14. Water legislation and enforcement.
15. Public awareness and participation.

For each of these issues, a policy statement should be formulated first, based on a background analytical briefing. The second step is to formulate the required strategy for each policy statement to lay down the method of implementation and its requirements. The third step is to put down an action plan detailing how the strategies can be implemented.

PART –2

STRATEGY DEVELOPMENT FOR WATER RESOURCES MANAGEMENT

INTRODUCTION:

Freshwater resources are an essential component of both the earth hydrosphere and the terrestrial ecosystems. Water is needed in all aspects of life. Its value goes beyond the conventional water uses. The multi-sartorial nature of water resources development and management, and the multi-interest utilization of water resources for the various activities of socio-economic development are well recognized.

The increasing multi-cause water scarcity in view of the increasing and competing water demand, the gradual and progressive depletion of groundwater aquifers, aflaj and springs, and the destructive progressive degradation of ground the water quality, all dictate a change in the water resources management, policies and strategies. The current and potential adverse effects of water resources development on the total environmental system, as well as on human health also stress the need for change. In addition, enormous investments on water resources development and related sectors have been spent, and will be threatened by a gradual and a progressive loss of the water resources.

The above-mentioned problems and inadequacies in water resources management are mainly caused by the absence of appropriate policies and strategies for managing our scarce and vulnerable water resources, particularly in the following aspects:

- Imbalance between limited, vulnerable and mostly non-renewable water resources and rapidly growing demand. The imbalance is caused by inappropriate resource assessment, inappropriate understanding of the resource behavior, and the lack of long-term planning of resource development, particularly for the groundwater resources.
- Lack of adequate, flexible, and updated legislation and enforcement for well drilling and groundwater abstraction licensing and control.
- Intensive utilization of limited, and mostly non-renewable groundwater in an inefficient and uneconomic irrigated agriculture, coupled with lack of realization of the adverse effects on the environment, and the role of groundwater resources in sustaining the natural ecosystem.

  Even the irrigated forestation projects based on groundwater pumping from the shallow aquifer, which are intended to improve the environment, would adversely affect the natural plants supported by the shallow groundwater, in addition to the potential risk of a relatively unsustainable groundwater resource on the long-term.

- Fragmentation of the responsibilities and duties in water resource planning, development and management among a number of institutions, with inadequate coordination and poorly defined institutional-linkages and relationships.

Context:

The environment Research and Wildlife Development Agency (ERWDA) has prepared a proposal for a broad strategic plan for the Emirate of Abu Dhabi to address the environmental needs of the Emirate over the next five years (2000-2004). The strategic goals expressed in that document is directed to support the sustainable development of the Emirate, to enhance the well being of its environment, and to ensure a legacy for the future generations.

The strategic plan focuses on the efforts and resources of ERWDA and its partners for achieving a vision for the environment of the Emirate. One of the main goals of this strategy is to develop and implement a management regime for the fresh water resources.

As stated in ERWDA environmental strategy, the water resources management strategy needs to be designed and directed according to the following steps:

7. Develop management strategy for water resources.
8. Establishing a water resources databases.
9. Development of indicators for critical water issues (resource depletion, degradation and sustainability).
10. Developing a monitoring program.
11. Implement management and enforcement.
12. Conduct recovery and rehabilitation.

Factors Stressing The Need For Water Resources Management Strategy:

1. The total demand on water in Abu Dhabi exceeds the total renewable water supplies. Increasing competition among the various water uses and sectors dictates the need for reconsidering the water allocation policies.

2. The groundwater supplies are facing progressive depletion and quality deterioration at an alarming rates, therefore threatening the socio-economic development, based on such resources.

3. The current water problems reflect the efficiency of the current management practices, which cannot be described as satisfactory. Therefore there is a need for change in this respect because of the continuous changes on the socio-economic objectives, the problems and needs, as well as the water resources themselves.

4. Long-term planning in an integrated manner is a requisite for sustainable development. This should be based on clear and realistic vision for the future. So far such planning process is almost missing.

5. The increasing multi-cause water scarcity caused by different factors.

6. The available groundwater resources are highly vulnerable to pollution, salt-water encroachment, and to depletion in response to abstraction. In addition, the natural environment in such arid region is also fragile and vulnerable to man interference.

KEY CHALLENGES FOR WATER RESOURCES MANAGEMENT

In spite of all the current inadequacies in our water resources management practices, we are still in a stage where we can decide, select and design our future in the fields of water resources and environment, instead idly of waiting, and unwillingly accepting a difficult situation that will be dictated upon us. However, this requires adoption of new and non-conventional ways and means, and a new thinking for resource management, that will deal with the arising difficult water issues of depletion, allocation, competition, etc... The following are the main and key challenges facing the management of our water resources.

1. The need to protect the environment and the natural ecosystem, and in the meantime to continue meet the water demands for the various activities of the socio-economic development. This is further complicated by the non-renewable nature of most of our groundwater resources.

2. The need to protect and sustain the groundwater resources from depletion and quality deterioration, while sustaining the existing water-based socio-economic developments, particularly in agriculture. This requirement is further complicated by the ongoing accelerated agricultural development, and the full support and subsidy of the government, as well as by the prevailing social values and traditions, and the large investment, already spent in the agricultural sector.

   A major difficulty in overcoming this challenge is the absence of an overall water resources policy and strategy, and the lack of intent and commitment to reverse or halt the progressive trend of resource depletion and quality deterioration.

3. The need to protect the water resources, in view of its vulnerability, non-renewability, and the limited exploitable and usable groundwater storage.

4. The need for a comprehensive, integrated approach for managing integrated physical and socio-economic system in a fragmented world of institutions, legislations, policies, strategies and programs.

5. The need of skilled and specialized team of multi-disciplinary experts in resource assessment, planning and management rather than merely in resource development. The provision of such experts is badly lacking in the present time, or they can be found scattered in different institutions.

6. The need to adapt and adopt the new concepts of resource development and management namely, integration and sustainability. Adequate guidelines and indicators need to be developed for measurement and evaluation.

7. The current social attitude, valuation and awareness of water are major factors in damaging and wasting our resources. Water has other values than the traditionally known values. Most

importantly protecting human health, welfare, and our environment. In addition, the water users, beneficiaries, and stakeholders should share some responsibilities with the government instead of letting her acting alone. Such participation and sharing are major factors for achieving protection, conservation and sustainability.

8. Water resources management needs data. There is a need for more efficient monitoring and assessment for the water resources and the effects of development on water resources and on the total environment. Monitoring should include the current and potential future impacts. This is very important for designing corrective and preventive measures, and for long term planning.

9. There is an urgent need for updating water legislations to deal with these challenges, and there is more need for enforcing the updated legislations.

10. The dilemma of food security versus water security remains an issue which needs to be resolved.

11. The fragmented approach and institutional structure, interferences, and poor linkages, for managing an integrated water and environmental system.

12. Increasing water demand versus decreasing the availability of fresh water resources.

In the light of these challenges, there is an urgent need for change, starting with developing a vision and a management strategy for water resources. Effective management is a key factor in confronting these challenges. The difficult questions need to be answered, and difficult decisions and choices need to be taken.

The adverse impacts of the current ground-water resources development and management are clear and demonstrated in continuous water level decline (storage depletion) and water quality deterioration. These results, if continued, would threaten the resource sustainability and consequently the water-based socio-economic developments, and the environmental system, particularly the natural ecosystem. In view of these results and adverse effects, we cannot describe our past and current management practices as adequate or satisfactory. There is a need for strategic management with serious interest and commitment from all players.

Views and hopes, expressed by some people, even at the decision-making level, that water desalination can substitute the natural groundwater, is a false idea. Only a small fraction of the total water use is and can be economically and environmentally provided by desalination. In addition, the major factor in water desalination, which is oil (energy) is exhaustible and non-renewable in itself. Therefore water desalination, at a large scale, cannot be ensured as a sustainable water source for all needs. In total, the existing conventional and non-conventional water resources in Abu Dhabi are insufficient, and would not be sustained, at the current level of development. This is particularly true for the groundwater resources, which are currently largely wasted in an economically and environmentally inefficient agriculture. This process is really a destruction of the national nature base and capital.

LINKAGES BETWEEN THE GROUNDWATER RESOURCES AND THE ENVIRONMENT IN ABU DHABI

Abu Dhabi is located in the dry arid region, which is characterized by low and variable seasonal and annual rainfall, absence of perennial streams, mostly low groundwater recharge and high rate of evaporation. These various elements of the hydrologic cycle are so important to the overall environment and particularly the ecosystem. They are also important to the sustainability and development of human activities.

If we do not manage our water resources properly, there would be little hope that we will be able to manage the ecosystems effectively. Therefore we have to identify the relationships of our water resources, particularly groundwater, to our ecosystems.

In Abu Dhabi, the annual rainfall is very small that direct rainfall utilization is not possible for even plant growth. However, it becomes useful after it collects as surface overland flow, or as floods in stream channels. Such concentrations of surface water are vital to all kinds of terrestrial lives.

The flood flows in stream channels also allow infiltration and recharge to the underground water. The groundwater resources along the alluvial plains and stream channels constitute the most important fresh water resources in Abu Dhabi. In many of these areas groundwater occurs within relatively shallow depths for economical water abstraction, as well as for supplying the deep rooted plants (phreatophites).

In addition, the wide spread areas of sand dunes in Abu Dhabi, capture significant percentage of rainfall. The relatively permeable and porous nature of the dune sand allows for rapid infiltration of rainwater and sub-surface storage of this water as groundwater. The occurrence of relatively low permeable rock surfaces underneath the dune sands, allows favorable storage conditions for the infiltrating rain water. In addition, the topographic conditions of the sand dune areas, allows for groundwater discharge as upward seeps, and provides suitable conditions for creating shallow water table, which in their turn are favorable for plant growth in the desert areas.

Interference by pumping wells in such areas will cause the water table to decline to levels far from reach by the plants' roots, and consequently to the loss of natural vegetation in typical desertification process.

Areas characterized by shallow water table, and potential ground water supply for the plants by capillarity rise or by plant roots over most of the year, are called wetlands, and are characterized by special ecosystems dependent on the sustainability of the water source/supply conditions. Such areas are greatly vulnerable to groundwater exploitation and its impact on the groundwater level and quality conditions.

Other types of wetlands exist closer to the seacoast, where surface water may accumulate from flood flows, or from direct runoff from rainwater. These areas are less vulnerable to human activities in Abu Dhabi.

Groundwater abstraction for irrigated agriculture and the subsequent return flow to groundwater would cause groundwater salinity buildup in both the top soil and the groundwater, because of salts leaching during infiltration, and will also cause groundwater pollution from the excessive use of pesticides and herbicides. This salt cycle between the soil and the groundwater is facilitated by the shallow water table conditions, the relatively permeable sandy soils, and the primitive, low efficiency irrigation methods. In addition, excessive salt accumulations in the topsoil will significantly and adversely affect its productivity for crops in a real process of desertification of agricultural land.

In the mid of our developmental process, the environmental need for water has been forgotten. If the country is to continue to develop, and the environment is to be maintained in healthy conditions, these environmental concerns and environmental water demands have to be considered more seriously.

Areas with rich natural vegetations should be preserved and protected from human interferences with the groundwater supplies. On the other hand, groundwater abstraction and utilizations for agriculture and/or forestation may be allowed where the natural vegetations are independent of the groundwater.

This can be achieved through the development and implementation of a strategy for integrated water resources management to meet such competing and sometimes conflicting water demands and interests between the environment and socio-economic development.

METHODOLOGY AND REQUIREMENTS FOR STRATEGY DEVELOPMENT

The purpose of strategy development is to highlight certain considerations, attention, opportunities and constraints in water resources management, and to draw guidelines and framework of work. We actually translate the vision objectives into a strategy. In order to develop a strategy, we would reverse each unfavorable scene, of the present or of the future, into a favorable one, which we would like to achieve. The selected scene should be based on a realistic strategic vision.

In an effort to achieve the socio-economic objectives as related to the water sector, ERWDA seeks to formulate appropriate strategy for water resources management, leading to the sustainable development and use of water resources in Abu Dhabi. This could be accomplished according to the following steps:

1. Reviewing the current status of water resources development, use and management, and identify problems and needs, and predict future demand, resource potential, and constraints.

2. Developing a future strategic vision for water resources development.

3. Identifying and analyzing the most relevant, short, medium, and long-term water resources issues in Abu-Dhabi.

4. Select realistic goals objectives.

5. Preparation of a descriptive profile for each issue according to the following suggested format:
   a) Background and objectives:
   A brief statement of why this issue is important to Abu Dhabi, and assessment of its relative importance and setting the future objective of each issue.
   b) Stakeholders/actors:
   Government, users and other interested parties or groups with description of their roles, responsibilities, and programs. Also identify interference in responsibilities, functions and roles.
   c) Current status of water resources management.
   d) Actions taken to resolve/address the issue, legislative, administrative engineering, etc...
   e) Gaps are the current management practices, and needs.
   f) Linkages to other issues.
   g) Constraints to resolving the issue.

6. Ranking of the issues in order of priority to Abu Dhabi.

7. Developing a grand water resources management strategy for each of the issues.

8. Preparing strategic action plan to implement the strategies.

9. Set means and tools for implementation through:
   - Suitable innovative programs,
   - Skilled manpower,
   - Adequate institutional and legal frameworks
   - Adequate resources and time frame
   - Adequate coordination and cooperation with the concerned parties
   - Adequate follow-up.

The strategy development process requires the following:

1- Strategy guides based on the national, regional, and international experience and lessons learned.

2- A clear understanding of the problem, constraints, potential and resource behavior and response to development.

3- Participation, consultations, coordination and cooperation between all concerned parties.

4- The adoption and understanding of clear concepts and approaches of the policy and strategy.

5- Interested and committed work team.

6- Agreement between all concerned parties on realistic objectives, issues, roles, responsibilities and programs.

7- Support and commitment from the government.

HIGHLIGHTS OF THE PROPOSED STRATEGY

STRATEGY CHARACTERISTICS:

The required strategy should deal with the most important and relevant water issues. It should also identify the expected constraints, which need to be overcome in order to achieve the strategy goals and objectives. The strategy would also highlight the potential opportunities and future priorities, and draw the road map, directions, guidelines and venues to achieve the strategy objectives, and indicate priorities of activities during implementation. Generally the strategy would be characterized by the following:

1. Strategy formulation and implementation are the responsibilities of all parties and individuals concerned.

2. The views, understanding, perceptions and objectives of all actors should be accommodated and recon ciliated by the strategy. The strategy should reflect the national overall socio-economic development objectives.

3. The strategy should be flexible in options to be able to deal with changing conditions and uncertainties.

4. Agreement of all parties factors, on goals and objectives is essential to ensure application of the strategy by all.

5. Implementation requires time, human, equipment and financial resources, as well as harmonized sets of standards, guidelines, and procedures for data collection, processing, analysis, and achieving.

STRATEGY-DEVELOPMENT OBJECTIVES:

The purpose of the current strategy development effort is to formulate a water resources management strategy with a focus on the environmental quality, particularly the ecosystem. The proposed strategy components include the strategy objectives, characteristics, principles and action plan.

This strategy development process will help achieve the following objectives:

- A framework and guidelines for the required water resources strategy.
- To enhance cooperation and harmonization between the various institutions at all levels of objective setting, policy and strategy formulation, and at the program level of resource inventory and monitoring, and to collect and compile a common water resources database.

- To agree on priority issues, such as water resources allocation, water charges, and division of responsibilities for planning and implementation, as well as on the specific objectives and action plan.
- To agree on, and to cooperate in the implementation of the proposed strategy and action plan, through pooling of the available resources.

STRATEGY OBJECTIVES:

The proposed strategy objectives have been set based on the following factors:

- Identification of the current and potential future problems, constraints and challenges, and potentials and opportunities.
- Development of a vision for the future conditions of the water resources and the socio-economic developments.
- Identification of the main issues, which will be dealt with by the proposed strategy.
- Identification of the possible solutions to the problems, challenges, and finding ways and means to overcome the constraints.
- Conversion of the current and future unfavorable scenes into favorable scenes, which practically represent the objectives.

In view of the above, the main strategy objectives may be defined as follows:

4. To support the sustainable development of the water resources and other related socio-economic developments:
   a. Proceed towards the integrated management approach, which would consider the conjunctive utilization of all available water resources and all other environmental and socio-economic conditions and activities.
   b. Maintain adequate water supplies for all uses in the required quantity, quality, time and space, and according to pre-established priorities for water allocation.
   c. Achievement of a water resources and socio-economic development, particularly for agricultural, which is technically, socially, economically, financially, and environmentally balanced and viable.
   d. To ensure equitable and fair water resources allocation and exploitation, with emphasis on the low-income sector of the society and the rights of the future generations.

5. To enhance human health and well-being.

6. To protect the environment and ensure sustainable and healthy ecosystems.

The specific objectives needed to be achieved in order to achieve the above mentioned general objectives/goals would be as follows:

- Develop and strength and update institutional and legal structures and frameworks and means of enforcement to support the implementation of the proposed strategy. This should include the following specific objectives:

  - Clear definition of the roles and duties of all parties.
  - Clear division of authorities and responsibilities and inter-relationships.
  - Harmonization of the development and management objectives, polices, legislations regulations and programs, as well as the data collection and achieving processes between all concerned parties in order to avoid conflicts, duplication and inconsistencies.
  - Strengthen capacity building and pool resources.
  - Clear definition of water rights and priority for use.

- Protection of the groundwater resources from serious and permanent damage, in quality and quantity that may be caused by intensive over-exploitation and other human activities.

- Assessment of the need for aquifer rehabilitation, and identification of the most appropriate techniques for each specific case.

- Protection of the environment, human health and ensure healthy ecosystems.

- Exploration, assessment and long-term planning for the development and management of all potential water resources, particularly the groundwater resources.

- Promotion of public awareness and participation in planning and managing the available water resources.

- Development of adequate indicators for measuring the state of water resources and the environment.

- Establishment of an adequate monitoring program, database and information management system for water resources.

- Water conservation and increasing the water use efficiency, particularly in agriculture.

- Development of an efficient, flexible adjustment and response system by appropriate administrative and technical control and preventive measures, particularly for the pollution and depletion problems.

STRATEGY PRINCIPLES:

- Recognizing the important role of water resources in advancing socio-economic development, securing better human health and welfare, and sustaining healthy environment and ecosystem.

- **Understanding** the constraints and limitations of the water resources, particularly groundwater.

- **Realizing** the insufficiency of the existing ground water resources to sustain socio-economic development, at the present rate and pattern of utilization.

- Being aware of the threats to our scarce groundwater resources, in terms of storage depletion and quality deterioration, by the current development pattern and management practices, and ensuring that with the awareness, understanding, commitment, participation and comprehensiveness, we can achieve sustainable development.

The following principles for managing the water resources in general, and the groundwater resources in particular are proposed as guidelines and directives to follow:

General:

- Consider the concept of sustainability for the water resources and the related activities of the socio-economic development, as well as for the environment particularly the natural ecosystem.

- Ensure group responsibility at all levels and throughout all stages of monitoring, assessment, planning, policy and strategy development, planning, development and management.

- Consider the total real value of water including scarcity value, opportunity cost, and environmental cost.

- Consider the following general rule in planning and management:
  "If any activity or practice is expected to cause adverse effects or deterioration of the natural system, it is necessary to modify it or change it to prevent or minimize such adverse effects or deterioration."

- Adopt the prevention principle rather than the corrective or remediation principle.

- Promote public awareness at all levels among water users, water managers and decision makers.

- The strategy should be guided by the selected strategy goals, and by goals of other sectors' strategies, and the general national socio-economic goals.

- Meanwhile, the strategy should provide guidance for all stakeholders, managers and decision makers in all actions.

- The strategy formulation and implementation process should be consultative among all parties concerned, and should be flexible to accommodate and reconcile all views from other sectors.

- Both the quality and the quantity of water should be considered in water resource management.

- Consider the close linkages between terrestrial water resources and the state of natural ecosystems.

- Adopt a balanced emphasis between resources development and resource management as dictated by the stage and level of development and the status of the water resource.

- Balance socio-economic development with environmental protection.

- Direct subsidies in the water sector, particularly in the agricultural sector, being the largest water user, as incentives for water saving.

- Introduce and apply the integrated approach with the water sector and with other related socio-economic sectors.

- Consider demand management aspects side by side with supply management.

- Allocate water resources based on appropriate economic analysis and feasibility studies particularly for agriculture, giving priority for drinking purposes.

Specific Principles for Groundwater Management

- Apply appropriate scientific understanding for the groundwater system and its possible behaviors and response to human interference and exploitation.
- Apply appropriate scientific and management concepts to define the following: "Available water" from both renewable and non-renewable groundwater resources, "exploitable groundwater storage", "sustainable annual groundwater yields", for both renewable and non-renewable groundwater resources, "groundwater mining" and "groundwater depletion".

- Attain appropriate understanding of the linkages between groundwater resources and the environmental ecosystems, and the potential impacts of resource development on the environment.

- Provide appropriate scientific groundwater resources assessment planning and monitoring.

- The strategy for managing the groundwater resources should recognize its low or non-renewability status, and limited exploitable storage (physically, economically and environmentally)

- The replenishment rate of the renewable groundwater resources in Abu Dhabi is only a small portion of the current rate of abstraction, and is subject to enormous variability in time and space. Therefore, most of the renewable groundwater resources are already over-exploited. Most of these resources have limited aquifer thickness and areal extent, and consequently limited groundwater storage. Such resources are highly vulnerable to depletion, in addition to their high vulnerability to pollution particularly from agricultural activities, because of their

occurrences at relatively shallow depths. **Therefore groundwater protection should be an essential component of the management strategy.**

- A pollution prevention strategy should be adopted for the groundwater resources. This is due to the slow movement and poor replenishment of these resources. Remediation / rehabilitation of polluted aquifers is time consuming, costly and may have low efficiency. Therefore the application of precautionary and preventative measure at early stages of development is recommended.

- A sub-strategy needs to be developed for managing the non-renewable resources. Global directions for developing and using non-renewable groundwater resources are as follows:

  - As a supplementary resource for municipal water supply.
  - As an emergency water source in cases of disasters and problems.
  - For exploiting another natural resource such as mining of a valuable mineral resource.
  - If groundwater is used for agricultural production, it should be sued for high value crops to be economical, and should be used efficiently.
  - Intensive use of non-renewable groundwater resources should be planned for a specified period of time. Abstraction should be managed to ensure sustainable water supply for the intended, planned project life. This is how the sustainability concept applies to non-renewable resources.

- All potential groundwater resources need to be explored, over the whole Emirate and within economic depths. Their exploitability, usability and potential need to be assessed in order to be able to plan their development.

- The strategy action plan should consider the variations in the status of the groundwater resources, and the level of development over the area of the Emirate. This requires aquifer classification system based on selected criteria, into different management units. Each unit may require a special level of attention and a special set of activities and measures.

- The groundwater strategy goals should reflect the government policy towards groundwater development. Such policy may have emphasis on one aspect of the following:
  b) A full-scale maximum economic development strategy, regardless of the environmental impacts.
  c) A minimum development strategy with maximum protection of the environment.
  d) A balanced recon ciliated development strategy.
  e) Specific criteria management strategy, where the specified criteria forms the main and only constraint on resource development.

- The following sub-strategies may be required in certain circumstances:

  - Groundwater rehabilitation strategy.
  - Groundwater resource protection strategy.
  - Groundwater quality protection strategy.
  - Groundwater allocation strategy.

Specific Principles for Wastewater Management:

- Wastewater is a renewable and growing water resource that, after appropriate treatment, could be used to augment our scarce natural water resources, and alleviate the acting stresses.
- Wastewater treatment in arid regions is not done for environmental and health aspects only, but for providing new non-conventional water resources. Once it is treated and used it becomes part of the hydrological cycle.
- Wastewater reuse should be extended to agricultural production. A lower level of treatment may be sufficient for certain crops and restricted agriculture, compared to the advanced costly treatment needed for the recreational uses.

Specific Principles for Desalinated Water Management:

- The relatively high cost of water desalination limits its use to domestic purposes at the present-state of- the-art.
- However, it provides a good potable water quality for drinking purposes when other fresh water resources are not available.
- Moreover, its contribution to the wastewater improves its chemical quality and consequently, its usability for irrigation.
- Under the prevailing water scarcity conditions of surface and groundwater, and the marginal to poor water quality of these resources, seawater provides a sustainable water source for desalination. However, the use of conventional energy sources is still expensive and non sustainable on the long term.
- The brine coastal disposal remains a problem to the marine environment.

STRATEGIC ACTION PLAN

Once the goals, objectives and the principles for action are well defined, an appropriate, comprehensive, and flexible action plan is developed. By doing this, the main components of the strategy would be completed. In the action plan, we set the means for strategy implementation. An action plan is usually directed to serving and achievement of a strategy. It is a translation of the strategy.

For each strategy an adequate realistic and flexible action plan needs to be prepared. The action plan should include, for each objective, a list of activities/actions and programs, means for implementation, a set of results or accomplishment, which should match the pre-set objectives, a time schedule, and division of duties and responsibilities.

Strategic Programs

These are the programs, which will serve the achievement of the strategy in conjunction with other activities. The programs may be of research type or operational. The main directions of the groundwater resources management program for Abu Dhabi should reflect the actual and practical status and needs and should include the following:

1. Aquifer inventory program.

2. A monitoring program particularly changes in the groundwater conditions, and the impacts of water resources development on the environment and the socio-economic conditions.

3. Aquifer classification program based on the hydrogeologic conditions, groundwater availability, exploitability, usability and vulnerability.

4. Aquifer analysis and aquifer management programs using special computer programs.

5. Exploration program for the deep aquifer to confirm the groundwater characteristics, exploitability and usability.

6. Development of usable indicators for:
   - Water Resource sustainability.
   - Aquifer depletion indicators.
   - Water quality degradation indicators.
   - Development indicators.

   These indicators should than be tested and refined using long-term monitoring and surveys.

7. Aquifer and well field protection program.

8. Identification and assessment of the need for aquifer rehabilitation.

9. Water conservation program.

10. A continuous groundwater resources assessment program (quantitative).

11. Groundwater quality assessment program.

12. Wet land monitoring and assessment.

13. Development of a database and information system.

Means And Requirements For Strategy Implementation:

The strategy implementation requires the following:

1. Participation, consultations, coordination and cooperation between all concerned parties.
2. The adoption and understanding and application of the agreed upon concepts and approaches of water resources management
3. Application of the recommended strategy principles, and targeting on the strategy objectives.
4. A Realistic and flexible action plan and adequate programs.
5. Interested, qualified, skilled and committed man power.
6. Adequate institutional setup, and working environment.
7. Support and commitment from the government.
8. Ensuring adequate resources and time.
9. Adequate database, and research program.
10. Supporting and appropriate legislations, regulations and enforcement framework.
11. Improved and continuous assessment, monitoring, follow-up, and long-term planning.
12. Guide investment and subsidies, and apply sound and appropriate economic principles, particularly in irrigated agriculture.

Management Tools

1- Use of assessment and management computer models.

2- Use of the geographic information system.

3- Careful management and regulation of groundwater extraction through adequate and practical licensing system.

4- Monitoring of the groundwater levels and water quality changes through a properly designed monitoring system.

5- Adjustment of the groundwater exploitation rate and pattern to: long-term goals and potentials, and to the long-term environmental and socio-economic impacts.

Implementation Schedule:

The strategy development program may proceed in the phases as follows:

Phase 1: (2 months)

Preparation of a general framework for the required strategy to provide:

- Guidelines on the procedure and approaches for strategy development.
- Preliminary identification of the main water issues relevant to Abu Dhabi.
- Preparation of a strategic vision for water resources development and management.
- Setting the strategic goals and objectives.
- Setting the characteristics and the main principles of the potential strategy.
- Identify the general highlights of the strategy.
- Identify data and informational needs for strategy development.
- Prepare a tentative action plan and programs, and a work plan for further steps needed.

Phase 2: (2 months)

- Revision of the working paper prepared in the first phase by a national team of experts, recommend any modifications, and finalize the list of water issues.
- Finalize goals and objectives for each issue.
- Determine criteria for prioritization of the selected water issues.
- Prioritization of issues.
- Prepare issues' profiles according to the proposed format.
- Prepare a second draft for the strategy and a detailed action plan including the specific activities needed to achieve each specific objective and the time frame for implementation.

Phase 3: (3 months)

- Review, by the national team, the proposed strategies and active plans, and recommend any potential desirable modifications.
- Prepare a final draft of the strategy document.
- Disseminate the document for all parties concerned and receive feedback.
- Prepare final strategy document.
- Seek approval of the government.

Phase 4: (3 years)

- Implementation of the strategy:
    - Update the water resources and water use data.
    - Conduct filed surveys (aquifer inventory).
    - Develop a database.
    - Update the monitoring programs.
    - Conduct studies and research.
    - Develop indicators.

- Implement management and enforcement.
- Assess the need for rehabilitation programs.

Each of the above items need to be studied in detail later on.