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TO THE ENVIRONMENTAL RESEARCH AND WILDLIFE DEVELOPMENT AGENGY ABU DHABI, UNITED ARAB EMIRATES

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

12-19 October 2001

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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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Presented And discussed in a workshop held on 15 Oct. 2001.

Revised during the period (12-17), Oct. 2001 in consultation with:

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TABLE OF CONTENTS

ملخص تنفيذي

بناء على طلب هيئة أبحاث البيئة والحياة الفطرية وتنميتها في إمارة أبو ظبي في دولة الإمارات العربية المتحدة، قمت بالمهمة الاستشارية الثانية للهيئة خلال الفترة ١٢-٢٠٠١/٤/١٨ وذلك لعرض مسودة إستراتيجية لإدارة مصادر المياه في إمارة أبو ظبي، والتي تم إعدادها في المهمة الأولى، في ورشة عمل نُظِمت لهذا الغرض، ولمناقشتها من قبل ممثلين عن المؤسسات ذات العلاقة والإهتمام.

ويمثل هذا التقرير المراجعة الثانية للإستراتيجية المطلوبة قبل المرحلة النهائية ومناقشتها في شهر شباط القادم ، وقبل رفعها للجهات العليا لإقرارها وتبنيها. وقد أُخذت بعين الاعتبار الملاحظات التي أبداها الحاضرون في ورشة العمل، وكذلك نتائج المناقشات التي تمت مع المسؤولين في هيئة أبحاث البيئة والحياة الفطرية.

كما تم خلال المهمة التركيز على وضع الإطار العام لخطة العمل للخمس سنوات الأُولى من بدء التنفيذ.

وتشمل المرحلة النهائية لإعداد الإستراتيجية، استمرار التشاور مع المؤسسات المختلفة حول تفاصيل خطة العمل من حيث الجهات المنفِذة، وأولويات التنفيذ، ومتطلبات تنفيذ البرامج والمشاريع، وأوجه التعاون وتبادل المعلومات.

EXECUTIVE SUMMARY

An advisory mission was implemented during the period 12-18 Oct., 2001, to the Environmental Research and Wildlife Development Agency (ERWDA) in Abu Dhabi, U.A.E., upon their request, and as a follow up on the previous mission of April, 2001.

The purpose of this mission was to present and discuss, in a workshop setting, with a national team of experts, the first draft of the water resources management strategy, which I prepared during the first mission.

This report represents the second revision of the required strategy, based on the results of the discussion during the workshop, as well as the consultations with the senior staff of ERWDA. The discussion with ERWDA was concentrated on the five-year strategic plan, and the plan of work until next February, the suggested date for the final review of the strategy.

It was agreed that ERWDA will continue consultations with the other concerned parties, particularly on the five-year action plan, the priority programs, the requirements and roles in implementation, and the mode of cooperation.

STRATEGY DEVELOPMENT
FOR
WATER RESOURCES MANAGEMENT IN ABU DHABI - UAE

INTRODUCTION

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:

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.

PROBLEMS AND CAUSES:

The decreasing fresh water availability, the multi-cause water scarcity in view of the increasing and competing water demand, the gradual and progressive depletion and degradation of the groundwater resources, in addition to the physical constraints and vulnerability of these resources, are leading to, continual negative imbalances and inadequacies in the water supplies, and consequently necessitate some positive changes and improvements in the management of our water resources. 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.

Future uncertainties and potential scarcity of our limited water resources, and the increasingly competing demands on water for the ambitious current and future socio-economic development plans require compatible and strategic planning efforts for the water sector. A pre-requisite to such planning

is the development of a realistic future vision for the sector. So far, enormous investments on water resources development and related sectors have been spent, which require to be safe guarded from unexpected failure in the water supply system as a whole, as well as by a potential gradual but progressive loss of the water resources. Factors, which may lead to such failure and loss of resources may include:

- In-consistent, un-coordinated, policies, strategies, and plans for the water sector and other related development sectors, such as agriculture and industry.
- Imbalance between the water resources potential and the level of development
- Insufficient coordination and cooperation among concerned parties.
- Under-estimation of the real and total social, economic and environmental value of.

FACTORS STRESSING THE NEED FOR WATER RESOURCES MANAGEMENT STRATEGY:

- The rapidly increasing and competing water demands for the various socio-economic development plans, and progressive decrease in fresh water availability. Water-based socio-economic development, can not be sustained at the present rate and pattern of extraction of the available groundwater resources.

- Alarming signs of groundwater depletion and water quality deterioration have become clearly observed in the most important agricultural areas, such as Al Ain, and Liwa. The groundwater salinity has greatly increased, leading to soil Stalinization and decreased productivity, and a large number of wells have dried out.

- The current water problems reflect the efficiency of the current management practices, which cannot be described as satisfactory. Therefore there is a need for rethinking and possible change in this respect.

- In such arid region the available groundwater resources are highly fragile and 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.

ENVIRONMENTAL SIGNIFICANCE OF WATER RESOURCES 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. 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.

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 and understand the relationships of our water resources, particularly groundwater, with the environment and its 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 supporting 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.

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.

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.

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.

STRATEGY DEVELOPMENT:

a) Strategy-Development Objectives:

The purpose of the current strategy development effort is to:

- ***Develop a general medium to long-term water resources management Strategy: objectives, principles, guidelines, and action plan.***
- ***Develop a five-year strategic action plan for water resources management.***

In addition, 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.
- To collect and compile a common water resources database.

a) Methodology And Approach:

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 evaluating and adopting the best and most relevant scenario for which the strategy will be developed.

4. Based on the elements of the selected scenario, we should be able to select the objectives to be achieved, identify the core water issues which are most relevant to Abu Dhabi, and the potential options and opportunities, as well as the possible problems and constraints.

5. For each of the identified core issues, the following aspects should be clearly evaluated and understood:
   a) The objectives: A brief statement of why this issue is important to Abu Dhabi.
   b) Stakeholders/actors: Government, users and other interested parties affected or interested in each issue. (These groups or individuals should be called upon for to be carried out later on on the different issues).
   c) Current status of the issue, and actions taken to resolve/address the issue, legislative, administrative engineering, etc…
   d) Linkages to other issues.
   e) Constraints to resolving the issue.

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

7. Each issue should be properly addressed in developing the overall strategy, including strategy objectives, principles, programs and action plan.

8. Preparing a strategic action plan which would achieve the strategic objectives. The plan should show the required resources, the means and tools for implementation.

c) *Requirements For Developing The Strategy:*

The strategy development process requires the following:

1- A review of the national, regional, and international experience and lessons learned.

2- A clear future vision which is based on an in-depth understanding of the present and realistic projection of the future.

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

4- The adoption of clear, and agreed upon, definitions and understanding of concepts and terminologies such as: sustainability, integration, vision, strategy, policy and action plan.

5- Agreement and reconciliation between all concerned parties on issues, objectives, roles, and responsibilities.

6- Interested and committed and officially designated members of the work team.

7- Support from the concerned government departments.

FUTURE VISION FOR WATER RESOURCES DEVELOPMENT AND MANAGEMENT IN ABU DHABI

VISION, POLICY AND STRATEGY CONCEPTS:

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, the expected problems 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

In view of the above it is necessary to assess the present water resources and water uses, as well as to project the future conditions and requirements. Then, future scenarios will be evaluated. The most favorable scenario will be selected, and that will dictate the course of action to be followed in developing the required strategy.

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.

CURRENT SITUATION:

1: Water Resources

a) 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.

b) Groundwater Resources

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. These resources are recharged from the relatively heavy rain storms. However, they have been exploited at much higher rate than the average annual recharge, with the consequent result of progressive water level decline, and groundwater salinity build up.

Brackish and saline groundwater occurs in deeper geological formations of sandstone and limestone, as well as at shallow depths in the sabkha and coastal areas. This deep groundwater is considered non-renewable. Based on reviews 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.

c) Seawater 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, in quality and quantity, **there will be an increasing demand for increasing the production capacity of desalinated seawater for domestic water supplies.**

d) Treated Wastewater :

About 25% of the municipal water supply is being collected and treated. About 70% of this water is being reused for recreational streets and parks gardening in the city of Abu Dhabi.

2: Water Use:

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 annex (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)

a) Municipal:

The average production for municipal water use in 1995 was 162 million gallons per day, annexes (1&2).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.

b) Irrigation Water Use:

Historical groundwater pumping for irrigation is given in, Annex (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, for either increased salinity or drying out of the aquifer

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 Annex (3). The historical development of irrigation wells is given in annex (4).

c) Industrial Water Use:

No data was available.

FUTURE WATER SITUATION:

1: Water Demand:

a) Municipal Future Water Demand:

A general look at the historical municipal water production in the U.A.E., Annex (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, Annex (5). The total future water demand is estimated as follows in MCM/yr :

	1995	2000	2010	2025
Municipal demand	162	197	277	415

b) 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
Industrial demand	16.2	19.7	27.7	41.5

c) 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, Annex (3) . The abstraction figures have been calculated based on the yearly cultivated areas, and an average irrigation water requirement of 3400 mm./yr, and applying an overall irrigation efficiency of 50%.

2: Future Water Supply Options:

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: Control, protect, rehabilitate.
- Water supply management: improving water use efficiency, and the water supply system efficiency, etc..
- Demand Management: Conservation programs, water pricing, etc.
- Adoption of socially and economically appropriate water allocation policy.

FUTURE SCENARIOS:

Based on the previous assessment of the present water situation, the projections for the future water demand and the potential future supply options, a number of alternative scenarios for managing and balancing the future water supply and demand have been suggested as basis for identifying and selecting the most realistic and appropriate scenario.

As a first step for evaluating the various scenarios, a water balance is calculated to show the amount of water deficit for each one, and the water resource options are determined. The proposed water resource options should in total meet the required demand, and in the mean time, should be suitable water quality for the intended use, and adequate capacity.

Because of the neither diminishing availability of fresh groundwater supplies for direct use for municipal purposes, neither additional supply from groundwater, nor sustaining the current groundwater supply rate are expected. Therefore, long term strategic plans for additional increase in municipal water supply is assumed to be provided by one or more of the following supply options:

- Increasing the overall efficiency of the water supply system, (storage, conveyance, and distribution).
- Increasing the water use efficiency.
- Decreasing water demand by various means.
- Building up an artificial strategic groundwater reserve using desalinated seawater.
- Water exports from outside the country.
- The remaining deficit, the balance, will be met from current and short to medium plans for seawater desalination.

However, because water desalination is the most costly option, the deficit in municipal water supply will be taken as the measure or the criteria for comparing and evaluating the different scenarios for municipal water supply. The scenario with the least requirement from seawater desalination would be the most favorable and would be selected. Detailed economic analysis for evaluating the alternative scenarios is not believed required at this stage. In addition, it is well agreeable that supply and demand management options are more efficient and more economically viable as compared to seawater desalination.

The proposed scenarios for the short- and medium-term future municipal water supply are based on providing additional water from the following options:

1) Groundwater, (at the current rate of 26 MCM/yr, or nothing),
2) Savings from reducing water losses from the water supply system(s) by 5 %,
3) Savings from applying water-demand management measures by 10 %.
4) Desalinated seawater, (the balance).

The following table gives the details of the various scenarios for municipal water supply.

Table (2) : Future Scenarios For Municipal Water Supply (MCM/Yr)

	Scenario "1"	Scenario "2"	Scenario "3"	Scenario "4"
1:Water demand, 2020 :	**376**	**376**	**376**	**376**
2:Water resources:				
a) Groundwater	**26**	**26**	**0**	**0**
b) Desalination, 2000	**172**	**172**	**172**	**172**
c) Savings: System Efficiency, at 8%	**0**	**30**	**0**	**30**
d) Savings: Demand Management, at 10 %	**0**	**38**	**0**	**38**
Total resources	**198**	**255**	**172**	**229**
Deficit/ Desalination requirement	**178**	**133**	**204**	**158**

It is obvious that the second scenario would be the best, followed by the forth scenario.

On the other hand, the scenarios for irrigation water supply are based on two sets of options: (a): Increasing the water supplies, and/or (b): Reducing the irrigation water demand.

(a) Increasing the water supplies may include the following options:

1) Increasing groundwater pumping from the currently used, and relatively shallower groundwater resources, (will increase the annual groundwater overdraft rate, and may lead to permanent adverse effects in quality and quality).
2) Developing new brackish groundwater in other areas and from deep aquifers, (need further exploration and investigations).
3) Diverting the newly developed treated wastewater for agriculture, direct use, or through building a long-term groundwater reserve of treated wastewater.
4) Water exports via regional projects.

(b) On the other hand, decreasing the irrigation water demands may include:

- Gradual reduction in the total cultivated area, and this is, socially and politically, a difficult option.

- Increasing the overall irrigation efficiency by various means.
- Better management of crops and farming practices

If the increasing future irrigation water demand is to be fulfilled only from the currently developed groundwater resources, which already suffers from over development and water quality deterioration, this means increasing the groundwater overdraft / depletion rate. Consequently, remaining with this lonely option would increase the adverse effects on the already affected groundwater resources, and accelerates their ultimate depletion.

Continuous unplanned groundwater overdraft from an almost non-renewable groundwater resource, as compared with the annual rate of pumping, would ultimately lead to permanent resource depletion and water quality deterioration. These results would subsequently lead to a set of adverse effects on the environment and its eco systems. ***Therefore the additional annual overdraft rate would be taken as the main criteria for evaluating the different scenarios for agricultural water supply.***

In addition, scenarios for the agricultural sector assume 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 additional annual groundwater overdraft from the groundwater reservoir. The following table gives a summary of the different scenarios.

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	Additional 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

Further environmental, socio-economic, and political evaluation criteria may be considered as the situation requires. Under certain conditions, such criteria may dictate a given strategy or course of action.

Based on the above, it can be concluded that additional groundwater overdraft would remain in all the scenarios. However, it is can be reduced by enforcing stricter control measures, increasing the overall irrigation efficiency, changing the cropping pattern, etc..

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 relatively better scenarios combine the largest number of water supply and management options.

Finally we may conclude that applying sound water resources management measures and practices are essential for achieving the future goals of reasonably sustainable water resources and socio-economic development.

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. It is obvious that there are some unfavorable scenes, which we would like to convert into favorable scenes. The achievement of these favorable scenes become our objectives for the future, which we would like to pursue. And that is how the vision development process can help identifying the main strategy objectives.

The selected scenario becomes the target for strategy development; and its elements constitute the core issues for the required strategy. The general strategy objective would becomes meeting the water demand in the most efficient way, which would minimize the adverse effects in terms of : reducing groundwater overdraft rate, and reducing the need for costly investment in new desalination projects.

The **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, which preasents a real threat to the sustainability of the 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.

- Consequently, these would present a real threat to the natural environment and its eco systems.

- Decreasing fresh water availability for all purposes, including environmental water demand, while increasing water scarcity and water shortages.

- Increased competition on such decreasing water resources among the various water users and uses, with the possible urgency for reviewing the water allocation policy under a new set of priorities.
- Increasing reliance on the more costly non-conventional water resources, namely, sea water desalination for municipal uses, and treated wastewater for irrigation.

The favorable future scenes would be the opposites of these unfavorable scenes, namely:

- **Sustainable water resources particularly groundwater, and the related socio-economic developments.**
- **Sustainable and equitable water supplies for the various uses, in the required quantity and quality, and in time and space.**
- **Proper and equitable water resources allocation among the various competing water demands, and in economically socially, and environmentally viable manner.**
- **Integrated development and management of the total water resources system, including the conventional and non- conventional water resources.**
- **Better human health and healthy environment and ecosystems.**

KEY CHALLENGES FOR WATER RESOURCES MANAGEMENT

In spite of all the current inadequacies in our water resources management practices, we may be still in a stage where we can act, 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 a change in thinking and in practice in water resource management. The following are the main and key challenges, which would confront us in our efforts:

1. The need to protect our increasingly scarce and vulnerable and mostly non-renewable water resources, and in the meantime meet the increasing water demands.

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

3. The need to develop a water strategy is complicated by multi-sartorial nature and roles of water resources development and management, and the multi-interest utilization of water resources for the various activities of socio-economic development.

4. The need to adapt and adopt the new concepts of resource development and management namely, integration and sustainability, in order to manage such integrated physical and socio-economic systems.

5. The need of skilled and specialized team of multi-disciplinary experts in resource assessment, planning and management rather than merely in resource development.

6. The general social attitude, valuation and awareness of water, and the need for stricter control on water extraction from the government side.

7. The dilemma of food security versus water security remains an issue, which needs to be resolved, based on sound economic, environmental, and resource sustainability criteria.

HIGHLIGHTS OF THE PROPOSED STRATEGY

Strategy Characteristics:

The required strategy should deal with the most important and relevant water issues. The strategy should reflect the national overall socio-economic development objectives. Through strategy development, we should be able to identify the expected constraints and problems, which need to be overcome in or resolved, 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.

Strategy formulation and implementation are the responsibilities of all parties and individuals concerned. The views, understanding, perceptions and objectives of all actors should be accommodated and recon ciliated by the strategy. Agreement of all parties on the strategy goals, objectives, principles for action, the action plan and its implementation is very essential.

The strategy should be flexible in options to be able to deal with changing conditions and uncertainties during implementation. Alternative routes of implementation should be provided.

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 OBJECIVES:

- ***Develop a general medium to long-term water resources management Strategy: objectives, principles, guidelines, and action plan.***
- ***Develop a five-year strategic action plan for water resources management.***

STRATEGY OBJECTIVES:

General Objectives:

In view of the above, the general strategy objectives may be 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.

Specific Objectives:

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

- Develop and strength institutional and legal frameworks and means of enforcement to support the implementation of the proposed strategy. This may be achieved through:
  - Clear definition of the roles, duties, authorities and responsibilities of all concerned parties, while maintaining cooperation and coordination.
  - Harmonization of the development and management objectives, polices, legislations regulations and programs, as well as the data collection and achieving procedures and techniques in the water sector.
  - Strengthen capacity building.
- Adopt and apply groundwater protection and rehabilitation policy.
- Resource management should include both quantity and quality aspects.
- Considering protection aspects and the water requirements of the environment.
- 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, in agriculture, and the municipal water supply system, and encourage multiple use, wastewater reuse, and recycling in industry.
- Control point and non-point pollution.
- Adopt and apply both supply and management practices.
- Establish an adequate monitoring system and database.
- Expand development of additional resources, particularly wastewater collection, treatment and reuse.
- Develop long-term emergency plans, including strategic groundwater storage and national bulk water conveyance system.

STRATEGY PRINCIPLES:

General:

- It is well **recognized** that water plays very important role in advancing socio-economic development, securing better human health and welfare, and sustaining healthy environment and ecosystem. However, in arid areas such as the UAE, we should **understand** the constraints and limitations of our natural water resources, in terms of their potential and their water quality, particularly groundwater. They are scarce fragile and vulnerable to human interference. They would not be sustainable at the present rate and pattern of utilization.

- Therefore, we should pursue achieving the following balances in their planning, development, and management:
  - Resources development and resource management.
  - Resource potential and level of development.
  - Socio-economic development and environmental protection.

- Because of the multi disciplinary nature of water resources, ensuring group responsibility at all levels and throughout all stages of monitoring, assessment, planning, development, and management is a key success factor affecting their sustainability.

- 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."

- As water is scarce, and is a common resource, it must be used economically. The total real value of water should be considered, including scarcity value, opportunity cost, and environmental cost. In addition, sound economic principles should be applied in water resources planning, development, and management.

- Water conservation and rational utilization of water requires that subsidies in the water sector, particularly in the agricultural sector, being the largest water user, should be directed as incentives to encourage water saving.

- The control and preventive approach should be adopted for protecting the water resources and the environment. Remediation / rehabilitation of polluted aquifers is time consuming, costly and may have low efficiency. Therefore the application of precautionary and preventative measure sat early stages of development is more cost effective.

- As the socio-economic objectives and the state of water resources change over time, it is necessary that strategic plans be flexible enough to reconcile possible changes.

Specific Principles for Groundwater Management

- Apply appropriate scientific understanding for the groundwater system and its possible behavior and response to human interference and to various levels of 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, such as: changes in the depth to the water table, increased water salinity, and changes in the groundwater discharge areas and rates.

- Provide appropriate and up-to-date scientific water resources assessment and long-term planning.

- The strategy for managing the groundwater resources should recognize constraints such as their low or non-renewability status, and limited exploitable storage (physically, economically and environmentally). Determining and applying appropriate long-term sustainable groundwater yields for both the renewable and non-renewable resources are a major success factors.

- In view of the high vulnerability of the existing groundwater resources, for both depletion and quality deterioration, **groundwater protection should be an essential component of the management strategy.**

- The following global directions for developing and using non-renewable groundwater resources should be considered as guidelines for managing such resources:
  - 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.

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.
- Under the prevailing scarcity of surface and groundwater resources, and their marginal to poor quality, seawater desalination provides a favorable alternative supply source for domestic uses.
- The brine coastal disposal remains a problem to the marine environment.

STRATEGY MAIN FEATURES

The proposed strategy shall focus efforts on the following main issues / elements, and stress the need for improved water resources management in a way that will surely make a positive change:

In Water Policy and Strategy:

- Develop, adopt, and declare the government water policy and strategy, which are in harmony with the national socio-economic development policy, as well as with other sectors policies.
- Revise and assess the agricultural policy in view of the important long-term national water security issue, and the limited, scarce, vulnerable, and mostly non-renewable groundwater resources, based upon sound economic feasibility studies and environmental impact analysis.
- Adopt and start implementing a groundwater protection and rehabilitation policy and strategy for critical groundwater areas and well fields. starting with the most critical groundwater development areas.
- Revise, re-assess, and possibly modify the current water allocation policy based on the changing long-term water use and demand pattern, the government policy and priorities, sound economic principles, and considering the environmental water demand.
- The following sub-strategies should be adopted and applied when ever, and where ever needed:
  - Groundwater rehabilitation sub-strategy.
  - Groundwater resource protection sub-strategy.
  - Groundwater quality protection sub-strategy.
  - Groundwater allocation sub-strategy.
  - Deep groundwater exploration and development sub-strategy.

In Planning:

- Apply a long-term integrated planning approach, within the water sector, as well as with the other related sectors.
- Ensure harmony and consistency with other sectors' plans.
- Ensure the availability of the required data and information for the planning process.
- Ensure public participation in the planning process.
- Ensure adequate resources needed for implementation.
- Ensure close follow-up and periodical evaluation.
- Ensure flexibility to accommodate the ever-changing socio-economic conditions and objectives.
- Study all possible alternatives, and apply sound criteria for evaluation and selection.

In Strategic Planning:

- Formulate a long-term water master plan based on long-term strategic goals and objectives.
- Study the feasibility of developing an artificial groundwater strategic fresh water storage and recovery system for emergency cases, or even for future generations use. The water source for municipal supply would be from desalinated seawater during the low demand season, and for irrigation supply would be treated wastewater.

In Water Resources Assessment:

- ❖ In view of the changing conditions of water resources with time, their assessment should be considered as a continuous process, which should be based on sufficient, adequate, and updated database, and should include both quality and quantity assessment.
- ❖ The monitoring system should include both causes (man interference), and effects (impacts).
- ❖ Apply groundwater assessment and management mathematical models as needed to understand aquifer behavior and response to alternative development plans.
- ❖ Develop and apply appropriate indicators for evaluation of impacts and performance.

In Water Resources Development:

- ❖ Consider all potential options for developing new and additional water resources, with emphasis on the non-conventional resources, and including the deep brackish groundwater resources.
- ❖ Ensure and maintain a balanced groundwater resources development, and avoid lengthy permanent and semi-permanent depletion and quality deterioration of these resources.
- ❖ Reconsider the economic feasibility and viability of desert agriculture using adequate economic and environmental criteria.

In Water Resources Management:

- ❖ Adopting and applying the sustainability concept is the right approach for managing the limited, scarce, and vulnerable groundwater resources.
- ❖ The integrated management approach is an effective means for achieving sustainability.
- ❖ There is a need for improving the current water resources management in various technical, legal, and institutional aspects
- ❖ Apply both supply and demand management practices and measures, and manage both quantity and quality.
- ❖ Apply protection zones for critical and significant groundwater areas and water supply well fields, and consider applying certain rehabilitation techniques.
- ❖ Apply the prevention approach for water quality management and pollution control.

In Water Legislation:

Revise and update, as necessary, the current water legislations, with emphasis on:

- Harmonization of the environmental standards in the water sector.
- Standardization of techniques and equipment in water data collection and analysis.
- Strengthen the government role and control on managing groundwater resources development.
- Redefine water rights based on the current status of water resources. Water rights should not be absolute. Ground water extraction permits should be issued periodically and separately from the well drilling permits.

In Water Conservation:

- Achieve the highest possible and practicable efficiency in water collection, conveyance, distribution, application and use, particularly in agriculture and municipal water supply.
- Encourage water recycling in Industry, and reuse of treated municipal wastewater in agriculture.
- Promote the water conservation and public awareness programs.
- Introduce new technological advances in water conservation.
- Direct subsidies in agriculture as incentives for water conservation.

In Water Supply And Demand Management:

- Pursue the maximum reduction in the un-accounted-for –water in the municipal water supply systems.
- Apply technological advances in house water facilities.
- Promote public awareness on the value of water.
- Maximize the economics of the municipal water supply systems through various means such as:
  - Considering partial or full cost recovery.
  - Sharing the private sector in various aspects of operation and maintenance

In Environmental Protection:

- Harmonize the water standards in the Environmental sector.
- Apply internationally viable standards in preparing environmental impact assessment studies in all water and water-related development projects.
- Apply appropriate sound criteria for evaluating the environmental impacts in the environmental impact assessments studies of water and water-related projects.
- Consider the environmental water demand along stream channels, in wetlands, and in shallow groundwater areas where the deep-rooted plants are supported by groundwater.
- Monitor environmental impacts of water and water-related projects.

In The Institutional framework:

- Assess the need for structural reform of the water sector for better definition and distribution of responsibilities, to enhance cooperation and coordination at the policy and implementation levels, and to remove any contradiction, overlapping, and inconsistencies as possible.

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 and it is a translation of the strategy.

The action plan should be flexible, and should include a list of priority programs, projects and activities. It should also indicate the means and requirements for implementation, as well as a time schedule. The duties and responsibilities of the implementing agencies should also be determined.

A) The General Water Resources Management Strategy:

Priority Projects:

- Establishing a water resources and environmental database.
- Aquifer inventory.
- Aquifer classification program based on the hydrogeologic conditions, groundwater availability, exploitability, usability and vulnerability.
- Aquifer analysis and aquifer management programs using special computer in selected critical groundwater areas.
- Deep aquifer exploration for the deep aquifer to confirm the groundwater characteristics, exploitability and usability.
- Development of usable indicators for:
  - Water Resource sustainability.
  - Aquifer depletion.
  - Water quality degradation.
  - Level of development.
- Delineation of protection areas for the important and critical aquifers and water supply well fields.
- Identification and assessment of the need for groundwater rehabilitation, (quality and quantity oriented projects.
- Harmonization of the environmental standards in the water sectors.
- Study the feasibility of building a strategic ground water storage, through artificial recharge, from desalinated seawater, and treated municipal wastewater separately.
- Study the feasibility of constructing a national fresh water carrier across the country for collection and distribution.

Strategic Programs

1. Water conservation program.

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

3. Groundwater quality assessment program.

4. Wetland monitoring and assessment program.

5. Update monitoring program for the groundwater conditions, the impacts of water resources development on the environment, and on the socio-economic conditions.

Implementation Schedule:

Phase 1: (April- Oct. 2001):

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, including:
  - -Assessment of the current and future water situation.
  - -Development of alternative water management scenarios.
  - -Evaluation of scenarios and selection of the best alternative according to preset criteria.
  - -Identification and characterization of the core water issues related to the selected scenario.
- Development of the general strategy:
  - -Defining the strategy characteristics.
  - -Setting the strategy goals and objectives.
  - -Determining the main principles of the strategy.
  - -Identify the main features of the strategy.
- Preparation of an action plan for the main strategy, including programs, projects, and time frame.
- Preparation of a five-year strategic implementation plan, including priority projects and programs.

Phase 2: (Oct.2001-Feb. 2002):

- 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.
- Presenting, and discussing the paper with a national team of experts.
- Continue consultation with the national team.
- Finalize the strategy goals, objectives principles, and action plans.
- Identify priority projects for the main strategy, as well as the five-year strategic action plan.
- Prepare a second draft for the strategy and a detailed five-year strategic action plan.

Phase 3: (March-May, 2002):

- Continue consultation with the national team on the following issues:
    - Additional suggestions on priority projects and programs.
    - Determine responsibilities for implementation of the selected projects and programs.
    - Identify the required support, cooperation, and coordination from other parties.
- Preparation of detailed profiles for each of the selected projects and programs, including the specific objectives to be achieved, the required activities, data requirements, field surveys, required resources, and means of implementation.
- Prepare a final draft of the strategy document as well as the five-year action plan.
- Disseminate the document for all parties concerned and receive feedback.
- Prepare final strategy document.
- Seek approval and adoption of the government.
- Start implementation.

B: FIVE-YEAR STRATEGIC ACTION PLAN:

* Baseline Information and Ambient Monitoring:

    -Develop a database.
    -Literature review.
    -Data assessment and gap identification.
    -Data collection to fill gaps.
    -Monitor resources and impacts.

* Vision Development:

    -Water supply availability, potential, and suitability.
    -Water demand assessment(projections for the future).
    -Develop alternative scenarios for supply and demand.
    -Identify and adopt evaluation criteria (for the alternatives).
    -Identify constraints, problems and challenges.
    -Select the most viable alternative (based on the selected criteria and constraints).
    -Identify the main issues for the selected scenario.

* Strategy Development:

    -Identify and select strategic objectives (based on the developed vision).
    -Develop a set of strategic principles for guiding strategy implementation.
    -Develop the general framework form freshwater resources management (features and directions).

* Develop Implementation Plan:

-Identify/develop and prioritize projects and programs. The following projects and programs may be selected from the general strategy action plan:
  - o Establishing a water resources and environmental database.
  - o Aquifer inventory.
  - o Aquifer classification program based on the hydrogeologic conditions, groundwater availability, exploitability, usability and vulnerability.
  - o Aquifer analysis and aquifer management programs using special computer in selected critical groundwater areas.
  - o Development of usable indicators for:

-Prepare profiles for each project/profile.
-Identify roles and responsibilities for implementation.

* Implementation And Monitoring:

-Select two or three projects and / or programs for implementation during the five-year-period, based on priority of projects and programs, as well as on resources availability.
-Develop methods and criteria for progress and performance evaluation.
-Implement programs and projects.
-Evaluate progress and performance, and provide alternative routes where needed.
-Prepare and submit progress reports as needed.
-Present findings as needed.

Means, Tools, And Requirements For Strategy Implementation:

- 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.
- Flexibility in implementation, without jeopardizing the main goals.
- Application of the recommended strategy principles, and targeting on the strategy objectives.
- Establishing an adequate database, and performing the needed field surveys, program and projects.
- Use of assessment and management computer models, and applying the geographic information system as needed, particularly for aquifer assessment and classification.
- Harmonization of data collection and monitoring practices and techniques.
- Developing adequate indicators for sustainability, performance, etc.

ANNEXES

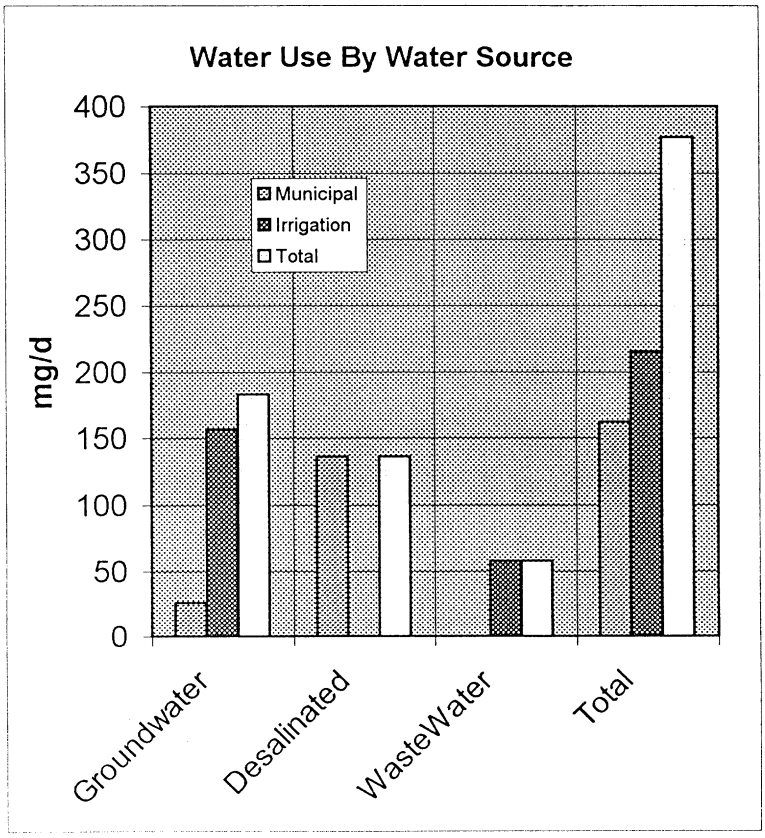
Water Use in Abu Dhabi Emirate In 1995, By Water Source & Type of Use

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

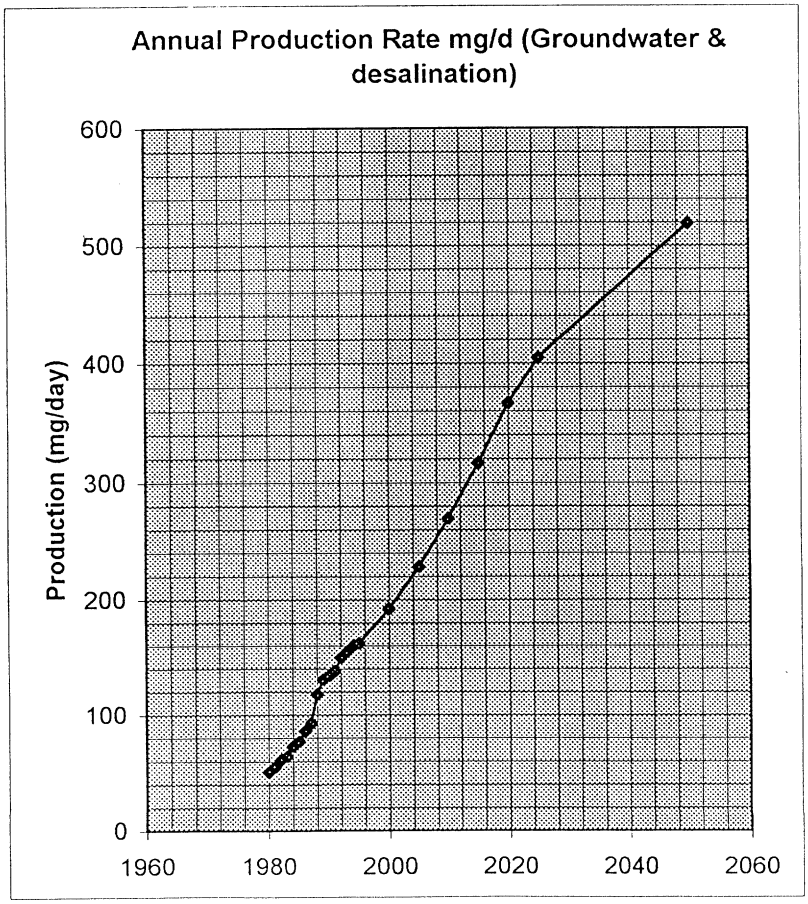


Annex (2)

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			



Annex (3)

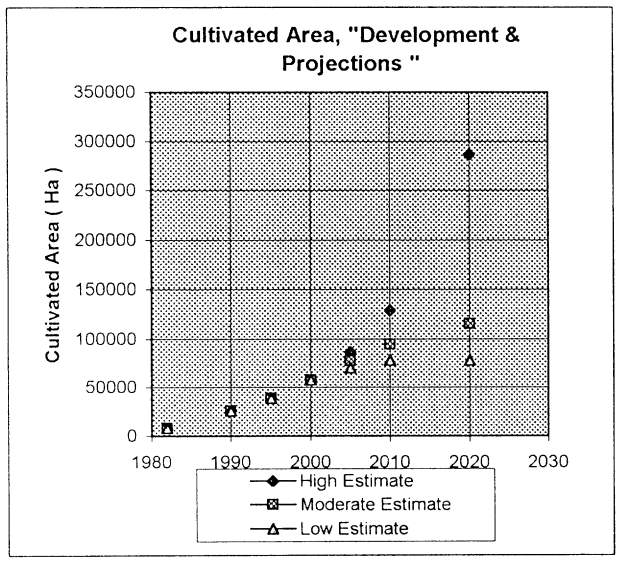
Past, Current, And Projected Growth In Cultivated Area And Grounwater Pumping In Abu Dhabi

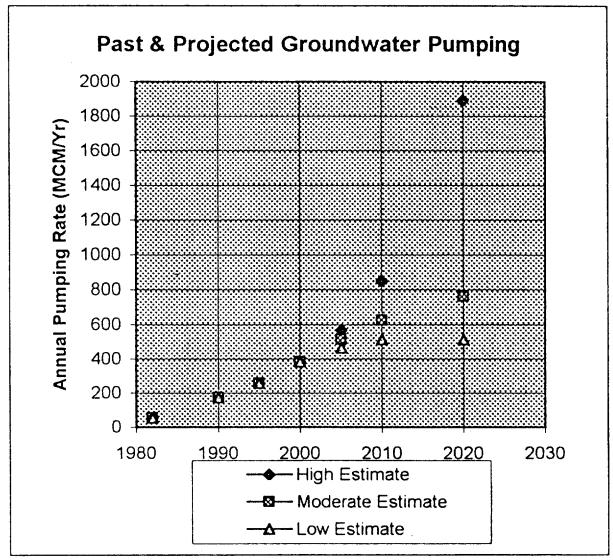
Cultivated Area (hectar)

	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

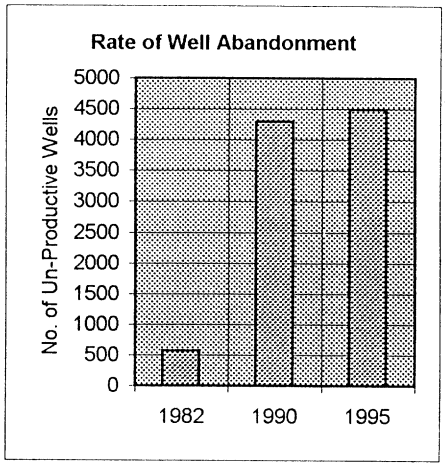


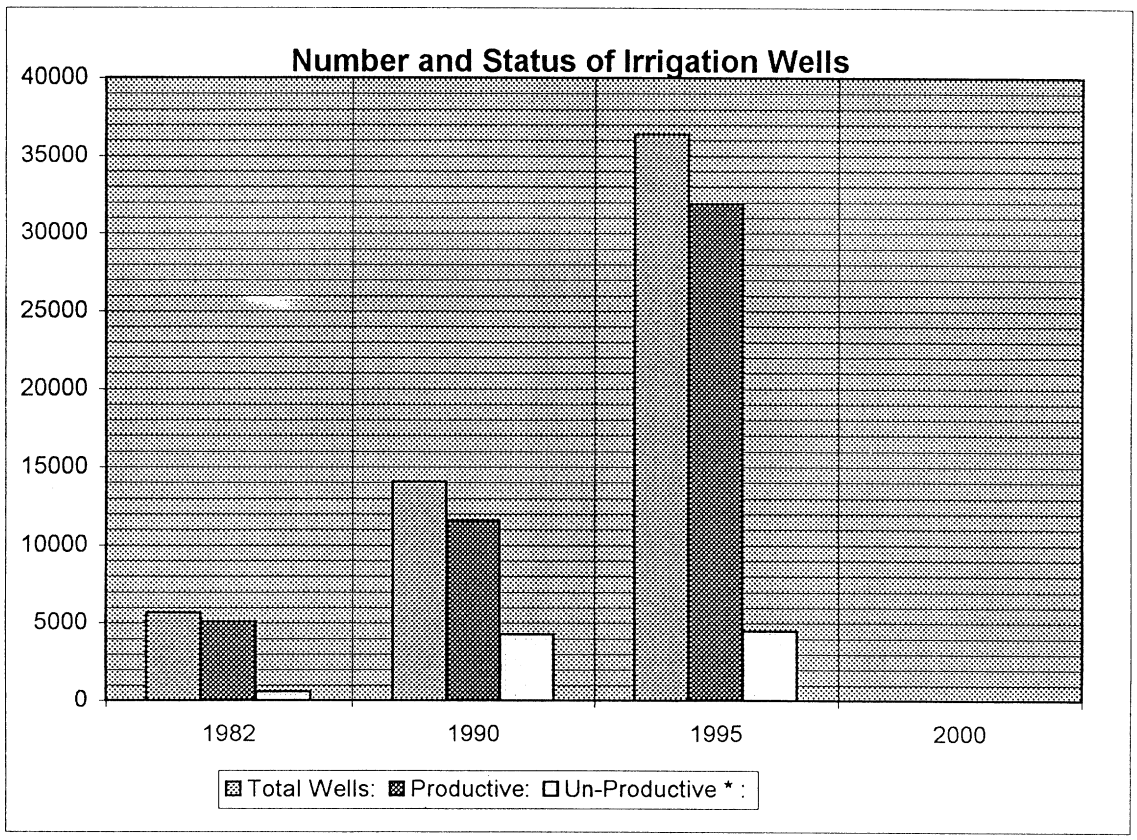


Annex (4)

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	





Annex (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