# A PLAN TO REDUCE WATER POVERTY IN THE FERTILE CRESCENT:

# GETTING FROM SCIENCE TO SOLUTIONS

A Dissertation
Submitted to the Graduate Faculty
of the
North Dakota State University
of Agriculture and Applied Science

By

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In Partial Fulfillment of the Requirements
for the Degree of
DOCTOR OF PHILOSOPHY

Major Program:
Natural Resources Management

December 2010

Fargo, North Dakota

# North Dakota State University
## Graduate School

**Title**

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The Supervisory Committee certifies that this ***disquisition*** complies with North Dakota State University's regulations and meets the accepted standards for the degree of

**DOCTOR OF PHILOSOPHY**

## ABSTRACT

Qtaishat, Tala Hussam, Ph.D., Program of Natural Resources Management, College of Graduate and Interdisciplinary Studies, North Dakota State University, December 2010. A Plan to Reduce Water Poverty in the Fertile Crescent: Getting from Science to Solutions. Major Professor: Dr. Jay A. Leitch.

Water scarcity is an ever-growing worldwide problem. In particular, most Fertile Crescent (FC) countries (i.e., Iraq, Syria, Lebanon, Jordan, Palestine and Israel) face severe problems related to water scarcity. Growing demand for water resources due to increased population and improved living standards, prompted public agencies and others in the Fertile Crescent (FC), a semi-arid region, to seek better ways to manage water. Water scarcity is the most serious natural constraint to the FC's economic growth and development. Three potential paths to address water scarcity dilemma are (1) non-traditional shifts in water reallocation, (2) innovative supply augmentation methods and (3) identification of substitutes for water in production and consumption. Water reallocation within uses (e.g., agriculture) and among users (e.g., agriculture, industry and municipal) as well as supply augmentation (e.g., desalination, water importing, wastewater treatment, recycling, water conservation, reducing evapotranspiration and storage) can all play a role in extending water resources. A conceptual reallocation method and information from the scientific literature suggest that some reallocation in the name of efficiency may be beneficial. A conceptual supply augmentation method operationalized with secondary data suggests water supply augmentation may also lead to decreasing water scarcity. Ultimately, substitutes for water will be necessary to further minimize water scarcity. These solutions, along with their economic, political, cultural, and technical dimensions and constraints, are presented in a strategic plan format that identifies paths for increasing

social benefit of the FC's water resources. The plan will assist decision-makers to identify and understand the constraints and the benefits related to non-conventional options. The plan posits a 20% shift in water from agriculture to municipal and industrial uses over the next 20 years, assumes reasonable supply improvements and speculates about the role of substitutes in the future. The plan further demonstrates a potential allocation of a hypothetical $100 million grant to a fictional FC water authority. These feasible, modest achievements would lessen water scarcity in the FC, by the year 2030.

## ACKNOWLEDGMENTS

First, I would like to present my sincere thanks to the NDSU Graduate School, the School of Natural Resources and the Natural Resources Management (NRM) Program for the opportunity to be able to start new work in the emphasis area of NRM planning and policy. By being able to be funded and having the chance to take a broad range of classes in a multidisciplinary area, my educational experience was enhanced. I want to express my gratitude for the different programs and emphasis areas associated with the NRM program.

Next, I would like to thank my adviser, Dr. Jay Leitch, for his guidance, support and encouragement during the preparation of my dissertation. I would like to express my thanks to my committee members, Drs. Robert Hearne, G. Padmanabhan and Jack Norland, for their assistance and time and for their support during my dissertation preparation.

I would like to thank Dr. Carolyn Grygiel for giving me the opportunity to pursue a doctoral degree in the NRM program at NDSU and for her continued support, encouragement and direction. Also, I would like to express my gratitude to Dr. Carolyn Grygiel because she has been totally confident in my abilities; she helped me to get funding from the Graduate School and interdisciplinary programs.

I would like to thank all the faculty, staff and graduate students of the NRM Program for their kindness and help. I am extremely grateful to Bonnie Cooper and Dr. Nancy Hodur for their assistance in editing my dissertation, correcting some English structures.

Most of all, I would like to thank my parents back home, Hussam and Maratha, for their continued love, care, prayers and support to finish my degree. Furthermore, I could not forget my brothers, Raad, Abdullah, Hashem, Mohammed Rasool, Rami and Belal, for their support and encouragement. Through opportunities given to me by Hashem, Mohammed Rasool, Rami and Belal as well as their assurance of my abilities, I have been able to pursue and achieve my goal. To Omar Ghazi Al-Azzam, thank you for the endless hours of support creating the figures and tables. Lastly, I offer my regards and blessings to all of my friends who supported me in any respect during the completion of my dissertation.

Tala Qtaishat

## DEDICATION

I would like to express my appreciation to all my family members and dedicate my work to them:

My best friend, my mother, Martha Abu-Salem, who always stands beside me, gives me complete support, encourages me and prays for me to achieve all my dreams.

My father, Hussam Qtaishat, who always has confidence in me and guides me to choose the best options in my life.

My brothers (Raad, Abdullah, Hashem, Mohammed Rasool, Rami and Belal) for their love and caring.

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## LIST OF ABBREVIATIONS

BCM........................................................................................... Billion Cubic Meter

CE...........................................................................................Classical Efficiency

CIA...........................................................................Central Intelligence Agency

DEA.........................................................................Data Envelopment Analysis

DSS.......................................................................... Decision Support System

EE...........................................................................................Effective Efficiency

EI......................................................................................Economic Instruments

EPA.........................................................................Environmental Protection Agency

ET.............................................................................................Evapotranspiration

FAO..................................................................Food and Agriculture Organization

FC................................................................................................Fertile Crescent

GDP.............................................................................Gross Domestic Product

GOJ...........................................................................Government of Jordan

IWMI............................................................International Water Management Institute

JTC..........................................................................Joint Technical Committee

MB...............................................................................................Marginal Benefit

MC.................................................................................................Marginal Cost

MCM............................................................................Million Cubic Meter

MCP..........................................................................Marginal Cost Pricing

ME.........................................................................................Middle East

MENA.................................................................Middle East and North Africa

METAP.................................Mediterranean Environmental Technical Assistance Program

O&M........................................................................................Operation and Maintenance

RO..........................................................................................................Reverse Osmosis

RWIR-ME..................The Regional Water Intelligence Reports on the Middle East Region

SAWAS Model...............................Seasonal Agricultural Water Allocation System Model

SD........................................................................................................System Dynamics

SIWI......................................................................................Stockholm International Water Institute

SMFA.......................................................................Swedish Ministry for Foreign Affairs

STP..................................................................................Situation, Target and Path

UN...........................................................................................United Nations

UNDP.............................................................United Nations Development Programme

UNEP..................................................................United Nations Environment Program

USAID...........................................United States Agency for International Development

WCD.......................................................................................World Commission on Dams

WD................................................................................................Water Dependency

WPI.................................................................................................Water Poverty Index

WWDR.....................................................................World Water Development Report

# CHAPTER 1. INTRODUCTION

Water is a vital component for life and necessary for human and economic development. Water contributes to food security. It is required for a quality environment for humans and other life forms on earth. Water poverty is a societal problem in arid and semi-arid regions in the Middle East (ME). In many Middle Eastern countries, water shortages threaten economic growth, social cohesion, environmental sustainability and political stability. There is evidence that water resources in the ME are being used in largely unsustainable fashion (Mediterranean Environmental Technical Assistance Program [METAP], 2007) and are not being managed based on present and future availability, but on sectoral and geographical allocations. Such water mismanagement may affect not only economic development, but also the overall quality of life.

'Water poverty' is society's inability to supply sufficient water resources to consumers. Definitions vary ranging from the "availability of water for municipal and food production requirements" (Salameh, 2000) to ''the difficulty people face in securing adequate and reliable access to water" (Shah and Van Koppen, 2006, P. 3418). Regardless of the definition, water poverty refers to inadequate water supplies.

The Water Poverty Index (WPI) illustrates the degree to which water scarcity impacts humans (Lawrence et al., 2002). WPI is intended to ''produce an integrated assessment of water stress and scarcity, linking physical estimates of water availability with socioeconomic variables that reflect poverty" (Sullivan, 2002, P. 1195).
The WPI describes the status of water resources and is used as a decision-making tool to prioritize water resource management goals and objectives.

Water scarcity is a critical resource constraint for economic growth and development of the Fertile Crescent (FC),[1] the Arabian Peninsula[2] and Egypt (Haddadin, 2002). The water availability threshold groups countries into the following categorize: arid, which need an internal allocation and plan to manage renewable water resources; hyper arid, which have very low levels of renewable resources; and transboundary, which are dependent on external water resources (Box 1 and Figure 1).

FC countries are water-stressed, with renewable water resources currently at 1,100 $m^3$ per year/per capita on average (FAO, 2003), far below the water-security threshold of 1,700 $m^3$ (Box 1). More than half the 22 Arab countries are classified as "water scarce" (Category C). Conditions are worse in the Gulf States, where the annual share of renewable water resources ranges between 35 and 550 $m^3$ per capita (Category D, water absolute scarcity).

Box 1. Water Availability Threshold and Categories

Threshold depends on estimations of water requirements in the municipal, agricultural, industrial and energy sectors as well as some other requirements for the environment. This number might vary based on geographic, ecologic and socioeconomic factors.

Category A: Water security: $\geq$ 1,700 $m^3$ per capita per year of renewable water.
Category B: Water stress: $\geq$ 1,000 and < 1,700 $m^3$ per capita per year of renewable water.

Category C: Water scarcity: $\geq$ 500 and < 1,000 $m^3$ per capita per year of renewable water.

Category D: Water absolute scarcity: < 500 $m^3$ per capita per year of renewable water.

Source: World Bank (2007).

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[1] Including Iraq, Syria, Lebanon, Jordan, Palestine and Israel.
2 Including the Republic of Yemen and the Gulf Cooperation Council members which are the State of Kuwait, the Kingdom of Bahrain, the State of Qatar, the United Arab Emirates, the Sultanate of Oman and the Kingdom of Saudi Arabia.

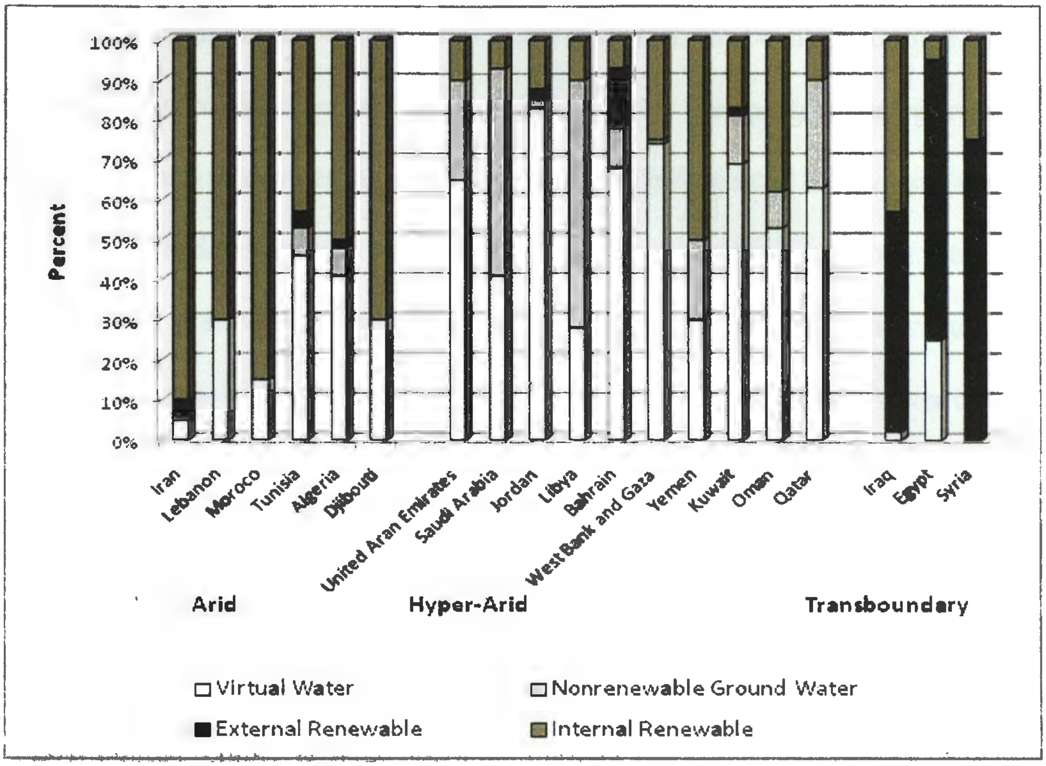


Figure 1. Renewable Water Resources by Region and Country.
Source: Adapted from World Bank (2007).

Demand[3] for water in the FC has increased with rapid growth in population and industrial development (Doppler et al., 2002). Water resources in the FC consist of ground (renewable and non-renewable) and surface water, with treated wastewater used

3 Demand is the amount of an economic good or service that a consumer is willing and able to purchase at a given price. Change in demand is a shift of the whole demand schedule to the right (increased demand) or left (decreased demand), and that change comes from the influence of non-price factors affecting purchases, such as size of market (number of buyers), tastes and preferences, income (more income typically increases demand), price of related goods and consumer expectations (expected future shortages increase the current demand). Change in quantity demanded is the change that comes from a decrease or increase in product price, while the demand curve does not move from a change in price. Supply is the total amount of a product (good or service) producers are willing to make available at any specified price. Change in supply is a shift of the whole supply schedule to the right (increased supply) or left (decreased supply), and that change comes from the influence of non-price factors affecting supply, such as seller numbers (more producers increase the market supply.), resource prices and technology. Change in quantity supplied is movement from one point to another along a supply curve as a result of a change in the price of the good.

increasingly for irrigation. Development of water resources has been constrained by regional political considerations and the high cost of water transportation infrastructure (Taha, 2006). Renewable water in the FC countries is supplemented with virtual water. Virtual water (embedded water or hidden water) reflects the water used in the production of an imported good or service. Allan (1993) studied the potential of importing virtual water as a partial solution to water problems scarcity in the Middle East. Virtual water could reduce pressure on the available domestic water resources. It becomes an alternative for water as an endogenous water resource. Imported virtual water has also been called "exogenous water" (Haddadin, 2003). Of course, virtual water does not reduce the amount of water used, it merely shifts it from the consuming country to the producing country.

Low rainfall, highly variable precipitation rates and recurrent droughts from 2000 to 2002 in Iraq, Jordan, Lebanon and Syria have contributed to the critical situation in the FC (Haddadin, 2002). Drought creates an imbalance between availability and needs, contributes to the degradation in the quality of surface water and groundwater, and creates conflicts about the allocation of water among sectors. Under drought conditions, water shortages can be mitigated by using water more efficiently, reducing demand (conservation) and increasing public awareness about the appropriate use of scarce water resources.

Long term water management in the FC must use an integrated approach, balancing economic efficiency, equity and socio-environmental sustainability. An integrated plan is an approach that enables decision-makers ability to rank sustainable management alternatives. An integrated plan is necessary to evaluate management alternatives and consider the needs and interests of all stakeholder groups.

Most water scarcity literature has focused on either economic instruments or analytical models to allocate water, or on engineering solutions to expand water supplies. However, in order to address critical water scarcity issues in the FC, natural resources managers must use the best of both economic tools and engineering solutions.

Wicked[4] problems, such as water scarcity with economic, engineering, political, cultural and geographic components, are often analyzed according to their smallest units. Once the analysis is complete, the results are frequently not bundled back together effectively to address the larger problem. For example, two popular methods used to address water scarcity--reallocation among users to maximize social welfare and supply augmentation to increase availability--rarely get bundled together in a practical framework.

Population growth, industrial development, urbanization, economic development and climate change are additional challenges facing national and international water-management agencies. Additionally, both surface and ground water in the FC flows across political boundaries. Most of the countries adjacent to the Jordan River, the Dead Sea, the Euphrates and Tigris Rivers, the Red Sea, the Litani River, the Yarmouk River, the Nile River or the Mediterranean Sea share an interest in those waters. Transboundary conflicts add another dimension to the challenges of managing water resources in the FC region (K. Assaf, 2006; L. Assaf, 2006; Wolf, 1995, 1996, 2000).

Much research has been accomplished to address water issues in the FC. The scientific literature is replete with water reallocation and water supply augmentation research. Further, international aid agencies, water planners and political decision-makers have developed a variety of plans and projects. However, to date, none are fully adequate

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[4] A wicked problem is one with no clear answers; solutions are only better or worse (Yoe and Orth, 1996).

to develop a comprehensive, integrated plan to reduce water-poverty in the FC. Continued efforts are necessary to address issues related to water scarcity in the FC.

This study combines disciplinary principles and concepts with information from the literature to form the basis for a strategic plan for water scarcity amelioration in the FC. This dissertation is organized into eight chapters. The second chapter introduces methods, conceptual models and an efficiency-based planning policy model. Chapter 3 describes the water situation in the FC. Chapter 4 discusses water reallocation. Chapter 5 discusses water-supply augmentation options. Chapter 6 introduces the idea of substitutes for water. Chapter 7 presents a proposed strategy to achieve the goal of alleviating water-scarcity in the FC over the next two decades. The final chapter is a summary, conclusions and recommendations for policy makers and further research.

# CHAPTER 2. METHODS

This dissertation uses a case study approach to develop a strategic plan to reduce water poverty in the Fertile Crescent. Strategic planning is used to organize and guide the decision-making process to achieve a desired outcome. The planning process takes into consideration project perspective, scope, impacts and analytical method (Litman, 2008). Strategic planning focuses on the macro level, while tactical or operational planning details specifically how to accomplish defined tasks within a strategic plan. Strategic planning defines goals and objectives rather than a plan of action for day to-day operations (tactical planning) (Helweg, 1985).

The strategic plan for water resources in the FC outlines processes and actions needed to alleviate water poverty. The strategic plan is predicated upon the fact that the region needs immediate action to sustain available water resources due to increasing water demands for industrial, municipal and agricultural uses. A comprehensive strategic plan is needed to address changes in demand and to develop sustainable water management systems.

A basic Situation—Target--Path approach is used in this study. A conceptual method for guiding water allocation decisions was developed based on the economic principles of marginal benefits and efficiency. A conceptual method for water-supply augmentation options was based on the economic principle of marginal costs. Data and results from other studies (water allocation and supply augmentation studies) were examined to operationalize these methods.

## 2.1. Situation, Target and Path (STP) Method of Strategic Planning

Situation, Target and Path (STP) is a strategic planning method. It divides the planning process into three parts: SITUATION assesses and evaluates the existing and historical conditions related to problem statement. TARGET defines broad goals, and PATH identifies a general approaches to accomplish the goals. The STP method is simple, but clearly illustrates the strategic planning process (Strategic and Business Planning Free Resources Center, 2010).

2.1.1. The Situation

Chapter 3 describes the water resource situation in the FC countries. Water scarcity is a growing problem in most FC countries; although the general public remains largely unaware. Water scarcity is masked by religious and political conflicts, and lack of awareness of available technology that could potentially mitigate water scarcity. The absence of water pricing policies in several FC countries and continued political support for agriculture and water-thirsty crops such as wheat, rice and cotton further strain water resources and will exacerbate the problem.

2.1.2. The Target

The target is a reduction in water poverty in FC countries. The target is to move each FC country up at least one level in the water available threshold by 2030 (Box 1). For example, Jordan, Israel and the Palestinian Territories are under Category D (water absolute scarcity with less than 500 $m^3$ per capita per year of renewable water resources). The target for 2030 is to move those countries to at least Category C (water scarcity between 500 and 1,000 $m^3$ per capita per year of renewable water resources).

2.1.3. The Path

The path identifies feasible, efficient methods for managing available water resources and identifies water-supply augmentation options for the region. The path includes three alternatives for reducing water poverty:

a. Reallocation: Water reallocation is addressed in chapter 4. Reducing agricultural water use may satisfy the need for water for other higher-value uses in the municipal and industrial sectors. Reallocating water from irrigation to other uses could provide sufficient and sustainable water supplies to meet the growing domestic and industrial demands for the next 20 years (2030). Most of the literature on water reallocation suggests that shifting water use from agriculture to other sectors would be feasible, but few studies address how much water should be reallocated. Because no work has been done to determine how much water should be reallocated, the path portion of the strategic plan will assume a reallocation of 20% of water currently used for agriculture production to other uses. Reallocation of 15%, 20% or 30% will give roughly proportional results.
b. Supply augmentation: Chapter 5 introduces supply-augmentation options in the FC countries. Options for increasing water supply in the FC include reducing evapotranspiration, rainwater capture with micro and macro dams, water conservation, desalinating seawater and brackish water, treating wastewater, and importing water from neighboring countries. However, all these options must be analyzed to evaluate efficiency and geopolitical feasibility. The Marginal Cost (MC)

principle will be used to select supply-augmentation options based on their MC.

c. Water substitution: Chapter 6 discusses water substitutes for some production and consumption activities. Water reallocation and supply augmentation will at some point be maximized. At which time, substitutes for water may be necessary. While there is no substitute for most biological uses of water, such as biotic (e.g., human, livestock, wildlife or crop) consumption, some non-biotic uses may not require water (e.g., dry cleaning, dust baths, ultrasound car washes, industrial cooling). The same marginal cost principle can be applied when exploring the feasibility of water substitutes

## 2.2. Review of Water Plans

This study is a "plan" not a preliminary engineering or economic design. A strategic plan integrates engineering and economic consideration to develop long-term strategy for water supply decision-making. The plan does not make decisions on water supply issues but, rather, provides the FC region with a strategic goal and general paths that will lead to a better water situation. The plan provides general timelines for strategies, actions and assessments and suggests fund allocations for various water management activities.

The plan details guiding principles for integrated water resources management, outlines a set of strategies to deal with major issues, and proposes some future project work to improve knowledge and governance procedures as well as to build capacity in the FC region. This study will use a planning horizon of 20 years, to the year 2030. The costs shown in the plan (Chapter 7) are in 2010 dollars and include allowances for administration and engineering costs and contingencies. Costs do not take inflation into consideration.

#### 2.2.1. Examples of Water Plans

A water plan is a strategic document that provides a country or state with a vision, mission and goals for meeting the challenges of sustainable water use. The plan supplies a framework for action to ensure a sustainable and reliable water supply throughout the planning period. For example, in Jordan, the national water plan was established in 2001, funded by the German government (Ministry of Water and Irrigation, 2010). The main objective of the national plan was to decrease the gap between available water resources (i.e., supply) and demand. The national plan assessed present availability, withdrawals, losses and uses of water resources and formulated alternative development scenarios for water resources and demand/use at various planning horizons. The national water plan was not sufficient to address water scarcity issues because the plan failed to adequately plan appropriate strategic contingencies for drought conditions.

California's water plan has a goal to reduce water demand, increase water supply, improve efficiency of water transfer, improve water quality and improve flood management (Department of Water Resources, 2009). Recommendations of the water plan varied dependent on the constraints (e.g., institutional, legal, knowledge, funding and public awareness). The constraints allow decision-makers to take further actions to achieve the water plan objectives and expand the integrated water-management plan (Department of Water Resources, 2009). The timeline for the California plan extends to 2050; however, the plan is dynamic and is updated every five years. The updated plan addresses the challenges of managing variable water resources. Decision-makers take into account the uncertainty and risk in water investments.

The National Water Resources Council in India adopted The National Water Policy (NWP) in 1987 (Ministry of Water Resources, 2010). The goal of the policy was formulated policies and programs for water resources development and management. In 2002, policy was revised in order to meet challenging water management issues. The reviewers came with some suggestions for water resources in eight States in India. The important suggestions were emphasized on the development of the groundwater; appropriate water harvesting, prevention of overexploiting of water resources and improvement of the flood management system (Ministry of Water Resources, 2010). The recommendations were to define the plan timelines, create a financial plan, generate a water database and monitor the actions and paths of the plan to accomplish the goal.

In summary, there is no one 'cookie-cutter' format for water plans. However, all useful plans include Situation, Target and Path or some variation thereof. A successful strategic plan must clearly identify and articulate the plan's mission, vision, timeline and budget. Water plans guide a decision-making processes and identify actions that address all of state/country water needs. A water plan is a complex and dynamic tool requiring participation from all constituent groups as well as all levels of government.

## 2.3. Reallocation: Marginal Benefits and Efficiency

Optimal reallocation is achieved when the Marginal Benefit (MB) is equal across uses, *ceteris paribus*. The MB of water as a factor of production is the increase in total revenue as a result of one more unit of water. Efficient allocation of water is achieved when the marginal price for each user is equal to the location efficiency price at the user's location (Dinar et al., 1997). That is, the Marginal Cost (MC) of an additional unit of water is the cost of the additional inputs needed to produce that water. The conceptual model will suppose that there are two users (A and B) and that their economic efficiency can be achieved when $MB_A = MB_B$.

### 2.3.1. Conceptual Model

The model assumes there are two users (A and B), a fixed quantity of water available (Q) and fixed other factors (Figure 2). Water is currently allocated to q* where $MB_A$ less than $MB_B$. By reallocating $q_1$ from user A to user B, the economic efficiency goal ($MB_A = MB_B$) can be achieved (Notice that, at q*, MB=0) (Figure 2).

Water prices and the marginal benefit to allocate water resources from agriculture to other water users were gleaned from the published literature. The data used to "operationalize" the conceptual reallocation model came from several studies (FAO, 2009; United Nations, 2003; Beaumont, 2002; World Bank, 2007). This study will review the data to assess if the data from the literature are sufficient to make decisions and to move from "science to solutions."

## 2.4. Supply Augmentation: Marginal Costs and Efficiency

The Marginal Cost (MC) principle will be used to achieve optimal water supply by adopting the supply-augmentation method with the lowest MC. The MC of water harvesting, wastewater recycling, water imports, and seawater and brackish water desalination must be measured and the least cost option selected first.

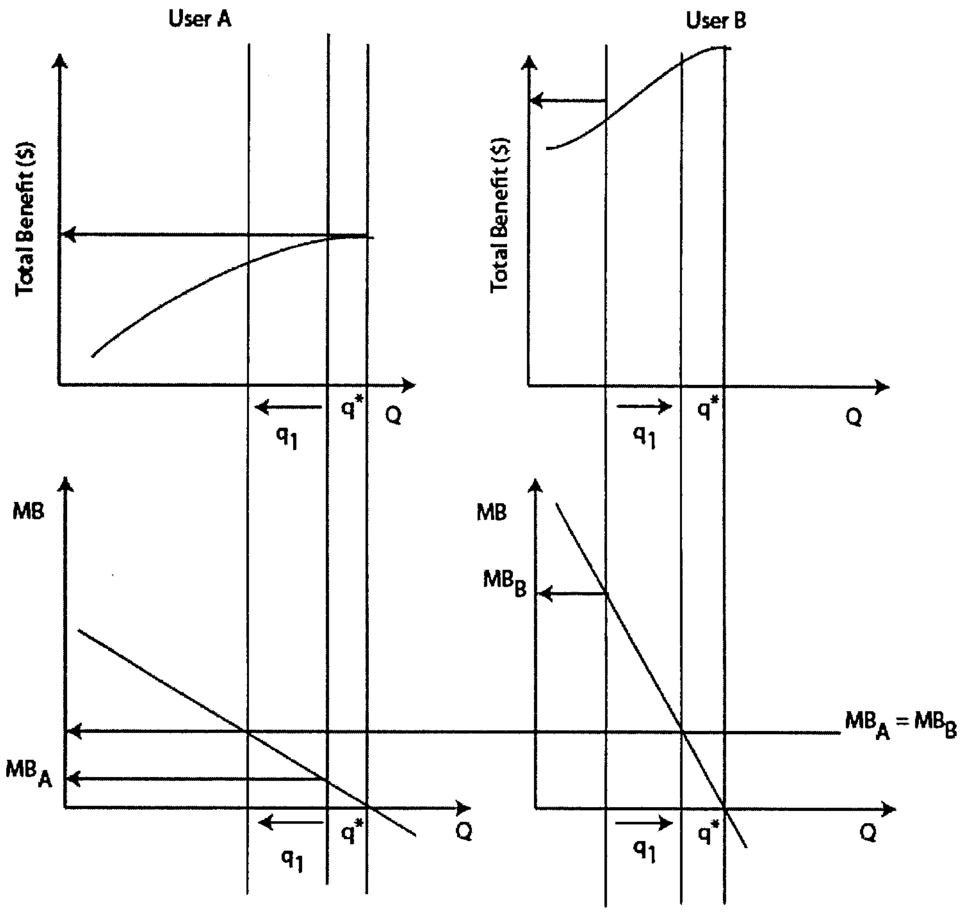



Figure 2. Conceptual Reallocation Model for Two Water Users (A and B).

The conceptual model will assume that there are two water supply options (A and B) and that their economic efficiency can be achieved by choosing the least MC option. A 'switch point' occurs when one water supply's rising MC meets another water supply's falling MC (or rising more slowly) and water use switches from one option to the other (for example, switching from water importation to desalination).

### 2.4.1. Conceptual Model

The conceptual model will assume there are two supply-augmentation options (A and B) and factors that affect option A and B will be held constant. Also, the model assumes option A and B are already in place and there are no additional capital costs (i.e., no start up costs). A practical issue with water supply is the ability to scale existing supply options or to start from zero with a new water supply option.

Both options will provide an optimal quantity of water ($q_1$) (Figure 3). The switch point is reached by allocating water to the least cost use at the margin, until the costs equal the marginal benefits of an additional unit of water. At the switch point the decision-maker can switch to the supply-augmentation option with lower MC.

Water cost and marginal cost data for supply-augmentation options are provided in the literature. The data used to "operationalize" the conceptual supply augmentation model came from several studies (FAO, 2009; Al-Mutaz, 2005; El-Sadek, 2010; World Bank, 2007; United Nations, 2003).

### 2.5. Substitutes

Little in-depth research has been done on finding substitutes for water. This section will explore what work has been done to date. As previously discussed, there are no substitutes for some water uses. Chapter 6 will identify some potential substitutes for water in production and consumption activities where substitutes may be appropriate.

### 2.6. The Draft Plan

The final step in the planning process is to review, critique, implement, and evaluate/adapt the plan. In addition to reallocation, supply-augmentation and water substitutes, constraints and other real world issues will be examined.

This study assumes, for the sake of demonstration, that there is a water management agency in the FC region with $100 million budget to help reduce water poverty in the region.

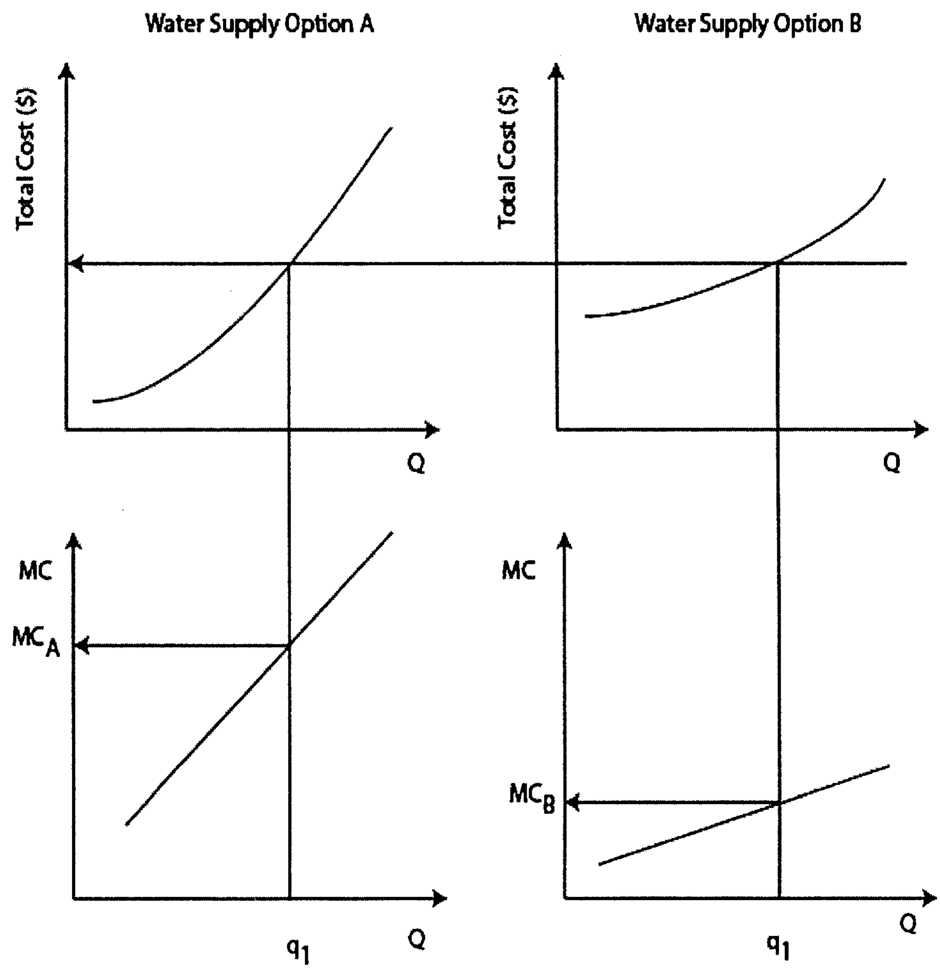



Figure 3. Conceptual Water-Supply Augmentation Model for Two Options (A and B).

The strategic plan suggests how to allocate the $100 million to maximize social well-being now and into the future, recognizing political and financial constraints. The reallocation path uses MB principle to achieve economic efficiency ($MB_A=MB_B$), where A and B are different water usages. Water reallocation options will be selected based on MB principles. Once allocation efforts that meet MB principle of $MB_A=MB_B$, supply-augmentation options will be selected based on MC principle of $MC_A = MC_B$. Any remaining resources will be used to examine water substitutes options.

# CHAPTER 3. WATER SITUATION IN THE FC

Worldwide, more than a billion people do not have clean drinking water, and about half of the world's population in 80 countries suffers from serious water shortages (United Nations Environment Program [UNEP], 2002). The FC countries face some of the most severe water shortages in the world. Population growth, economic development, higher standards of living, increased water use for agriculture and declining rainfall in the region have contributed to water shortages (UNEP, 2002).

Since the 1910s, most policy-makers and researchers considered the scarcity of water and its effects on both developing and developed countries as a global threat (Bontemps and Couture, 2002). Water shortages restrict economic development, impact urban industries and affect the environment (United Nations, 2003). Further, many FC countries lack an integrated and comprehensive plan to address water shortages and water allocation.

This chapter describes the current water situation in the FC. The chapter examines current water use management issues and future considerations. The challenges that may impact FC countries' ability to address water scarcity are discussed. Political considerations for the FC countries which often exacerbate water management in the region are introduced.

## 3.1. Study Area Countries

The FC countries of Jordan, Iraq, Syria, Lebanon, Israel and the Palestinian Territories (West Bank+Gaza Strip) have common, yet distinctive, characteristics (Appendix A). Together, the FC countries (Figure 4) cover about 750,000 $Km^2$.


Figure 4. The Middle East and the Fertile Crescent Map.
Source: Adapted from Travel Note Guide (2010).

Most FC countries are semi-arid with the following land areas:

| Country | Area ($Km^2$) | Source |
|---|---|---|
| • The Palestinian Territories | 6,000 | (Central International Agency [CIA], 2008). |
| • Lebanon | 10,452 | (U.S. Library of Congress, 2008). |
| • Israel | 20,770 | (U.S. Library of Congress, 2008). |
| • Jordan | 88,778 | (Department of Statistics [DOS], 2006). |
| • Syria | 185,180 | (U.S. Library of Congress, 2008) |
| • Iraq | 437,072 | (U.S. Library of Congress, 2008). |

The population of the FC has grown steadily since the end of World War II. The population of Jordan was 5.6 million in 2006, up from 1.3 million in 1950, and was increasing at about 3.4% per year. Iraq's population was 26.8 million in 2006, up from 5.2 million in 1950, with an estimated growth rate of 2.7% per year. In 2003, Syria's population was 18.2 million, up from 3.5 million in 1950, with a slightly lower estimated growth rate of 2.4%. Lebanon had the smallest estimated growth rate of 1.4%, going from 1.4 million in 1950 to 4.0 million in 2009 (CIA, 2009). The Palestinian Territories and Israel had the highest estimated growth rate of 5.6%, going from 2.6 million in 1950 to 7.4 million in 2008 (Israel Central Bureau of Statistic, 2008).

The population in the FC is projected to increase to 95 million by 2025, from around 60 million in 2000, and in some countries, water resources are totally committed (United Nations, 2003). Several authors (Rosegrant et al., 2002; Playan and Mateos, 2006; Falkenmark, 2007) suggest that a lack of available water is the main factor restricting the expansion of food production to meet population growth in the region.

### 3.2. Study Area Water Situation

Water use in the FC falls into three categories: municipal consumption, industrial production and agricultural production (including livestock). Per capita municipal water demand in the FC has increased with growing urbanization and rising incomes (Allan, 2001). Most of the FC policy-makers agree that water for human consumption, including drinking, cooking, bathing and cleaning, should be given priority over other uses.

#### 3.2.1. Economic Summary

People in the FC are dependent on agricultural production even though agriculture has a relatively small contribution to the GDP in the FC (Table 1). The industrial sector represents roughly one-third of the region's GDP and is mainly present in larger urban centers. The service sector provides more than two-thirds of the total GDP in the FC countries, ranging from 60% in Palestine to 77% in Israel. Agriculture contributes as little as 4% and 5% to GDP, respectively, in Jordan and Iraq while, in Syria, agriculture contributes about 25% to the GDP (Table 1).

Table 1. Gross Domestic Product (GDP), Per Capita GDP and Sectoral Contribution in the FC Countries in 2005

| Country | GDP (billion US$) | GDP (per capita US$) | Sector share of GDP (%) Agriculture | Industry | Service |
|---|---|---|---|---|---|
| Palestine | 12.0 | 1,036 | 9 | 31 | 60 |
| Jordan | 15,830 | 2,227 | 4 | 26 | 70 |
| Lebanon | 24,000 | 6,011 | 11.7 | 26 | 62.3 |
| Iraq | 25,860 | 1,031 | 5 | — | — |
| Syria | 38,080 | 1,480 | 28.5 | 29.4 | 57.9 |
| Israel | 161,820 | 19,292 | 2.8 | 20.1 | 77.1 |
| **Totals** | 265,602 | 31,077 | | | |

Source: Adapted from FAO (2009).

Agriculture is contributing a very small portion to the economies of Israel and Jordan. The service sector is the main contributor to GDP in the selected countries (Table 1). The GDP of Syria is still moderately dependent on agriculture, although agriculture is the economic sector that contributes the least to the country's total GDP. The per capita water resources available in Syria are much higher compared to Lebanon, Israel, Palestine and Jordan, explaining why agriculture continues to play a more important economic role in Syria.

3.2.2. Water Use Situation in the FC Countries

More than half of the countries in the FC are ranked in the world's lowest 10% of annual, per capita total renewable water resource availability (Table 2). Iraq has the greatest supply of total annual renewable water resources per capita with 3.2 MCM/cap/yr (Table 2). Palestine has the least total annual renewable water resources per capita in the FC with only 52,000 MCM/cap/yr. Jordan and Israel also have less than a million MCM/cap/yr in renewable water resources. Lebanon and Syria have 1.2 and 1.6 MCM/cap/yr, respectively. Lebanon has the greatest internal renewable water resources in the region with more than 1.2 MCM/yr. The surface water and groundwater together are about 146,600 MCM/yr which means that the water situation in Lebanon is better than the other FC courtiers. The Palestinian Territories have the least internal renewable water resources at 500 MCM/yr.

Table 2. Water Availability in the FC

| Country | Ranking* | Total renewable water resources (MCM/cap/yr) | Total internal renewable water resources (MCM/yr) | Surface water: produced internally (MCM/yr) | Groundwater: produced internally (MCM/yr) |
|---|---|---|---|---|---|
| Palestinian Territories | 179 | 52,000 | 500 | 0,00 | 500 |
| Jordan | 170 | 179,000 | 680 | 400 | 500 |
| Israel | 167 | 276,000 | 750 | 250 | 500 |
| Lebanon | 149 | 1,261,000 | 128,500 | 97,300 | 49,300 |
| Syria | 141 | 1,622,000 | 7,000 | 4,800 | 4,200 |
| Iraq | 108 | 3,287,000 | 35,200 | 34,000 | 1,200 |

Source: Adapted from World Water Development Report (WWDR, 2003).
*Rank of FC countries among 182 countries according to their annual, per capita total renewable water resource availability from the least (182) to the most (1).

Water resources in the region consist of groundwater, surface water (conventional water resources), wastewater reuse and desalinated brackish water (non-conventional water resources) (Table 3). Available water from each source varies from country to country. Israel has the greatest percentage of renewable water resources from surface and groundwater, about 46% (Table 3). The water available to the FC ranges from conventional to non-conventional sources. For 2005, the available water was the most for Iraq and the least for Palestine. Desalination is more dominant in Israel than other countries, with about 140 MCM (Table 3). Wastewater treatment is more prevalent in Iraq than other countries, with about 2500 MCM (Table 3).

Table 3. FC Water Resources in 2005 (in Million Cubic Meters)

| Country | Surface water | Ground water | Desalination | Wastewater reuse | Totals | Per capita ($m^3$/yr) |
|---|---|---|---|---|---|---|
| Palestine | 87.00 | 750.00 | 0.50 | 2.00 | 839.50 | 384 |
| Jordan | 650.00 | 540.00 | 9.80 | 83.50 | 1,283.30 | 161 |
| Israel | 555.00 | 1,225.00 | 140.00 | 550.00 | 2,470.00 | 265 |
| Lebanon | 3.80 | 3.20 | 47.30 | 6.00 | 60.30 | 1,259 |
| Syria | 12.63 | 6.17 | 2.00 | 2.24 | 23.04 | 882 |
| Iraq | 74.33 | 3.28 | 7.40 | 2,500.00 | 2,585.01 | 2,625 |
| **Totals** | **1,382.76** | **2,527.65** | **207** | **3,143.74** | **7,261.15** | **5,576** |

Source: Adapted from FAO (2009).

More water is used for agricultural production than other uses in most FC countries. Between 56% and 99% of all water in the FC is used for agriculture (Table 4). On average, 88% of water is used for agricultural production, 7% for municipal uses and 5% for industrial uses (FAO, 2003). Historically, most water resources have been used for irrigation, with demands from other sectors being insignificant in relation to resource availability, even though there is an expanding domestic demand and rapidly growing industrial requirements (Table 4).

Table 4. Past and Current Water Uses in the FC (in Million Cubic Meters)

| **Country** | **Municipal** | | **Agriculture** | | **Industry** | | **Totals** | |
|---|---|---|---|---|---|---|---|---|
| | **1990** | **2005** | **1990** | **2005** | **1990** | **2005** | **1990** | **2005** |
| Iraq | 3,800 | 4,300 | 45,200 | 52,000 | 1,450 | 9,700 | **50,450** | **66,000** |
| Israel | 482 | 712 | 1,216 | 1,129 | 106 | 113 | **1,804** | **1,954** |
| Jordan | 190 | 291.3 | 650 | 611.2 | 43 | 38.4 | **883** | **941** |
| Lebanon | 271 | 380 | 875 | 780 | 65 | 150 | **1,211** | **1,310** |
| Palestine | 78 | 101.4 | 140 | 174 | 7 | 14.4 | **225** | **290** |
| Syria | 650 | 1,426 | 6,930 | 14,669 | 146 | 595 | **7,726** | **16,690** |
| **Totals** | **5,471** | **7,210.7** | **55,011** | **69,363.2** | **1,817** | **10,610.8** | **62,299** | **87,185** |

Source: United Nations (2003) and FAO (2009).

Precise data on water use in the FC are hard to obtain and vary from one country to another. The Food and Agriculture Organization (FAO) has developed the most comprehensive data set (Appendix A) of FC water use (FAO, 2009).

a. Jordan

Water use in Jordan varies according to the year. The amounts were around 0.866 and 0.941 $Km^3$ in 2004 and 2005, respectively. In 2005, agricultural water use accounted for 65% of the total water use. Water withdrawal for domestic (municipal) and industrial purposes was reported as 31% and 4%, respectively (FAO, 2009).

b. Iraq

Total water use among FC counties was the greatest in Iraq and was estimated at 66 $Km^3$ in 2000. Iraq's water use was as follows: 79% for agricultural purposes, 6.5% for domestic supplies and 14.5% for industrial use (FAO, 2009).

c. Israel

Water consumption in Israel amounted to 1.95 $Km^3$ in 2004, which was almost identical to 2000 and 11% more than in 1986 (1.76 $Km^3$). Agriculture use was reported as 58% in 2004, whereas it was 64% and 71% in 1993 and 1983, respectively. Domestic use accounted for 36% while industrial use was 6% which is approximately the same as Lebanon (FAO, 2009).

d. Syria

The total annual water withdrawn in Syria was estimated at 16.69 $Km^3$ in 2003, 87.9% of which was for agricultural purposes. In 1993, the total water withdrawn increased by almost 31%. Agricultural water use followed the same trend, but municipal and industrial uses increased by 39% and 89%, respectively (FAO, 2009).

e. Lebanon

In 2005, water withdrawal in Lebanon was estimated at 1.310 $Km^3$. Usage was approximately 60% for agricultural purposes, 29% for municipal use and 11% for industry (FAO, 2009).

f. Palestinian Territories

In 2005, the total water withdrawal in the Palestinian Territories was estimated at about 0.418 $Km^3$, 45% was for agriculture. In 2000, agriculture utilized about 0.174 $Km^3$, of which 0.89 and 0.85 $Km^3$ were used in the West Bank and Gaza Strip, respectively (FAO, 2009).

Water dependency (Box 2) is high for many countries in the FC (Table 5). In Syria, Palestine, Israel and Iraq, 50% to 80% of water supplies originate outside country boundaries.

Box 2. Water Dependency

Water dependency indicates the level a nation relies on foreign water resources (through importation of virtual water). Water dependency (WD) can be calculated as the ratio of net virtual water as a percentage of total water consumption.

Source: Tropp and Jägerskog (2006).

Table 5. Water Dependency Ratio

| **Country** | **Water dependency ratio percentage** |
|---|---:|
| Syria | 80 |
| Israel | 55 |
| Jordan | 23 |
| Palestine | 75 |
| Iraq | 53 |
| Lebanon | 7 |

Source: WWDR (2003) and Phillips et al. (2006).

The water-dependency ratio (Table 5) does not account for shared groundwater aquifers. In spite of the FC's heavy dependence on groundwater (about 60%), most political conflicts are about shared surface water (WWDR, 2003).

Many FC countries fully allocate most of their renewable water resources. This, however, has not limited economic development and has increased water consumption. For example, Israel has fully utilized its renewable water supplies since the late 1960s. However, it has continued to grow by mining groundwater, reallocating water and recycling sewage water (Lonergan and Brooks, 1994). In Jordan, the critical time for allocating irrigation water will be in the next five years (Salameh and Bannayan, 1993). With Iraq's continuing population growth, the country's water shortages will worsen (Bagis, 1994).

### 3.2.3. Current Allocation

FC governments allocate water resources by setting water- use priorities and allocating water among various users. In most FC countries, competition for water among the agricultural, municipal and industrial sectors is very high. Governments often subsidize farmers with low cost irrigation water. The subsidies are a government policy to increase food production (Meinzen-Dick and Appasamy, 2001). Most farmers in the FC have no motivation to reduce their water use because of the subsidies and because the cost of water is very low. Consequently, many farmers choose to plant water-intensive crops like rice or sugarcane.

In addition to domestic water requirements in the FC, water is an input for economic development. Industrial production needs water; the amount differs depending on the industry and the technology used. With a growing number of factories in rural FC areas, there is an increased demand for water. Most industries need water for manufacturing (e.g., for cooling or cleaning).

Agriculture is the largest water-consumption sector worldwide (United Nations, 2003), including the FC countries. Irrigation has been, and will continue to be, significant to achieve food security. Increased food production needed for growing populations will require even more irrigation. Within the agricultural sector, crop production needs the most water, but fish and livestock also require considerable water. Compared to crop production, animals (including fish) consume a relatively small volume of water and can produce a very high value of output (Bakker, 1999). Moreover, as the FC demand for animal products increases, the importance of supplying water for aquaculture and livestock is also likely to increase.

### 3.2.4. Future Needs and Constraints

Challenges related to water allocation among agricultural, municipal and industrial sectors in the FC will continue. Water for industrial development will continue as the highest economic priority. The agricultural sector will continue to depend on irrigated crops. By 2025, 17% more irrigation water will be needed to meet world food demand (International Water Management Institute [IWMI], 2000). Moreover, water for domestic use will increase with population growth. If the FC seeks to sustain economic growth and to improve social and environmental conditions, changes will need to be made (Richards, 2001).

There will be rapidly growing demand for water by 2025 in the industrial sector. The same is true for the irrigation because the agricultural sector still pressures for increased water consumption. Iraq has the highest projected water use in 2025 while Palestine has the lowest projected water use (Table 6).

Table 6. Projected Future Water Uses in the FC in 2025 (in Million Cubic Meters)

| Country | Municipality | Agriculture | Industry | Totals | Per capita ($m^3$/yr) |
|---|---|---|---|---|---|
| Iraq | 8,000 | 76,000 | 10,000 | **94,000** | **2,682** |
| Israel | 820 | 1,050 | 202 | **2,072** | **296** |
| Jordan | 700 | 900 | 160 | **1,760** | **165** |
| Lebanon | 1,100 | 2,300 | 450 | **3,850** | **366** |
| Palestine | 800 | 420 | 70 | **1,290** | **219** |
| Syria | 2,825 | 19,430 | 1,300 | **23,555** | **921** |
| **Totals** | **14,245** | **100,100** | **12,182** | **126,527** | **4,649** |

Source: United Nations (2003) and FAO (2009).

Jordan faces the most severe water problems in the FC (Salameh and Bannayan, 1993; Beaumont, 2000). Water shortages in Jordan are becoming more severe because the available water resources cannot meet the increasing water needs. The projected water demand for municipal use is 700 MCM by 2025 (Table 6). Jordan would need 113% of its present irrigation use to meet needs due to population growth (Tropp and Jägerskog, 2006).

The growing population in the FC will continue to strain available water resources. Improvements to the standard of living will further strain available water resources. Liberal immigration policies will also strain existing supplies and may increase the long-term pressue on water resources. The greatest increases in population will be in Iraq and Palestine, where the population is expected to increase by more than two-thirds from 2003 to 2025 (Table 7). The population of Jordan will grow slightly from 2003 to 2025. In Syria, the increase will be about 10%. Palestine is the most densely populated country, with 593 people per square kilometer.

Table 7. Population Growth in the FC

| | Populations | | | Population density |
|---|---|---|---|---|
| **Country** | **2003** | **2015** | **2025** | **(Inhabitant/Km$^3$)** |
| Jordan | 5,473 | 6,982 | 8,116 | 64.2 |
| Iraq | 25,175 | 34,226 | 41,707 | 65.7 |
| Palestine | 3,557 | 5,260 | 6,903 | 1,022 |
| Syria | 1,7800 | 23,018 | 26,979 | 102.8 |
| Lebanon | 3,653 | 4,207 | 4,554 | 343.9 |
| Israel | 5,723 | 6,609 | 7,568 | 323.8 |

Source: United Nations (2003) and the Central Bureau of Statistics (Israel) (2009).

Most FC countries have already fully allocated their renewable water resources and are now exploiting non-renewable reserves. Therefore, population growth has to be taken into account by policy-makers in the future. Any plan for water-allocation will require satisfying both the presented and possible demands.

### 3.3. Political Water Conflict in the FC

The history of the FC is replete with geo-political conflicts and is considered highly unstable. Water scarcity compounds the area's historic geo-political problems. With increased demand for all water uses, many experts claim water will be the source of future conflicts in the FC (Dolatyar and Gray, 2000).

Wolf (1996) showed that most past attempts--from the early 1950s to 1991--to resolve water issues in the Nile, Tigris-Euphrates and Jordan basins without considering socio-political implications failed. Political and water-scarcity issues need to be addressed simultaneously.

### 3.3.1. Political-Cultural Relations Between Arab Countries and Israel

The core of the Arab-Israeli conflict lies in Arab nations' refusal to accept Jewish self-determination (Wolf, 2000). Fundamentalist religious thoughts concerning the right of either party to control the land have played an essential role for the Jews' religious settler movement and for Palestinian groups like Hamas (Wolf, 2000). The Arab-Israeli conflict is complicated by the presumptions of both sides. The Israelis view Arab states as undemocratic with immature economies, backward cultures and extreme religious beliefs that lead to terrorism. The Arabs see the Israelis as colonial invaders and conquerors who are looking to control the entire Middle East (Wolf, 2000). Many attempts to negotiate peace agreements have failed and have been a factor in the ongoing unrest (Figure 5).

### 3.3.2. Hydro-Political Environment in the FC

Economic development, the persistence of conflict in the FC and population growth affects the conservation, development and distribution of water resources. This effect can be observed throughout the FC's hydro-political history.

**1948-1949**
The Arab-Israeli War: Arab forces captured the Gaza Strip and the West Bank.

**1956**
The Suez Crisis: Israel invades the Sinai Peninsula and the Gaza Strip, and then withdraws.

**1967**
The Six-Day War: Israel captures the Sinai Peninsula and the Gaza Strip.

**1973**
The Yom Kippur War: Israel successfully defends occupied territories.

**1979 and 1980**
1979: Camp David Accords: Egypt and Israel sign a peace agreement.
1980: Lebanon's first war.

**Mid 1990s**
Hamas Power: Hamas carries out an unprecedented number of suicide attacks inside Israel.

**Summer 2000**
Peace Negotiations: The peace process starts with negotiations at Camp David.

**December 2000**
Bridging Proposals: U.S. President Bill Clinton presented a peace agreement for Israel and Palestine.

**March 2002**
Re-Occupation: Israel re-occupied the areas earlier transferred to the Palestinian Authority.

**2003**
Road Map to Peace: Peace launched by the quartet of the U.S., UN, EU and Russia.

**Summer 2006**
Second Lebanon War: Israel starts the second war against Lebanon.

**Currently**
Peace Negotiations Stopped: Recently, no serious peace negotiations have taken place.

Figure 5. Political-Cultural Relationship Between Israel and Arabs.
Source: Adapted from Council for Peace and Security (2010).

Two FC river systems supply fresh water resources to the region: the Euphrates-Tigris and the Jordan rivers. These rivers have contributed to the socioeconomic development of the FC. The Jordan River extends from Lebanon to the Dead Sea. Its flow fluctuates widely by season. Five FC countries draw water from the Jordan River: Syria, Lebanon, Jordan, Israel and parts of the Palestinian Territories. Israel, Jordan and the Palestinian Territories, however, suffer from water deficits and are dependent on the Jordan River system (Table 8).

Turkey, Syria and Iraq depend heavily on the Euphrates-Tigris Rivers. The majority of the Tigris basin is in Iraq (54%), 12% is in Turkey; and the rest is in Syria with a small part in Iran. Even though Syria is dependent on the Tigris, it has sufficient resources for the immediate future. While Lebanon is dependent on the Jordan River, it has many internal rivers which are able to satisfy its needs. Half of Syria and two-thirds of Iraq are arid areas where rainfall is scarce (Dolatyar and Gray, 2000).

Table 8. Hydrological Profile of Jordan, Euphrates and Tigris Rivers

| **River** | **Length (Km)** | **Total discharge(bcm)/yr** | **Drainage area/Km$^2$** |
|---|---|---|---|
| Jordan | 360 | 1.5 | 16,000 |
| Euphrates | 2700 | 33 | 444,000 |
| Tigris | 1900 | 47 | 472,000 |

Source: Adapted from Dolatyar and Gray (2000).

### 3.3.3. Examples of Treaties/Water Agreements in the FC

Water conflicts arise from the natural, uneven distribution of water resources which have led to a long history of conflict in the FC (Table 9). The FC water allocation literature is focused on laws or political agreements among the FC countries (Green and Hamilton, 2000; Eckisten, 2003).

Water agreements can ensure that stakeholders have access to certain shares of water or have tradable water permits in a water-market system. For example, in the Tigris and Euphrates River basin, Turkey has rejected an agreement about distribution or allocation of water.

Table 9. Water Conflict Chronology

| Date | Parties involved | Basis of conflict | Description |
|---|---|---|---|
| 1948 | Arabs and Israelis | Military | Arab-Israel war forces Arab to cut off west Jerusalem's water supply |
| 1951 | Israel, Jordan and Syria | Political tool, and military and development disputes | Jordan announces plan to irrigate the Jordan Valley from the Yarmouk River. Then, Israel starts drainage from the Huleh swamps which are located between Israel and Syria. |
| 1953 | Israel, Jordan and Syria | Development disputes, military target and political tool | Israel sets up the National Water Carrier to transfer water from the Sea of Galilee to the Negev Desert for irrigation. Syria disapproves Israel's action and asks Israel to move away from the Sea of Galilee border. |
| 1956-1966 | Israel and Syria | Military and political tool. Control of water resources and development disputes | Arab plan begins to divert Jordan River and to preempt Israel National Water Carrier. |
| 1967 | Israel and Syria | Military target | Israel destroys Arab diversion work on the Jordan River. Israel occupies Golan and Banias Tributary to Jordan and West Bank. |
| 1969 | Israel and Jordan | Military target | Israel says that Jordan is over-diverting the Yarmouk River which leads to destruction of the East Ghor Canal, but secret negotiations mediated by the U.S. lead to an agreement in 1970. |
| 1974 | Iraq and Syria | Military target, political tool and development disputes | Iraq warns about bombing the Al-Thawra Dam in Syria because it claims that the dam reduced the flow of Euphrates River water to Iraq. |
| 1975 | Iraq and Syria | Military, political tool and development disputes | Iraq asks the Arab League to intervene because it alleges that the flow of the Euphrates River reaches an unbearable level. At the same time, Syria claims that it is receiving less than half of the river's normal flow. Saudi Arabia mediates the conflict. |

Table 9. (Continued)

| | | | |
|---|---|---|---|
| 1980-1988 | Iraq and Iran | Military | Iran switches water to flood Iraqi defense positions. |
| 1982 | Israel, Lebanon and Syria | Military | Israel disconnects the water supply of Lebanon during the siege. |
| 1990 | Iraq, Syria and Turkey | Development dispute, military and political tool | The flow of the Euphrates River is stopped for a month until Turkey finishes construction of the Ataturk Dam. |
| 1991 | Iraq, Kuwait and the U.S. | Military target | Iraq destroys most of Kuwait's desalination capacity during the Gulf War. |
| 1991 | Iraq, Turkey and UN | Military | Iraq's modern water supply system and sanitation system are targeted by the Allied coalition. |
| 1992-current | FC countries | Water resources and political tool | Building dams and importing water resources from other countries. |

Source: Adapted from Gleick (1998) and Wolf (1998).

Whereas Iraq and Syria agreed that Syria would keep 42% of all water (from the Tigris and Euphrates) and Iraq would keep the rest (58%) (Jobson, 2003). In this case, because the river passes through international borders, determining and recognizing the accessibility of riparian rivers will help satisfy the politics of water distribution. On the other hand, in many cases, there are no formal agreements to manage water distribution. In addition, there are conflicts within national borders.

A range of potential water conflicts has led to development of several mechanisms to help resolve disputes. For example, an economic policy approach can be applied to water conflicts in the Jordan River basin. Water management for the Jordan River riparian area could be enhanced after developing a joint system which has "a greater reliance on free-mechanisms in order to moderate water demand" (Rouyer, 2000, p. 6).

a. Treaty of Peace Among Israel, Jordan and Palestine

The Treaty of Peace between Israel and Jordan was signed in Jordan in 1994 (Brooks and Trottier, 2010). It is one of the exceptional patterns of cooperation between Israelis and Arabs; this cooperation has been studied by many policy-makers and politicians. It consists of the following arrangements: 20 million $m^3$ of Yarmouk water will be stored by Israel in the winter and released to Jordan in the summer; 10 million $m^3$ will be released from Tiberias Lake for Jordan in the winter until a desalination plant is built; storage facilities will be constructed on the Yarmouk and Jordan Rivers; and 50 million $m^3$ of drinking water must be allocated to Jordan through cooperation between both parties. In addition, both countries have agreed to cooperate to alleviate water shortages by introducing and developing new and existing water resources, further preventing contamination of water resources and minimizing water waste.

In the past (1955), all countries along the Jordan River--Jordan, Israel, the Palestinian Territories, Syria and Lebanon--agreed to their rights to share the water in a plan drawn up with the assistance of an American diplomat (Manna, 2006). Many policy-makers (e.g., Haddadin, a former water minister for Jordan) later clarified the weakness of the agreement: the technical resolution did not become a political agreement because it would involve implicit Arab identification of Israel.

The most important effect of the treaty is the normalization of relations between the Palestinian Territories and Israel to solve their territorial conflicts. Signing this treaty is linked with efforts to create peace and stability between Israel and Palestine. The main positive outcome of the treaty is known to be the 1995 Israeli-Palestinian Interim Agreement, also known as "Oslo II," that specified basis for cooperation and an additional negotiation on water. Thus far, water management for the parties has not fulfilled objectives stated in the treaty (Manna, 2006).

b. Peace Water Pipeline

The "Peace Water Pipeline" project was proposed in 1986 to bring water from the Seyhan and Ceyhan Rivers through two pipelines to supply water for Syria, Jordan and the Arab gulf states (Rende, 2007). The pipelines can transmit 10 million $m^3$ of water daily, an amount sufficient to meet the needs of 15 million people. The "Peace Water Pipeline" development plan included Turkey, Syria and Iraq; it required more than 150% of the normal total flow of the Tigris and Euphrates to meet the population growth in those countries. This plan was difficult to implement due to the relationship between Turkey and Arab nations. However, the proposal made a good-faith effort for Turkey to help Syria, Iraq and other Arab neighbors, as well as Israel, to manage the shortfall in water availability. The proposal also addressed the growing domestic demands of the population along with the expanding requirements for agricultural and industrial production (Rende, 2007).

c. Protocol for Controlling the Waters of the Tigris and Euphrates

Turkey and Iraq signed the Protocol for Control of the Waters of the Tigris and Euphrates and their tributaries in 1946 (Swain, 2000). The agreement was to build flood-control dams and storage facilities upstream in Turkish territory. Turkey and Iraq agreed to exchange hydrological and meteorological data during flood periods. The normal flow of the Tigris and Euphrates Rivers was sufficient to manage the needs of the populations of Turkey, Syria and Iraq until 1996.

In the mid-1960s, Turkey, Syria and Iraq started large-scale projects to construct major dams to produce hydroelectric power and increase the areas of irrigated agriculture. In 1965, Turkey proposed the formation of a Joint Technical Committee (JTC) to analyze the Tigris-Euphrates basin (Kalpakian, 2004). In the beginning, Syria approved this idea, but Iraq wanted the flow of the Euphrates to be considered separately from the Tigris. Turkey disagreed and said that the Iraqi position was not reasonable because there were already plans to develop canals to link the two rivers in Iraq. Moreover, the Tigris and Euphrates naturally flow together into the Shatt-al-Arab, or into what others call it, the Coast/Beach of the Arabs, in southern Iraq before emptying into the Persian/Arabian Gulf. In 1980, Syria adopted the Iraqi position; the JTC met several times, but it was not authorized to make major political decisions (Kalpakian, 2004).

d. Nile River Option

The Nile River is a source of water for Palestine (Gaza Strip) and also for Israel. Israel proposed an arrangement to provide technical expertise about drip irrigation and other water-saving technologies for agriculture in the Nile Delta. That proposal was a contribution to Arab-Israel peace (Hassan and Al Rasheedy, 2007). This plan helped to meet the needs of the water-stressed Palestinians in the Gaza Strip and also led to resettlement in the Sinai Coast (Bilen, 2000).

e. Turkish-Israeli Water Agreement

The Turkish-Israeli water agreement of 2004 brought a new dimension of cooperation between the two countries. Additionally, the agreement enhanced stability and peace in the Middle East (Ajans, 2004). The agreement forces Turkey to sell Israel 50 MCM of drinking water annually for 20 years, with a possibility to extend the contract for an additional 5 years. The agreement specifies that a Turkish-Israeli panel will select the method of shipping and award the shipping contract. The estimated cost of water is between 70 and 80 cents per cubic meter (Sheva, 2004). Transporting water might be more expensive than adopting desalination, which means that the best long-term solution may be to build large-scale desalination plants (Gruen, 2004). Many policy-makers have pointed out that Israel can buy water from Turkey which will strengthen the two countries' relations (JINSA, 2004).

In summary, there are many water-management treaties in the FC region. Most of those treaty efforts are toward joint management of water in the FC (Table 10). An agreement about water conflicts among the riparian states in the FC has never been achieved. With the actual boundary alterations in the FC and with the constantly changing political and demographic conditions, water allocation quotas and schemes have to adapt and develop. Initiating some water treaties in the area helped to solve the disproportional distribution of water and decreased the conflict. Today, the hope is to stop the use of force and military power to gain control of water resources. It is time for this community to take action, reversing uneven water distribution and ensuring a fair water distribution in the future. A water war will eventually start if there is an unclear and inequitable settlement of the water crisis.

### 3.3.4. Impact of Culture and Religion on Water Use in the FC

The water shortage is one of the most serious problems facing the FC. Many policy-makers consider it an intractable problem with multidimensional conflicts between Israel and the other FC countries. The major source of disputes in peace negotiations between Israel and the Arab countries is water (Eckisten, 2003).

Table 10. Summary of Peace Water Treaties in the FC

| Treaty | Year | Progress | Problems |
|---|---|---|---|
| Treaty of Peace Among Israel, Jordan and Palestine | 1994 | Jordan received 40 MCM from Israel; Israel got 45 MCM from Jordan. Now, there is nothing to exchange (Israel stopped the negotiations.) | Political problem (meaning of peace treaty: gives Israel an identification) |
| Peace Water Pipelines | 1986 | Transfer fresh water from the Seyhan, Ceyhan and Euphrates basins by a series of dams and diversion tunnels to supply Arab countries. | The project was not simple to implement due to the political relationship between Turkey and Arab nations. |
| Protocol for Controlling the Waters of the Tigris and Euphrates | 1946 | Building dams to control the flood and storage facilities on the upstream portion of the Turkish territory. | Political disputes |
| Nile River Option | 1929 | The plan helped to meet the needs of the water-stressed Palestinians and used drip irrigation technology in agriculture. | Political conflicts |
| Turkish-Israeli Water Agreement | 2004 | Turkey sold Israel 50 MCM of drinking water annually for 20 years. Now, there is nothing to exchange (Turkey stopped the negotiations.) | Political conflicts |

There are many contributing factors that make water such a politically charged issue. In practicality resolving water issues in the FC is particularly challenging:

1. Transboundary nature: Every main river in the FC crosses one or more international borders, and 50% of the population in the FC depends on water flowing from neighboring countries (Kolars, 1986). Political borders between countries have a major effect on individual policies about water and may lead to impractical and unpredictable water management systems, which then cause a serious threat to security.

neighboring countries (Kolars, 1986). Political borders between countries have a major effect on individual policies about water and may lead to impractical and unpredictable water management systems, which then cause a serious threat to security.

2. Geography and climate: The management of FC rivers is difficult because of their unpredictable characteristics. Most FC rivers and their flood plains have been the last priority to be developed, and in general, they are used for hydroelectric generation and agricultural matters. This geographical setting adds tension between upstream and downstream countries.

3. Population and economy: An increasing population, as well as the inefficient use of water, exacerbates the existing water problem. More economic development, rising pressure from population growth, urbanization and industrialization will affect the quality and quantity of available water.

4. Political uncertainty: The FC is a politically unstable area of the world. The region was affected by the two world wars. None of these disputes was directly about using water. On the other hand, these disputes made it hard for governments to cooperate with their water resources. Until recently, there was no national or international institution able to bring the FC countries together for economic and political issues. There is only one organization (the Arab League), and it does not include Ethiopia, Turkey and Israel. Even within this association, it is difficult to predict the future of the FC given the fast, dramatic changes over the past three decades.

5. Uncertain databases: Despite the large body of work from the United Nations and World Bank to supply more data about water resources in the FC, one of the obstacles to create a policy is a lack of reliable and agreed-upon information about the

overall supply and demand of water resources. The essential statistics of the FC rivers and aquifers are frequently deficient and unreliable. There are many reasons for the uncertainty. First, figures for the same waterway may show a discrepancy because different "runs" of the year have been used to establish an average. Second, data may be shown in different ways for a variety of political reasons. The complexity of obtaining accurate, agreed-upon data hinders scientific work on rivers and aquifers in the FC (Lowi, 1996).

Overall, increasing the number of water users (agricultural, industrial and domestic) will enhance the competition for available water. Obviously, these factors might have an impact on transboundary water management. Most hydro-political studies neglect the psychological characteristics of water use. In other words, water is not only necessary for irrigation and economic development, but it is also required for life; water has deep ideological, religious and nationalistic meanings.

## 3.4. Impact of Rural-Urban Migration on Water Use in the FC

Rural-urban migration is the process of rebalancing economic resources in order to create a new stage of economic development. Rural-urban migration, mostly caused by labor shortages in urban areas and the high population growth, means that the number of people living in cities will continue to grow rapidly (Zohry, 2002). In the FC, adding more people to urban areas will create enormous social, political and physical challenges. Those challenges will apply not only to cities, but also to rural areas. Rapid urbanization and population growth in the FC will increase the pressure on national water authorities and water planners to satisfy growing urban water and sanitation requirements. The biggest challenge imposed on natural resources by this fast urbanization is the allocation of limited water supplies (Meinzen-Dick and Appasamy, 2001).

Water demand in urban areas comes from (i) the concentration of people in cities, which means their need for water resources to survive will increase, and (ii) urban economic activity such as using water in industrial production. Meeting the growing water requirement in urban areas is a technical and financial challenge. As water becomes scarce in the FC countries, meeting the demands of urban areas for municipal, industrial and other uses will require shifting regional water resources from rural to urban users. In other words, the demand will generate rural-urban and sectoral competition for limited water resources.

Water use is not only a matter of quantity, but also quality. Water usage in agriculture involves drainage back to rivers and aquifers, and that water could be returned as wastewater in urban areas. The industrial effluents discharged in urban areas may pollute surface or groundwater, affecting water quality. Discharging of wastewater can impose a negative externality (a social cost) on the next user; wastewater has to be treated to minimize pollution and maximize its utility. The intersectoral linkages (quality and quantity) have potential conflicts that may emerge and have to be managed by appropriate institutions.

Overall, supplying water in an efficient, equitable and sustainable way to both urban and rural areas in the FC poses institutional and technical challenges. To meet urban water needs, water authorities have to expand their vision to extend services while protecting the quality of surface and groundwater. Decision-makers and administrators in the FC must develop official negotiation processes to transfer water from agricultural use to urban use with minimal, negative impact on rural livelihoods.

### 3.5. Sustainable Water Development

There are some issues about water management that need further discussion. These problems are related to fluctuations of supply, water pricing, water quality and user participation.

#### 3.5.1. Fluctuations in water supply

The main water resource in the FC is surface water which depends on base flow and flood flow. Because of the inconsistent distribution of rainfall from one year to another, the potential water supply in the FC is uncertain, and the range of fluctuations from one year to another is high. During the Gulf Crisis (1990), an emergency plan was implemented to supply water for domestic uses.

#### 3.5.2. Water pricing

Tariffs for water vary according to water use. Before any increase in water pricing, an evaluation of ability and willingness to pay has to be taken into account. Many studies mentioned recovering operation and maintenance costs for irrigation water in the FC as well as the revenues from irrigation water (Abu-Sharar and Battikhi, 2002). These recovery costs and pricing could guarantee the stability and competitiveness of agricultural production through handling the water in an efficient way.

#### 3.5.3. Water quality

One of the most important environmental problems in the FC is related to water pollution. This problem is caused by water-resource contamination with inadequately treated wastewater and other environmentally hostile practices (Shatanawi and Al-Jayousi, 1995).

### 3.5.4. User participation

Involvement and shared responsibility by both governments and users for operating an irrigation system would be an efficient and sustainable way to develop an irrigation management system in the FC. This system requires a revision of relationships and user involvement in decision-making. The decision-makers in the FC have to open the door for the private sector to participate in the operation and management of irrigation activities (Abu-Sharar and Battikhi, 2002).

### 3.5.5. Formulate water policy in the FC

Many recommended solutions for water problems have been identified, including measures to increase the supply from conventional sources, measures to increase the supply from non-conventional sources, and measures to promote greater efficiency and conservation. The water situation in the FC is an important concern for policy-makers and water experts as populations and economies grow. Effectively managing the available water resources in the FC needs collaboration from institutions and conventions governing individual behavior as well as solving political disputes for transboundary water. The public sector (government) in the FC countries plays a leading role in managing large investment programs to alleviate water poverty.

## 3.6. Summary

The chapter addressed water use among different sectors. The situation in the region naturally calls for increased water-use efficiency and improved accountability to help create a bridge between the quantity of water demanded and the quantity of water supplied. However, water scarcity should not be considered in isolation from other important drivers: population growth, urbanization, economic growth, policy implications, cultural/regional issues, and industrialization, and agriculture and agro-trade.

# CHAPTER 4. WATER REALLOCATION

This chapter discusses water reallocation in the FC and introduces principles of efficiency and a conceptual model. The scarcity of water makes efficient allocation increasingly important (Dinar et al., 1997). The chapter also summarizes describes FC countries' experience with water reallocation and indentifies real-world decision making and policy tools and constraints that may limit their use. The last section describes a potential reallocation path in the FC countries to alleviate water-scarcity. The potential reallocation assumes a 20% shift of water away from agriculture to other sectors (municipal and industry) and discusses their impact on national economies and returns to water use in each sector.

## 4.1. Allocation Efficiencies

Efficiency is maximizing the value of output from a given amount of input(s) or, alternately, achieving a desired level of output using the minimum amount of input(s). Economic efficiency is the study of how to maximize the use of natural resources, business inputs, or producing goods or services for the greatest output. Economic efficiency is achieved when there is no way to rearrange the production or allocation of goods in a way that makes one person better off without making anybody else's situation worse (Dinar et al., 1997). To achieve efficient allocation of water resources among sectors the marginal benefit from the use of the water resources must be equal across uses. In other words, the benefit from using one additional unit of water resources for one use must be the same as for any other use (Dinar et al., 1997). Efficient allocation of water is achieved when the marginal price for each user is equal across all uses.

Allocation of water resources should also be equitable; that is fairly allocated among competing uses. For instance, in the municipal sector, an equitable allocation of water resources means that all households, regardless of ability to pay have access to basic water services (a fundamental right). To meet that objective, government may have to provide subsidies or adopt a price structure that is compatible with households' income (Dinar et al., 1997). Equity is a necessary consideration in water management and reallocation, but is beyond the scope of this study and accordingly not addressed within the context of this study.

#### 4.1.1. Multiple Models Exist to Define and Find Efficiency

Many models have been developed to address the optimal allocation of water in the FC. The optimal efficiency models in the FC are based on efficient allocation in terms of available water resources and developed marginal benefits of water use. This sub-section will address many economic tools, optimization models and efficient allocation instruments that can enhance achieving the economic efficiency in water resources.

An economic model was used to evaluate the trade-offs of allocating Nile River water among competing regions and projects in Egypt (Wichelns, 2002). The purpose of the model was to maximize net social benefits considering scarcity and public policies. The net social benefits of Nile River water will be maximized when the scarcity value (the incremental net value) of water is the same for all uses. The study attempted to encourage farmers to consider scarcity values and opportunity costs when choosing crops and irrigation strategies. Currently, farmers do not consider either the opportunity cost or the scarcity value of water when estimating net profit because of the absence of appropriate water-pricing or allocation polices. Farmers are behaving rationally, the market is flawed.

The Seasonal Agricultural Water Allocation System [SAWAS] model by Salman et al. (2001) used net water requirements of activities in the northern, middle and southern districts of the Jordan Valley, as well as water supply quantities and prices for 10 years, to develop a tool for decision-makers and planners to help determine efficient use of water. Cropping patterns were studied to identify which crops use water most efficiently and how to allocate scare water resources among alternative agricultural activities. The model also generated estimates of the allocation effects of different water prices. The results indicated that estimated demand elasticities for water obtained from SAWAS were close to the actual responses farmers had to water price changes (Salman et al., 2001).

An optimized, spatial-temporal allocation model was used to suggest allocation of water resources in six southern districts in the Hebei province of China (Jinfeng et al., 2004). The paper presented a balanced marginal revenue theory for spatial allocation of water resources. The experimental model provided an optimal water allocation scheme that could lead to the maximum economic benefit for the province that is when marginal revenue of water in all districts was equal. When marginal revenue of water for all sub-areas and the available water resources were known, economic benefits are maximized (Jinfeng et al., 2004).

An Effective Efficiency (EE) model analyzed the different meanings of "water saving" by taking into consideration Classical Efficiency (CE) indictors (Haie and Keller, 2008). They recognized project-level and basin-level efficiencies. Two EE models were developed, one based on water quantity and the other on quantity and quality, considering water reuse. Data were collected from four irrigation case studies, a city in the United States and the country of Egypt. The results showed failure of the CE model to evaluate irrigation efficiency, while the EE models presented a more complete picture of irrigation efficiency conditions and applications. The EE model was useful for water resource allocation, planning and management.

Three propositions to estimate water pricing were suggested by Jordan (1999). The first, marginal scarcity rent, takes into account both the cost of resource extraction and user cost. The second proposition was to capture the external costs and benefits of the resource. The study defined externalities as costs or benefits of water services, external to the supplier or user, that are not included in the cost of service. The third proposition was to include the full cost of water transfers in water pricing. Using such a full-cost approach for water markets may achieve water efficient allocation.

Rising water prices were shown to affect water allocation and land use in Jordan using linear programming models (Doppler et al., 2002). The first model maximized the total gross margin of production in the irrigated areas of the Jordan Valley by evaluating production activities under average conditions. The second model modified the achieved optimal solution by considering risk by incorporating the potential variation in gross margins due to changing market prices for products. Both models used data on water requirements per unit area of land for different crops, total land and water availability and market capacities for the different crops. Water and land constraints, as well as constraints to prevent the exaggerated expansion of fruit trees, were formulated in the models. The study concluded that optimizing cropping patterns (optimizing the crop selection within a piece of land) and re-allocating irrigation water had substantial potential to increase financial returns. Moreover, a small change in irrigation water price had large impacts on quantity demanded and gross margins, in other words water demand was price elastic.

The justification for and impact of water pricing policies in the Jordan Valley was analyzed by Molle et al. (2008). Policies to recover operation and maintenance (O&M) costs in order to save water and raise economic efficiency were modeled. Producers with five different types of farming systems were surveyed to analyze responses to increased water prices. Results showed that recovering O&M costs increased water prices which increase the potential for allocating water more efficiently. The current system of quotas, as well as the lack of water storage and technical difficulties such as poorly designed irrigation equipment contributed to wasting water. A substantial increase in water prices can be expected to promote overall economic efficiency by motivating farmers to cultivate higher-value crops.

Hambright et al. (2000) studied the effect of efficient use of limited water and economic development in arid regions. A system of water-quality indices and standards designed for conservation and sustainable management of Lake Kinneret (Sea of Gallia, Israel) was based on observed variability in various chemical and biological parameters during a 25-year period (1969-1992) (Hambright et al., 2000). Effective water management required concurrent optimization of water supply and resource quality. Conflicts arose due to different objectives for obtaining better quality and the different management programs in use. The system could be used as a tool for optimal management.

Generally, there is no shortage of attempts, including sophisticated modeling, to obtain water use efficiencies. The common conclusion is that some reallocation of water within agricultural uses, or among sectors, will lead to greater overall output and economic efficiency.

### 4.2. Water Allocation Mechanisms

Water allocation can be more complicated than allocation of other economic goods because water has exceptional characteristics. For example, water has few substitutes, supplies range from excess to scarce, water is a common property resource, and water is bulky and not inexpensively stored or transported. These characteristics make water allocation somewhat problematic, although many allocation tools have been developed (Tsur and Dinar, 1997; Boggess et al., 1993; Kaiser and McFarland, 1997; and Brill et al., 1997).

Marginal cost pricing (MCP), water allocation via government policy, water markets and user-based allocation are examples of water-allocation mechanisms. However, no one allocation tool is appropriate for all applications or situations.

#### 4.2.1. Marginal Cost Pricing (MCP)

MCP equates the price of water with the cost for supplying the last (i.e., marginal) unit of water. Economic efficiency, that is optimal allocation of water resources, will be achieved when the marginal value of water is equal to its marginal cost. However, water also has scarcity value that might not always be reflected in the cost that consumers pay or in MCP (Tietenberg, 1988; Spulber and Sabbaghi, 1994). MCP also has to incorporate the fact that there are different prices for different quantities (e.g., block-rate pricing) or qualities of water. For example, higher-quality water has a higher marginal cost of provision (Spulber and Sabbaghi, 1994). The use of water pricing as an appropriate allocation tool continues to be widely debated among economists (Dinar, 2000).

#### 4.2.2. Public Allocation

Because of public good characteristics of water, allocation by government policy is appropriate in water resource management, especially in large-scale systems. Public allocation of water resources can support food security and public health and can enable strong oversight mechanisms such as regulations to decrease water pollution. Public allocation however relies on the political power of different stakeholders.

Governments can fail in efficiently allocating water and managing water resources. Public allocation can fail because: multiple agencies control many agendas which lead to poor performance of government-operated irrigation systems, leaking municipal water supply systems controlled by public utilities, licensing irregularities and a lack of regulations to control industrial water use.

### 4.2.3. Market Allocation

Allocation using free market forces encourages users to find the highest-value applications for scarce water resources. Market allocations require well-defined, quantifiable and transferable property rights. Government plays an important role by monitoring, regulating and providing legal support to a functioning market. Market allocation however may not lead to water use equity because some users may be unable to compete in the market. Third-party (externality) and market failures can also limit the effectiveness of market allocation. For example, transfer of water from agriculture to urban use may reduce return river flows, which may affect a third party (i.e. transfer of water from agriculture to urban use can affect farmers or producers). Water allocation using market based mechanisms may require some form of institutional support to manage externality.

### 4.3.4. User-Based Allocation

User-based allocations are used more frequently in small-scale systems, and are more flexible than bureaucracy-laden public allocation. Farmer-managed irrigation systems are good examples of user-based water allocation. Because those directly involved in water use--either for agriculture, households, or industry--have more information on local conditions than the government, they do not have to rely on strict formulas for allocation (Sadeque and Turnquist, 1995). User-based water allocations may require institutional (government) support to make socially optimal decisions about water (Yoder, 1981).

#### 4.3.5. Summary of Water Allocation Mechanisms

Various water-allocation methods each have advantages and disadvantages (Table 11). Market-based approaches substantially improve efficient water allocation and preserve water for higher-valued uses and provide incentives for the most efficient use of water without overexploiting the available water resources. In order for markets to work effectively, water rights should be well defined, quantifiable and transferable. The market mechanisms also have disadvantages (Dinar et al., 1997). Some stakeholders may be incapable of effectively competing in the market due to limited purchasing power. Water markets can have a profound effect on water-use patterns and conservation behavior (Green and Hamilton, 2000). It is important to consider both social and political considerations when choosing a water allocation system. Allocation systems should consider both efficiency and equity.

Public allocation has an essential role in the development and management of water resources, particularly in large-scale systems, and can support food security and public health. Negative externalities associated with improper water use (e.g., downstream

Table 11. Water Allocation Mechanisms (Advantages and Disadvantages)

| Water allocation mechanisms | Main idea | Advantages | Disadvantages | References |
|---|---|---|---|---|
| Marginal Cost Pricing (MCP) | Equalizing the price of water with the marginal cost for supplying the last unit of that water. | 1- MCP is efficient.<br>2- MCP can avoid the tendency to under-price.<br>3- Pollution charges or a tax system may also be connected with MCP (Dinar et al., 1997). | 1- There are complications in defining the MCP itself (Saunders et al., 1977).<br>2- MCP neglects equity issues.<br>3- Policy-makers may not understand the MCP (United Nations, 1980). | Tietenberg (1988), Spulber and Sabbaghi (1994), Dinar et al. (1997), Saunders et al. (1977) and United Nations (1980) |
| Public Water Allocation | Government distributes water among different parts of the system. | 1- Public allocation ensures distribution of water among different sectors which can protect the poor people and provide equity.<br>2- May give account for externalities. | 1- Public allocation mechanisms may misallocate water.<br>2- Inadequate performance of government as a public allocator can lead to damage in some sectors.<br>3- The users lose the incentive to use the water resources efficiently | Koehler (1995), Republic of South Africa (1996) and Meinzen-Dick and Mendoza (1996) |
| Water Markets | Depends on competitive market, treating water as a market good. | 1- Profitability for the seller will increase.<br>2- The benefits for the buyer come from the promotion to increase water availability.<br>3- Improved water management and efficiency<br>4- Motivate water users to considerate the external costs. | 1- Hard to measure water/meter because water flow is variable.<br>2- Externality has an effect on the water markets system.<br>3- Some environmental degradation could happen. | Holden and Thobani (1995) and Rosegrant and Binswanger (1994) |
| User-Based Allocation | Agricultural managers are one example for user-based allocation. | 1- Flexibility to deliver water to the users.<br>2- Achieve equity.<br>3- Political acceptable and sustainability. | 1- Transparency of the decisions is not always feasible.<br>2- The user-based allocation does not include all other sectors.<br>3- Inefficient. | Watson (1994), Yoder (1981),and Rosegrant and Gazmuri Schleyer (1994) |

pollution) call for a strong regulatory presence for public allocation. However, at the end, public allocation is based on the relative political influence of various stakeholders.

User-based allocation is more flexible than public allocation, however high transactions costs for larger systems means that this type of allocation is more often appropriate for small-scale systems. User-based systems are most effective where there is strong demand for water and a history of cooperation.

### 4.3. Water Allocation Models

Many models were designed to maximize water allocation in different regions. Water allocation models and mechanisms and water policy tools have been developed to achieve water use efficiency and sustainability in the FC.

In the eastern Mediterranean area, reallocating freshwater resources through a water-rights market combined with increased efficiency gains was studied by Becker et al. (1996). The authors analyzed the efficiency of water allocation using two market-allocation mechanisms:

1. Percentage claims market: Countries bid to share uncertain water quantities.
2. Priority claims market: Water was auctioned; however bidders with high priority for water obtain preferred status.

Claims markets facilitate the reallocation of the water supply through transferable claims. The conceptual framework is to maximize the aggregate annual economic benefits for both water sellers and water buyers (Becker et al., 1996). Percentage claims markets were preferred because the total regional benefit was higher than for a market for priority claims (Becker et al., 1996).

Russell et al. (2007) examined Economic Instruments (EI) and found that EI could provide incentives for the adoptions of alternate irrigation technologies. The authors suggested that taxes, prices and subsidies could provide incentives for more efficient use of water. Russell et al. (2007) illustrated that efficiency, the incentive to use technology and increased government revenue would be the outcomes related to applying EI to management of both water quality and quantity. The results concluded that EI provided incentives for resource-saving technology.

The safe yield concept which is defined as "water that can be abstracted permanently without producing undesirable results" was introduced by Meinzer (1923, p. 719). The concept includes all of the economic considerations of groundwater development, water quality preservation, environmental impacts and legal issues. Dottridge and Abu Jaber (1999) used this concept in a study that examined the overexploitation of an aquifer in Jordan. The aquifer was overexploited in Jordan because withdrawal exceeded recharge and, therefore, was not sustainable (Dottridge and Abu Jaber, 1999).

Dudu and Chumi (2008) examined partial equilibrium and general equilibrium models relevant to irrigation water-management issues. Most models focused on water markets and water pricing. General equilibrium models incorporate both the irrigation sector and the other sectors in the economy, and allow the sectors to interact with each other. The researchers concluded that, although there has been a substantial improvement in tools used to analyze water-related problems, analytical and empirical research in the field is still deficient and that more study is needed.

The concept of using added value (net revenue) to irrigation water-use options was applied in the Jordan Valley region (Al-Weshah, 2000). The objective was to minimize water importation and to manage irrigation water use under geographic, socioeconomic and demographic constraints. The author built an objective function maximizing net revenue from agricultural production subject to limitations on water and other production and marketing factors. Results showed net water savings of about 9% when the objective function was to minimize water use under the same level of profitability.

Tarawneh et al. (2008) summarized water use for four sectors (municipal, tourism, industrial and agricultural) in Jordan. Municipal water consumption was defined as water used in the household and commercial sectors and some light industries (e.g., textiles, food processing and construction materials). Industrial water consumption was defined as the amount of water used by heavy industry, mainly from deep wells. The authors suggested reallocation of water among competing sectors could decrease water shortages, particularly in the dry seasons. Water reallocation should be based on economic, social and environmental considerations, with first priority given to sectors and water use with high economic and social returns.

There is a huge gap between the projected demand and supply for water resources in Israel and the Palestinian Territories (Yaron, 1999). Yaron (1999) suggested that gap could be mitigated only by reallocating water among users (Yaron, 1999). He suggested that using new technology for water irrigation can lead to a reduction in water demand. For example, modern pressurized-irrigation technology can save about 30 to 50% of water used for irrigation. At the same time, Yaron (1999) recommended a link between a modernized irrigation system and a new mix of crops (crop patterns) to maximize returns. Raising water prices could also increase water saving by providing incentives for conservation. Yaron (1999) suggested a mixed-quota allocation policy, which included (i) a quota allocation system modified according to condition over time, (ii) block prices and (iii) substantially higher price levels for water used above the quota level.

Optimal allocation of water resources in the FC can be enhanced by using mathematical models that maximize profit or minimize cost). Most models use linear programming to reach optimality by maximizing the objective function or by minimizing the cost function. Constraints for optimization were water accessibility and sustainability over time. Reallocation of water resources within a sector (e.g., agriculture) requires using agro-economic models to optimize the marginal benefit and determine the cropping patterns subject to land, water and labor constraints. Optimization analysis is useful for agricultural planners and farmers (Loucks et al., 1981; Haouari and Azaiez, 2001; Mimi, 2001; Hillier and Liebermam, 2005). For example, in the Palestinian Territories, changing the cropping patterns can reduce agricultural water use by up to 4%. Nazer et al. (2010) concluded that water reductions in irrigation system can be reached while also increasing aggregate profit by as much as 38%.

A model developed for the Mekong River basin integrated hydrologic and economic models. The objective function of the model was to optimize water allocation within some constraints (Ringler, 2001). The model takes into account hydrologic, agronomic, economic, political and institutional components. The model considered economic-benefit functions; and provided a solution for the optimal allocation of water resources at the basin level. The model was constrained by physical limitations, system-control and political issues related to water supply and demand in the region. The optimal allocation of water among water-using sectors was established according to the economic value of water.

In summary, economically efficient water allocation requires that prices reflect the true costs of water provision and water's scarcity value. Setting the right price is necessary to achieve optimal water use not only within, but also among sectors. Furthermore, reallocation of water within agriculture and to other sectors may lead to not only better water management in the agricultural sector, but in other sectors as well.

### 4.4. Experience of the FC in Water Reallocation

Current water allocation in the FC has resulted in wide variation in the marginal benefits of water across use sectors (Abu-Sharar and Battikhi, 2002). Returns from irrigation in the agricultural sector vary (Bakker, 1999). Industrial and municipal sector returns also vary (Beaumont, 2000). Each cubic meter of water used in the industrial and service sectors produces at least 200 times more wealth than water used in the agricultural sector (Beaumont, 2000). Water reallocation in the FC could bring about an increase in the total water benefits and an increase in overall social well-being.

Currently the agriculture sector consumes a majority of water resources in the FC. About 80% of the total water in the FC is used for irrigation, although water for agriculture varies from country to country. About 20% of total water resources are used in the industrial and domestic sectors, 10% for each. Water reallocation strategies such as changing cropping patterns and moving away from crops where the product value per unit of water is relatively low could improve the economic gains. Water reallocation could have a substantial impact on the municipal and industrial sectors, and might lead to an increase in GDP for the region and create jobs in the industrial sector. A small water reallocation (5%) from agriculture could dramatically increase water available to other sectors, particularly in the municipal sector. If the FC seeks to achieve sustained economic growth and improved social and environmental conditions, changes in how water resources are allocated and managed are required (Richards, 2001).

#### 4.4.1. Jordan's Experience Allocating Water Resources

Household demand for water in the FC is increasing. The demands of industry will grow as the FC countries industrialize. The marginal value of water is at least ten times higher for municipal uses than for agricultural uses (Bhattia et al., 1995). A 5% reduction in water use for agriculture in Jordan could increase the municipal sector's share of water by almost 15% (Berkoff, 1994). Reallocating water to domestic consumption will benefit domestic consumers and increase per capita availability by 150 cubic meters. The net present value of the net benefit for domestic water use by the end of year 20 would amount to US$69 per cubic meter of water at a discount rate of 15% (Dudu and Chumi, 2008).

Such a reallocating of water in Jordan would cause revenues in the agricultural sector to drop in the first year because farmers will be coping with a reduction in water supply and investing in new technologies (Dudu and Chumi, 2008). In year 2, their revenues will rise at an accelerated rate until peaking in year 10. Under these conditions, water used for agricultural production will still be profitable, and the net present value will be about US$2.6 per cubic meter of water by year 20.

Reallocating water from the agricultural sector to the industrial sector would also be beneficial. The net present value at the end of year 20 would be US$53 per cubic meter of water at a discount rate of 15%. Negative returns for the industry would only be recorded in year 1, as a result of required investment to find alternate water supply (Dudu and Chumi, 2008).

4.4.2. Israel's Experience

The rent-seeking activity of Israeli farmers has a political impact for water resources (Margoninsky, 2006). About 56% of Israel's water is supplied to farmers. Therefore, water resources open the door to rent-seeking activity aimed at farmers who buy water at subsidized prices. Actually, buying water at subsidized rates was a political struggle against the Ministry of Finance for the Israeli farmers. The rent-seeking activity was successful because the Israeli farmers organized as cohesive interest groups and used Israel's geo-strategic situation to give them an advantage in the political economy. Success of rent-seeking activity by Israeli farmers had direct consequences, such as an influence on income distribution, and indirect contributions to building a desalination plant and depleting an aquifer.

In Israel, water allocation is sustained by a price-quota system for agricultural users. In 1990 under drought conditions, water prices were subsidized for agricultural users. Industrial users paid about \$0.15 /$m^3$, and households were charged from \$0.32 /$m^3$ to \$1.23/$m^3$. Whereas marginal costs of water vary between \$0.02 and \$0.50/$m^3$. Over 40% of Israel's water (most of which is sold for agricultural use) is sold at less than its economic value, with agricultural users being subsidized by household consumers and taxpayers (Becker and Zeitouni, 1998).

In 1999, after a very dry winter, decreasing the quantity of water allocated to the agricultural sector was taken into account by the Israeli Water Authority, and that decrease was about 250 million $m^3$ (a reduction of 40% from 1998). The Ministry of Agriculture in Israel (1999) also took another action to allocate the quantity that needed to be saved among the different crops using a lexicographic decision rule, i.e., first minimizing long-term damage to the produce and then allocating water based on the marginal value of production. For example, water allocation was reduced for cotton and wheat irrigation by 100%; for vegetables, including potatoes, by 30%; and for fruits, including citrus, by 20%. The government compensated farmers for that reduction in water usage by about $0.25/m$^3$ (Heiman, 2002).

### 4.4.3. Summary

Irrigation for the production of low-value crops is not feasible as pressure on water resources continues to grow. Some irrigated agricultural production may need to be forgone to allocate water for higher-valued alternative uses. However, with the changing nature of economic activity within the individual countries, this will not pose the same challenges as it would have a few decades ago. Water policies should concentrate on the municipal and industrial systems as the main wealth providers in the 21st century. Detailed analyses of the available water resources show that most FC countries will not be able to meet the water needs of their populations in the next two decades. To accomplish this goal, the reallocation of at least some irrigation water to other uses will be essential.

## 4.5. Role of FC Governments in Water Reallocation

Water use in the FC is established by national policies, Islamic law and local laws. Islamic law recognizes two primary water rights: the right to thirst and the right of irrigation (Farouqi, 2001). These two rights form the foundation for customary use of water in the region. Laws and regulations in Syria, Jordan, the Palestinian Territories and Israel vest a government institution (a ministry and/or an agency) with the responsibility of setting water-allocation priorities. Water law sets the terms and conditions for when, how much and for what water is used. Governments allocate water resources among sectors by setting water use priorities and water use limits for each sector. Legal frameworks among FC countries vary greatly in their comprehensiveness, detail and effectiveness, because of limited resources, gaps in the legal frameworks, outdated laws, laws that do not reflect local traditions and a lack of political will. There are however some new policies that may provide guidance to FC countries seeking to improve their legal and institutional frameworks. Bruch et al. (2007) reviewed legal frameworks, regulations, decrees and other rules, to reveal the gaps in government oversight.

There is growing awareness of economic considerations in water allocation, and there are many ways to estimate the economic value of water (Dinar, 2000). Economists have debated the use market mechanisms (such as tradable water rights and pricing). Water pricing may force users to decrease non-essential uses of water, such as using water in swimming pools. Water pricing for domestic water use can maintain the value of water for other users and support investments for water-supply systems (Meinzen-Dick and Appasamy, 2001).

In many developed countries such as United States, water markets have been successful (Bhattia and Falkenmark, 1993). Currently, in the FC countries, water markets are inefficient. Water prices differ widely across and within sectors. Agricultural users pay lower prices than industrial and municipal users. Prices also differ among countries in an inconsistent way with water transportation costs. In addition, consumers face a growing block-rate pricing structure where higher prices are charged at higher levels of consumption (Just and Gilligan, 1998).

Water allocation in the FC is affected by: (i) the sources of water supply and the amount of water each source is expected to supply, (ii) the various demands of each use or user (i.e., agriculture, industrial and municipal) and their size, and (iii) the costs and benefits of supplying the allocated water to each use or user (World Bank, 1998).

### 4.6. Policy Tools to Reallocate Water in the FC

Many policy tools can be used to allocate water in the FC. Water allocation in the FC can take several forms, ranging from total government control to a combination of market and government allocation, to user-based systems, to marginal cost pricing allocation systems.

#### 4.6.1. Government Allocation

Water has many characteristics that lend itself to public or government allocation. Water services can be considered public goods (i.e., their supply to one individual does not reduce other individuals from using them) making government allocation appropriate. In the agricultural sector (rotation case) public water allocation could be applied to specify the particular times and places individual farmers are entitled to water. For industrial water uses, public allocation could grant water withdrawal and effluent discharge permits for individual companies and industries.

Zhang et al. (2008) used a system dynamics (SD) model as a public allocation tool to allocate water resources in Tianjin, China. For 12 years, the system constituent interactions were dynamically examined. The model gave feedback which helped in the system interactions and synthesized the component level of the knowledge into system behavior simulation at an integrated level. The model helped water policy-makers and water managers make predictions about some simulation scenarios (Zhang et al., 2008). The Tianjin-SD model can give decision-makers a solid foundation for logical decisions to compare some simulation scenarios. System dynamics were considered to be a suitable method to model complex water dynamics and to analyze the relative implications of regulatory policies (Zhang et al., 2008).

#### 4.6.2. Market Allocation

Water pricing and water markets can improve water allocation systems, provide incentives to preserve scarce water resources and encourage improvements in efficiency and conservation. Lewis et al. (2005) used a market water allocation system as a solution for agricultural water-resource management in response to drought. The authors identified market mechanisms that would address farmers' preexisting attitudes toward water markets. The results showed that farmers responded to short-term water mechanisms such as spot-water markets and water banks, particularly those that fully separate water rights from land. Moreover, the selection of market mechanism did not differ significantly among farmers based on their *a priori* intention to buy and/or sell in water market or vary substantially among type of farmers.

Some market mechanisms for temporary water allocation over a four-year period in The Falaj, Oman played a major role in water improvement (Al-Marshudi, 2007). The Falaj system considered incentives for water markets and arranged, organized and managed a community's water shareholders based on well-accepted customary and religious guidelines. The conclusions were consistent with the theory of supply and demand, and were helpful to water resources managers. The water market in The Falaj was successful because water ownership was separated from land ownership.

The appropriate water-market mechanism suitable to farmers' pre-existing attitudes toward water markets was identified by (Hadjigeorgalis, 2008). Data were collected through a survey of 166 farmers in the Lower Rio Grande Basin of New Mexico. The aim of the survey was to estimate farmers' willingness-to-participate in alternative, market-based water transfer mechanisms to manage their variable water supplies under drought conditions, in addition to determining if the choice of market mechanism is affected by farmer characteristics and the attributes of their farming operations. The results indicated that approximately 80% of farmers would participate in at least one short-term water transfer mechanism, such as spot-water markets and water banks. 65% of farmers indicated that they would manage water rights on a permanent basis and 35% of farmers would participate in a water-rights market where water rights could be transferred separate from land. Whereas 55% said they would be willing to use this system only if land and water rights were tied together. The choice of market mechanism results showed that there was no significant difference between farmers based on their intention to buy and/or sell in these markets. The study also showed the choice of market mechanisms did not vary by farmer types, except for small, life-style farmers where they clearly preferred spot-water markets to other types of short-term mechanisms.

#### 4.6.3. Marginal Cost Pricing (MCP)

Economic efficient allocation of water resources is achieved when the marginal value of water equals the marginal cost. MCP can be used to develop differential prices for different qualities of water where water with high quality has a higher marginal cost of provision (Spulber and Sabbaghi, 1994). A model was developed to estimate the trade-offs of allocating Nile River water among competing regions and projects in Egypt (Wichelns, 2002). The objective of the model was to maximize net social benefits produced with limited water resources.

#### 4.6.4. User-Based Allocation

When farmers manage rotation timing and land use, it is considered user-based water allocation. Water conservation can be achieved with user-based allocation that depends on local norms and the strength of local institutions.

Hoogendam et al. (1996) presented the rules that the water users of Vila Cova in Portugal as user-based allocation system created to allocate water resource. The author analyzed the extent to which these rules enable water users to turn their water rights into water flows. The conversion of water rights into a day-to-day water distribution system is a sensitive matter that could create an inefficient and unfair distribution. Issues such as duration of the irrigation period, user sequence, and night turns, were addressed and negotiated by the community priest and other community institutions. The rules resulted in a water distribution system that avoided conflict and created equal conditions for all water users.

In summary, most water projects require large capital investments. Therefore, most water projects are undertaken by the public sector (World Bank, 1993). Public (government) allocation of water has been the main mechanism in the FC because water has a physical quality which makes it hard to transport or allocate the water resources.

### 4.7. Constraints to Water Reallocation and Application of Literature in Real World

There is a vast body of literature, mostly economic analysis, which addresses water-scarcity problems. While the literature identifies and characterizes the FC's water problems, it fails to provide sufficient detail and data for decision-makers. Linear programming models, social planner allocations, system dynamics models, economic-engineering optimization models, safe yield concepts, mixed-quota policy and mathematical models all address narrow aspects of the issue, but do not an integrate straightforward, comprehensive approach which is needed by policy-makers. Natural resources managers face the complex challenge of reallocating water taking into consideration economic, cultural, social and political interrelationships. Furthermore, little research has examined both micro and macro policy interventions for improving water allocation. Many studies attempt to resolve water-allocation issues and find solutions for the constraints based on market-based solutions.

Cultural, political, environmental and fiscal constraints make allocation of water in the FC more difficult than the theories based on simplified models suggest. Following are some of the most commonly recognized constraints which affect allocation of water in the FC:

1. Efficiency constraints: Efficiency is achieved when the marginal value of water among competing uses is equal. In the real world it is difficult to discover, much less equate, marginal values.
2. Transformation: There is a transformation process to convert untreated water to treated water, for example, treating wastewater for use in the agricultural sector. Water losses are associated with transformations; rarely 100% of water is retained during transformation processes (Mahan et al., 2002).

3. Incomplete information: Water prices are an important part of the efficiency principle. In some countries, lack of information limits market's ability to set a permanent price for water. One of the conditions for market competition is setting a rational price of water. Decision-makers have to be able to find information about prices and the way to cost-saving innovations in water projects. Moreover, they have to be able to learn about profitable opportunities in other water industries. Incomplete information will mislead decision-makers.
4. Institutional constraints: There are formal constraints (e.g., rules, laws or constitutions) and informal constraints (e.g., norms of behavior, conventions or self-imposed codes of conduct) that limit the efficient allocation of water resources (North, 1994). For example, in FC countries lack of government regulation often results in both third-party effects and externalities.
5. Financial constraints: Considerable investment in water development infrastructure and transportation will be needed to meet future water needs. Policy-makers need to consider the fiscal implications of large investments.
6. Government/Fiscal constraints: Many FC government projects have reduced funding for water development for agriculture. Water and infrastructure development will require a substantial government investment which may financially strain some FC countries.
7. Resource overexploitation: overexploitation of water resources in FC countries, such as overuse of aquifers could lead to water quality impacts (Hadadin and Tarawneh, 2007).

An integrated management approach is needed to address those constraints. Any approach must meet basic human needs and preserve environmental integrity. An integrated approach must also achieve the desired level of environmental protection, be flexible to meet changing social and economic priorities, facilitate the development of effective local institutions; and use a cost-effective pricing strategy to ensure that payment for water use covers development, operation and management costs.

Each country has its own particular set of issues and characteristics which must be taken into consideration when designing policies. Natural resources managers must use best available tools, both economic tools and engineering models to achieve economic efficiency. Much of the scientific literature suggests using pricing systems for efficient water allocation. Water reallocation based on the principle of efficiency works in theory, but is more difficult to put into practice. However, there are no existing tools integrating economic, technical, environmental, political and engineering solutions to solve the water shortages problem in the region. Additional research is needed to solve the water scarcity problems in the FC. The complexity of incorporating economic, engineering, social and environmental constraints presents major challenge to apply the findings of scientific research to real world problems.

### 4.8. Potential Effects/Impacts of Reallocation

The main goal of water reallocation is to enhance economic efficiency. The following assumptions are taken into consideration:

1. Average annual water availability is constant. Water quantity (surface and ground waters) is assumed to be constant even though, in real life, water

availability for the next two decades is not likely to remain constant. The real-life droughts, floods, excessive rainfalls and overexploitation of groundwater could and will, likely affect water availability in the next 20 years. Water availability is assumed to stay constant with respect to reallocation challenges.

2. Water-use technology and efficiencies are constant. The study assumes no new innovations or technology that could mitigate water-supply issues. The study assumed that productivity and efficiency levels will be constant.
3. Increasing population. A growing population will put additional pressure on the available water resources. The study assumes population will increase by 3.1% (United Nations, 2010).

The study compares prices in different time periods. Nominal prices must be converted into real prices by using the GDP deflator (World Bank, 2010) (Table 12). The deflater measures changes in the prices of goods and services by a change in living cost (i.e., inflation). It reflects inflation and how the purchasing power of money changes. The prices of water reallocation from 1998 were adjusted to 2008 by using the GDP deflator (World Bank, 2010).

Table 12. Water Prices (Real and Adjusted) for Different Sectors

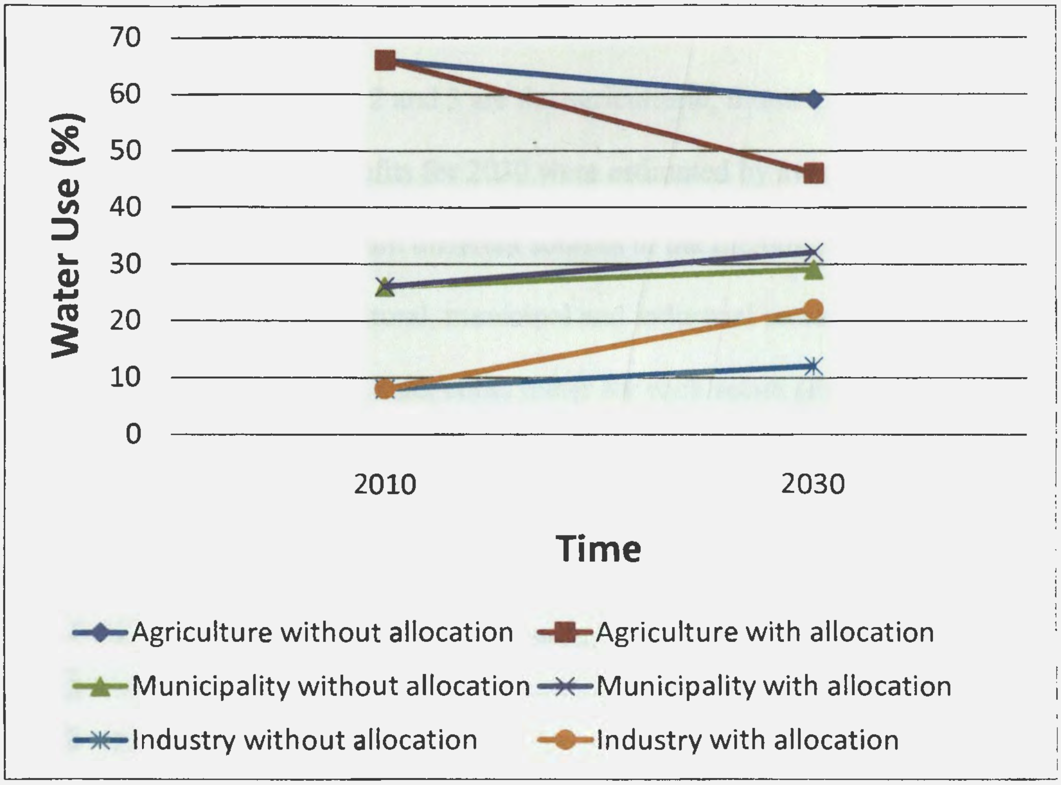
| Sector | 1998 prices ($\$/M^3$) | 2008 prices (adjusted) ($\$/M^3$) |
|---|---|---|
| Industry | 0.15 | 0.35 |
| Municipal | 0.77 | 1.8 |
| Agriculture | 0.27 | 0.64 |

This study assumes a reallocation of water away from agriculture at 1% of average total water use per year for the next 20 years for a total reallocation of 20% by year 20. A

20% reallocation assumed plausible. Varying the amount of water reallocated from agriculture to alternate uses will result in proportional changes in GDP%. For example, shifting 1% of water from agriculture to other sectors results in a 10% increase in GDP%, and shifting 2% of water results in a 20% increase in GDP%. The shift in water away from the agriculture sector to other sectors was proposed frequently in the literature. For example, Beaumont (2002) showed that the industrial and service sectors in the Middle East were able to generate upwards of 100 times more wealth for each cubic meter of water than water used by the agriculture sector. In the agriculture sector of the Middle East, 1 cubic meter of water is capable of generating about US$2 per year, on average. Actual values range from US$0.40 per cubic meter to US$9.89 per cubic meter (Beaumont, 2000).

#### 4.8.1. Water Uses (%)

Agricultural water use in the FC countries in 2010 accounts for about 66% of total water use. Water withdrawal for domestic (municipal) and industrial purposes is reported as 26% and 8%, respectively (Figure 6). Without a reallocation plan (without a 20% reallocation of average total water use from agriculture to other sectors) agricultural use in 2030 will be 59% of all water resources; municipal and industrial use will be about 32% and 9%, respectively (FAO, 2009; United Nations, 2003; WWDR, 2003; Beaumont, 2002; World Bank, 2007). With the reallocation plan (with a 20% reallocation of average total water use from agriculture to other sectors), the total water use in the agricultural, municipal and industrial sectors will be around 46%, 32% and 22%, respectively. Of the 20 % of water allocated away from agriculture, 14% will be allocated to industrial use and 6% for municipal use.

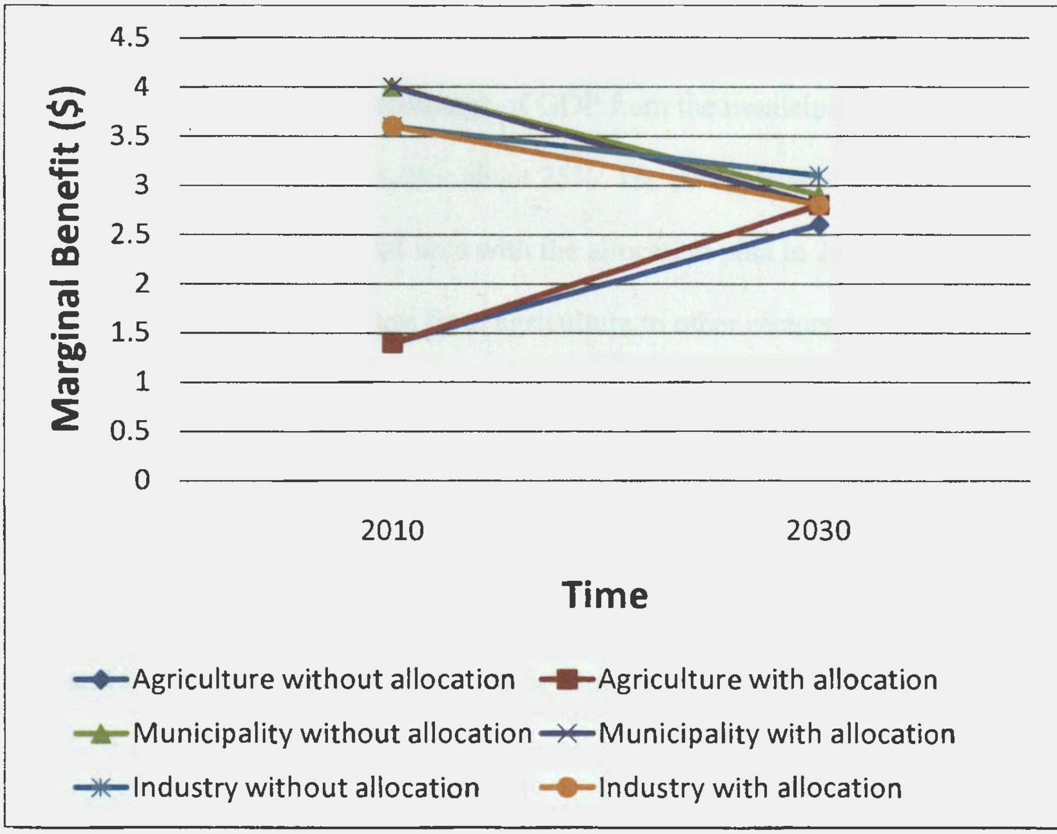



| | Agriculture (%) | Municipality (%) | Industry (%) | Total (%) |
|---|---|---|---|---|
| **2010** | 66 | 26 | 8 | **100** |
| **2030 (without allocation)** | 59 | 29 | 12 | **100** |
| **2030 (with allocation)** | 46 | 32 | 22 | **100** |

Figure 6. Total Water Use (%) Among Different Sectors and Different Periods of Time (2010 and 2030) in the FC Countries.
Source: FAO (2009), United Nations (2003), WWDR (2003), Beaumont (2002) and World Bank (2007).

### 4.8.2. Marginal Benefit (MB)

In 2010, the projected MB for the agricultural sector was \$1.4 per cubic meter, the MB for the municipal use was \$4.0 per cubic meter and the MB for the industrial sector was \$3.6 per cubic meter (FAO, 2009; United Nations, 2003; Beaumont, 2002; World Bank, 2007). With no reallocation in water use among sectors, the MB in 2030 for agricultural, municipal and industrial purposes was estimated by several studies to be \$2.6, \$2.9 and \$3.1 per cubic meter, respectively (FAO, 2009; United Nations, 2003; Beaumont, 2002; World Bank, 2007). Efficiency cannot be achieved unless the MB is equal across the sectors ($MB_1=MB_2=MB_3$), where 1, 2 and 3 are the agricultural, municipal and industrial sectors, respectively). Marginal benefits for 2030 were estimated by averaging the projected 2030 marginal benefits (from different sources in the literature) for each user. The marginal benefits for the agricultural, municipal and industrial sectors with reallocation were estimated to be \$2.8 per cubic meter for each sector (Figure 7).




| | Agriculture | Municipality | Industry |
|---|---|---|---|
| **2010** | 1.4 | 4 | 3.6 |
| **2030 (without reallocation)** | 2.6 | 2.9 | 3.1 |
| **2030 (with reallocation)** | 2.8 | 2.8 | 2.8 |

Figure 7. Marginal Benefit (MB) (\$/$m^3$) Among Different Sectors and Different Periods of Time (2010 and 2030) in the FC Countries.
Source: FAO (2009), United Nations (2003), Beaumont (2002) and World Bank (2007).

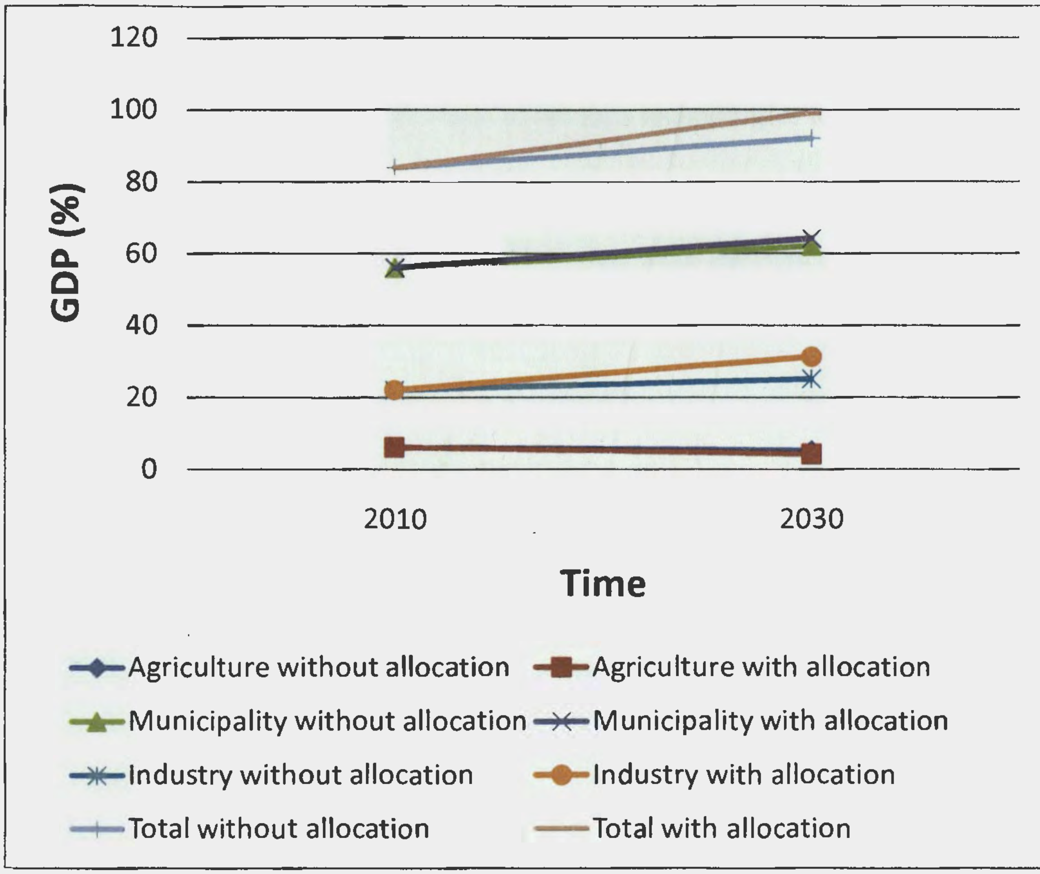
### 4.8.3. GDP (%)

The study assumes a constant, linear relationship between GDP% and water use in the feasible range of reallocation amounts. Productivity and efficiency are assumed to be constant. Each sector's contribution to GDP will shift as water is reallocated away from agriculture (Figure 9). In 2010, 6% of the total GDP (projection) will be from agriculture, 56 % of GDP from domestic (municipal) use and 22 % from industrial uses(Figure 8) (FAO, 2009; United Nations, 2003; WWDR, 2003; Beaumont, 2002; World Bank, 2007).

In 2030, without water reallocation, the percentage of GDP from agricultural usage will still be low (about 5%). The percentage of GDP from the municipal sector will be about 72% and from the industrial sector about 25%. The percentage of GDP for agricultural, municipal and industrial uses with the allocation plan in 2030 (with a 20% reallocation of average total water use from agriculture to other sectors) will be 4%, 64% and 31%, respectively (Figure 8).

## 4.9. Conclusion

Many studies suggest the use of water-allocation models to improve economic efficiency and improve water allocation systems. However, there are many challenges associated with water-allocation modeling. Models often are unable to incorporate economic, engineering, political, social and environmental constraints. Water models have addressed some constraints such as transparency, risk and uncertainty, model validations and externalities.




| | Agriculture (%) | Municipality (%) | Industry (%) | Total (%) |
|---|---|---|---|---|
| **2010** | 6 | 56 | 22 | **84** |
| **2030 (without allocation)** | 5 | 62 | 25 | **92** |
| **2030 (with allocation)** | 4 | 64 | 31 | **99** |

Figure 8. Gross Domestic Product (GDP) (%) Among Different Sectors and Different Periods of Time (2010 and 2030) in the FC Countries.
Source: Adapted from FAO (2009), United Nations (2003), WWDR (2003), Beaumont (2002) and World Bank (2007).

Economic efficiency is the objective of water allocation modeling. Most economists agree, however, that reallocation at the margin to higher-valued uses is a complicated task. In the case of FC water, there is opportunity for considerable non-marginal reallocation. Market mechanisms can be used to achieve a more efficient allocation of the available water resources, but each mechanism has its own set of prerequisites. If water users pay the full marginal cost of water, significant progress toward increasing water-management efficiency could be made. For example, increasing the price of water for farmers will encourage them to conserve more water and adopt new technologies to minimize their non-socially optimal water use.

In 2030, the reallocation of about 20% of water from the agricultural sector to other sectors would increase GDP and lead to more efficient use of water. Any similar-sized shift in water use (e.g., 15% or 30%) would have a proportionate impact on GDP and could help alleviate the water-scarcity problem in the FC. Reallocating water from agriculture to other sectors would increase GDP. There is considerable room, well before sophisticated models are needed, for economic progress to be made through water reallocation away from agriculture.

# CHAPTER 5. WATER SUPPLY AUGMENTATION

This chapter discusses water supply-augmentation options to alleviate water scarcity in the FC countries. Conventional and non-conventional measures to augment water supplies and narrow the gap between water supply and demand in water-scarce countries and regions are introduced. The last section demonstrates the role supply-augmentation methods could play in the FC countries.

Securing additional water can reduce water scarcity. Reducing evapotranspiration, capturing rainwater with micro- and macro-storage dams (building dams), desalination of seawater and brackish groundwater, wastewater reuse and importation of water from neighboring countries via virtual water can all augment water supply. Conservation, or using current water supplies more efficiently, can also augment water supply. Supply-augmentation options must consider costs and constraints.

The use of non-conventional supply-augmentation methods, such as the desalination of seawater and highly brackish water, the harvest of rainwater, the collection, treatment, and use of wastewater, the capture and reuse of agricultural drainage water and the extraction of groundwater containing a variety of salts were introduced by Qadir et al. (2007). The authors suggested an integrated water management plan with collaboration from stakeholders to develop appropriate strategies for the efficient use of conventional and non-conventional water resources that would ensure achieving food security in water-scarce countries (Qadir et al. 2007).

The water footprint as an indicator of water use to produce goods and services in a country was introduced by Hoekstra and Chapagain (2006). The water footprint is the total direct and indirect water used to produce goods and services. The global water footprint is

7,450 $Gm^3$/year, with an average 1,240 $m^3$/cap/year. Four factors determine the water footprint of a country: 1) the volume of consumption, 2) consumption patterns, 3) climate and 4) agricultural practices. Adopting techniques that require less water per unit of production such as; shifting consumption patterns to those which require less water or shifting production from activities with low water productivity to activities with high water productivity are examples of how a country can reduce their water footprint and increase water-use efficiency (Hoekstra and Chapagain, 2006).

In the FC, a variety of water-resource development techniques could be part of a long-term water resource strategy. Potential supply-augmentation options are reducing evapotranspiration, capturing runoff by building dams, desalinating brackish water and seawater, reusing wastewater, water imports via virtual water and conserving water (water management).

### 5.1. Reducing Evapotranspiration

Water that evaporates from the soil surface and is removed by plants through transpiration is a bio-physical phenomenon called evapotranspiration (ET). Reducing ET could help alleviate water-poverty in the FC. ET is influenced by several factors including rainfall patterns, air and soil temperature, wind speed, soil characteristics and type of vegetation. About 85% of total surface water available for use in the FC is lost to ET (Shannag and Al-Adwan, 2000).

The greatest loss from ET is evaporation from natural water bodies, such as lakes. Considerable effort and investment have been made to store water in reservoirs, but evaporation limits efficiencies. For example, the total available water in Turkey is 107.3 x

$10^9$ $m^3$ and the annual evaporative loss from the surfaces of lakes and reservoirs is around 6.8 x $10^9$ $m^3$, 16% of total available water. Annual evaporation volumes at high temperatures and under direct exposure to the sun in the Middle East may reach 1.5 to 2.5 $m^3/m^2$ of water surface (Varma, 1996). In Israel, 70 to 80% of average annual precipitation evaporates (Shevah, 2008).

ET can be reduced in the FC, but it is difficult on a large scale. Building dams and reservoirs in deep valleys with a correspondingly smaller surface area can reduce water lost to ET. Mechanical wind fences and parasol-type floats could also be used to prevent water loss due to evaporation (Gökbulak and Özhan, 2006; and Segal and Burstein, 2010). Segal and Burstein (2010) concluded that parasol-type floats reduced water loss in proportion to the protected surface area. Subsurface storage could also reduce ET and the risk of surface water contamination (Hut et al., 2008).

Monolayers have also been used to reduce water evaporation from large dams when the conditions are favorable. Monolayers are chemical films one molecule thick which produce a diffusion barrier on the water surface reducing evaporation (Barnes, 2008). While monolayers are considered an economical solution to the evaporative loss of water from storage, there are practical difficulties due to the short lifespan of monolayers on the water surface. Monolayers may not be appropriate for long term applications (Barnes, 2008). Monolayers also have other constraints, such as impurities and contaminants, vaporization of film material, displacement by wind, bacterial decomposition, microlayers, inhibition of monolayer spreading, bacterial attack and photodegradation.

Barnes (2008) used findings from small projects to estimate monolayer costs. The potential volume of water gain was about 15.18 MCM (Appendix D). The average total cost (ATC) was estimated to be $1.92/m$^3$, average variable cost (AVC) was $0.82/ m$^3$ and the marginal cost was $0.83/m3 (McJannet et al., 2008) (Appendix D). Davenport et al. (1976) estimated the cost of reducing ET was about $1.3/m$^3$ while Gay (1988) estimated the cost to reduce ET would be $0.8/m$^3$.

The main constraint to reducing ET is technology. Additional research is needed to develop technologies and reduce the cost of ET reduction techniques. Reducing ET might potentially conserve as much as 50 MCM by year 2030 in the FC (Table 13).

Table 13. Potential Volume in 2030 and Costs in 2008 of Different Methods for Reducing ET in the FC

| **Methods** | **Potential volume (MCM/yr)** | **Cost ($/m$^3$)** |
|---|---|---|
| Deep valley storage | Low | - |
| Improved water distribution systems | High | - |
| Wind fence | High | - |
| Parasol-type float | High | - |
| Subsurface storage | High | - |
| Monolayers | Low | - |
| Combined all methods | 50 | 0.83 |

Source: McJannet et al. (2008) and Barnes (2008).

### 5.2. Capturing Runoff by Building Dams

Storage may be an important supply augmentation tool (Tullos et al., 2009). Dams collect water in one time period for use in a future time period and function as storage reservoirs to ensure that water is available during periods of water shortages. Jordan has constructed about 10 dams with a total capacity of around 275 million m$^3$ in the last 5 decades. All the dams are used for flood control by controlling base flow and storage for irrigation. Dams (water storage) in the FC region provide water for agriculture, commercial, municipal, hydropower and recreation uses (World Commission on Dams [WCD], 2000).

However, dams and dam construction have biophysical, socioeconomic, geopolitical and environmental impacts (Adams and Hughes, 1986). Dams can negatively affect ecosystems, hydrology and water quality and disrupt existing cultural and economic institutions (Poff and Hart, 2002). Risks of large go beyond ecological and social considerations. Worldwide, 46 large dams disastrously failed between 1860 and 1995, eight of which resulted in overall deaths of at least 1,000 people (McCully, 2001). Any additional water provided by building dams will be distributed for domestic use and will add 30 to 50 MCM/yr, or around 5%, to Jordan's water supply (Salameh and Bannayan, 1993).

Sub-surface groundwater dams also capture rainfall and store it for livestock, irrigation and domestic use (Hut et al., 2008). Water is stored below the surface instead of at the surface. A subsurface dam stores groundwater with a "cut-off wall" across a groundwater channel. The sub-surface technology is preferred for numerous reasons including increasing the capacity of traditional wells, simplicity and less expensive to construct, replicable and easily maintained by the community, and less contamination of water. To understand hydrological processes and flows around the sub-surface dam, a simple groundwater-flow model was developed. The model was applied in two different situations in Kenya (Hut et al., 2008). The first case in Voi showed how groundwater levels upstream of the dam and in the adjacent riverbanks were influenced when sub-surface water was used for relatively intensive irrigation. The second case in Kitui showed little effect on groundwater levels from domestic uses. Long-term effects on expected groundwater levels were strongly correlated to the way the water is used. In other words, household water use and river-bank infiltration can go hand in hand in the Kitui area. On the other hand, when water in the dams is used for irrigation as is done in Voi, the infiltration effect will be minimal.

Sand dams have made a substantial impact on more than 100,000 people in Kenya. Sand dams are a relatively low cost measure that improves individuals' access to water (Lasage et al., 2008). A sand dam is a subsurface dam built across a seasonal river. Sand and gravel are accumulated upstream of the dam, which is raised progressively before each rainy season until it reaches an appropriate height to provide water storage. Access to water is improved and farmers use water from the dam to grow water-demanding crops such as tomatoes, onions and fruit trees raising their average incomes by 60%. Additional research on sand dams is necessary to expand the technology and adapt to droughts (Lasage et al., 2008).

The Al-Wehdah dam project is on the Yarmouk River; the border between Syria and Jordan. The project was funded by the government of Jordan, the Arab Fund for Economic and Social Development, and the Abu Dhabi Fund for Development in 2003. Dam capacity was about 1,144,000 $m^3$. Construction costs were $135 million, about $1.970/$m^3$ (Molle et al., 2008) and operation and maintenance (O&M) costs were about $7.03 million/yr. The operation and maintenance (O&M) costs include labor, administration, clean-up operations, electricity, rehabilitation and resettlement, environmental and forest aspects, the catchment area treatment and drainage system cost, and others. Average total cost (ATC) was $4.72/$m^3$, average variable costs (AVC) were $0.25/$m^3$ and the marginal cost was $1.87/$m^3$ (Molle et al., 2008).

The potential quantity of water that can be gained from building dams in the FC is 280 MCM by 2030 (Table 14) (FAO, 2009). The lack of research and development about the importance of dams as well as high costs of construction and operation of dams are the main constraints for the dam-building option. Micro and groundwater storage dams may be readily adopted in the next two decades.

Table 14. Potential Water Storage Volume in 2030 and Costs in 2008 of Different Methods of Building Dams in the FC

| **Methods** | **Potential volume (MCM/yr)** | **Cost ($/m³)** |
|---|---|---|
| Micro dams | High | - |
| Medium/large dams | Low | - |
| Groundwater Storage | High | - |
| Combined all methods | 280 | 1.87 |

Source: FAO (2008) and Molle et al. (2008).

### 5.3. Desalination

Among the options for water-supply augmentation is desalination of salty groundwater, brackish drainage water and seawater. Desalination in the FC is receiving considerable attention from scientists, resource planners, policy-makers and other stakeholders. Desalination removes dissolved minerals from seawater and brackish water. Desalination is not a new technology. Studies done centuries ago discussed distillation of drinking water from seawater by Mediterranean and Near East civilizations (Abu Zeid, 2000). Water desalination in the FC is a feasible and economical option to produce excellent quality water (Ammary, 2007). Desalination of Red Sea water by reverse osmosis (RO) and brackish groundwater desalination by nano-filtration could be viable technically and economically (Afonso et al., 2004). RO is considered efficient because it reduces the content of organic and inorganic matter in water at a relatively affordable price ($0.36/m$^3$) (Afonso et al., 2004).

Desalination technology has evolved significantly, making it cheaper, more reliable, less energy-intensive and more environmentally friendly than a few decades ago (Schiffler, 2004). Advanced technologies that reduce the cost of desalinated water have been attracting attention. Recent studies show large reductions in seawater desalination capital, operation and maintenance costs. Capital costs and O&M costs range between US$0.61 and US$1.55 per $m^3$, an average of US$0.70 per $m^3$. Cost savings were due to several factors including lower interest rates, lower energy consumption and unit price, less expensive membranes, cheaper equipment and pretreatment chemicals, larger plants and more efficient plant management (Murakami and Musiake, 1991; Leitner, 1998; Glueckstern and Priel, 1998; Semiat, 2000; Glueckstern, 2004). The largest desalination plant in the world is the Ashkelon seawater reverse osmosis (SWRO) plant in Israel. Current production is 330,000 $m^3$ per day (100 MCM/yr) (Kronenberg, 2004). The estimated total cost to build the plant was about $250 million.

Non-conventional water-supply methods may have negative environmental impacts. For example, continuous withdrawal of large quantities of water from a river or lake (especially in brackish water desalination) may negatively affect the water quality and, impact aquatic life. Consequently, environmental impacts may limit development of non-conventional water.

The Ashkelon plant is expected to operate for 25 years, from 2002 to 2027. Plant production is expected to rise to 750 MCM by 2020 (de la Torre, 2008). The total cost of desalinated water from the Ashkelon plant, consisting of contracted total water price and the government's own project-related costs, is $0.53/$m^3$ (Appendix D). About 42% of the water price covers energy costs, variable O&M costs, membranes and chemicals costs. The remaining 58% covers capital expenditure and fixed costs (Appendix D). The average total cost (ATC) is about \$1.00/$m^3$, average variable cost (AVC) is \$0.85/$m^3$ and the marginal cost is \$0.53/$m^3$ (de la Torre, 2008; and Kronenberg, 2004).

In 2010, water desalination provided 30 MCM; by 2030, desalination is projected to provide about 170 MCM (Al-Mutaz, 2005; El-Sadek, 2010; World Bank, 2007; United Nations, 2003). In the FC, the total per cubic meter cost of treated brackish water ranged from US\$0.30 to US\$1.00, while, for seawater desalination, this cost ranged from US\$0.84 to US\$1.70 (Glueckstern, 2004).

Schiffler (2004) argued that desalination should be the last option after considering cheaper alternatives (gray water collection and reuse, rainwater harvesting and water demand management). Adoption of desalination process in the FC has been slow because of the time required to adopt water desalination and the start-up costs. The potential volumes and cost of the different methods of desalination in the FC are summarized in Table 15.

Table 15. Potential Volume in 2030 and Costs in 2008 of Different Methods of Desalination in the FC

| **Methods** | **Potential volume (MCM/yr)** | **Cost (\$/$m^3$)** |
|---|---|---|
| Nano- Filtration | High | 0.54 |
| Reverse osmosis | High | 1.70 |
| Combined all methods | 170 | 1.12 |

Source: Al-Mutaz (2005) and El-Sadek (2010).

Use of desalination technologies in the FC is quite new compared to the Gulf States, but interest has begun to grow as conventional water resources became fully allocated. Desalination is currently used primarily in industrial and tourism sectors because of the high cost of seawater desalination. The use of desalination for other purposes (agriculture and municipal) will depend on technological improvements that reduce costs.

### 5.4. Wastewater Reuse

Wastewater reuse is synonymous with "wastewater recycling" and "wastewater reclamation." The U.S. Environmental Protection Agency (EPA) defines wastewater reuse as reusing treated wastewater in agricultural and industrial processes. In the FC, water reuse is an existing tool for managing scarce water resources. Overtime, wastewater reuse has changed from simply irrigating field crops with untreated wastewater to a sophisticated reclamation process for agricultural, industrial and domestic reuse (Durham et al., 2005).

Wastewater treatment and reuse as a tool for addressing food and water security in the Middle East and North Africa (MENA) was introduced by Faruqui (2002). The most practical solution for water scarcity is reuse of domestic wastewater for some municipal purposes, such as flushing toilets, irrigating green spaces, and for agriculture. Reusing wastewater is cheaper than developing new supplies and protects existing sources of valuable fresh water from overexploitation (Faruqui, 2002).

Wastewater reuse can also threaten public health, soil and water quality, if it is not done appropriately. Some components of wastewater can be toxic for some crops and wastewater may salinize soils and reduce soil permeability. To be socially and economically acceptable, wastewater treatment must carefully follow accepted procedures (Faruqui, 2002). The main problem with using treated wastewater for agriculture is contamination of water by bacteria, viruses and parasitic organisms.

In Israel, the use of treated municipal wastewater is becoming an increasingly important source of water for agriculture and industry. Currently, 65% or about 220 MCM of effluents, treated to varying degrees, are used for irrigation. Use of treated wastewater is expected to increase to about 425 MCM by the year 2020 (Shevah, 2008). Grey-water from households is also recycled for irrigated agriculture (Tropp and Jägerskog, 2006; Stockholm International Water Institute [SIWI] et al., 2005; and Allan, 2001).

Ammary (2007) focused on the reuse of wastewater from the two largest treatment plants (As-Samra and Wadi Zaraqa) in Jordan. Other, smaller wastewater treatment plants used their effluent for agricultural purposes. Wastewater treatment plants enhanced the production of good-quality water for multiple applications such as industrial cooling, municipal application and groundwater recharge. Wastewater treatment plants yield higher-quality water by considering some steps related to monitoring and adjusting the standards and regulations to cope with new pollutants.

The As-Samra wastewater treatment plant in Jordan was funded by USAID to replace the existing wastewater treatment plant. The project budget was $169 million, with half from USAID and the rest from the Jordanian government (Al-Zboon and Al-Ananzeh, 2008). The As-Samra plant is the largest wastewater treatment plant in Jordan and can treat about 75% of the 267,000 $m^3$ of wastewater collected each day (Ammary, 2007). The project began in 2000 and was completed in 2007. The plant's life cycle is from 2000 to 2025.

The government buys water from the plant at a price of approximately $\$1.1/m^3$ (Al-Zu'bi, 2007). The average cost for O&M of treating wastewater in waste stabilization ponds ranges from $\$0.15/m^3$ to $\$0.9/m^3$. The total cost of the As-Samra wastewater treatment plant includes depreciation, salary, electricity, operation and maintenance, chemicals, sludge disposal and contracted testing (Appendix D). The average total cost (ATC) is about $1.51/m$^3$, average variable cost (AVC) is $0.53/m$^3$ and the marginal cost is $1.23/m$^3$ (Mohsen, 2007).

The potential volumes and cost of the different methods of wastewater reuse in the FC is summarized in Table 16. Wastewater treatment is assumed to become much more widely adopted in the next two decades because it is an applicable and feasible technology (Mohsen, 2007).

Table 16. Potential Volume in 2030 and Costs in 2008 of Different Methods of Wastewater Reuse in the FC

| **Methods** | **Potential volume (MCM/yr)** | **Cost ($/m$^3$)** |
|---|---|---|
| Grey water reuse | High | - |
| Treatment water reuse | High | - |
| Combined all methods | 230 | 1.23 |

Source: Mohsen (2007).

The main constraints for wastewater recycling in Israel and the Palestinian Territories for irrigation and other appropriate industrial and municipal uses are potential contamination and long term supply reliability over the years (Yaron, 1999). Investment and operation costs for wastewater treatment and reuse are high. However, treated wastewater is increasingly being used for agricultural irrigation. Policy-makers must find financial support to make services and facilities viable and sustainable for wastewater reuse. Many efforts, such as increasing awareness and information campaigns, are needed to encourage participatory approaches.

5.5. Importation of Water from Neighboring Countries and Virtual Water

Virtual water imports from neighboring countries may be another option for meeting the growing demand for water in FC (Gruen, 1995). Water importation in the FC can be actual water or water as a component of foods or products. Water importation as a food component represents "virtual water" and may be an economic alternative to avoid domestic irrational water use and to insure food security, a growing concern in most of the FC countries.

It may be rational to import high water-consuming crops (i.e., virtual water) from countries with adequate water from natural, renewable sources (Shuval, 2006). For example, Israel's annual water imports are approximately three times its available internal water resource (Phillips et al., 2006). Israel also imports about 80% of its food and the Palestinians import over 65% of their food.

Water importation using the Trans-Arabian Pipeline may also be an option for the FC region. Water could potentially be imported from Turkey, Iraq, Lebanon and Egypt (Hussein and Al-Jayyousi, 1999). Under the Peace Pipeline Project, Turkey is willing to sell water. Despite high costs and environmental impacts, this option is potentially viable. In Iraq, there is a route designed to transfer water from the Euphrates River, however this option is not politically viable because of the lack of upstream and downstream agreements to share the water. In Lebanon, the Litani River pipeline can export about half the river's annual total flow (Figure 9). There are few political constraints as Lebanon is ready to adopt market-oriented water policies and is willing to trade water (Hussein and Al-Jayyousi, 1999). In 1979, the peace negotiations with Egypt proposed that Egypt can supply water to Gaza and Israel from the Nile River, but this option seems unacceptable due to political aspects.

There is potential for water importation in Jordan (Hussein and Al-Jayyousi, 1999). Evaluation of diverse import options has shown that Lebanon had the highest likelihood scheme, and the least likely options were in Iraq and Egypt because of the political and technical constraints.

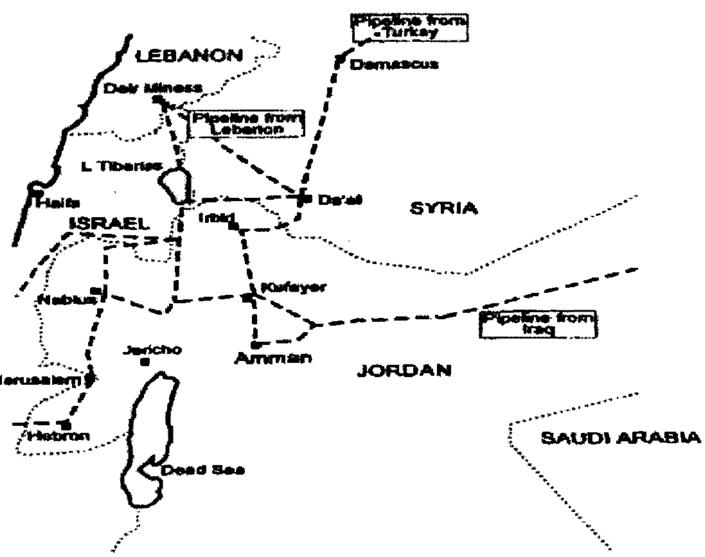



Figure 9. Possible Import Options.
Source: Hussein and Al-Jayyousi (1999, p. 245).

Oil tankers are another option for transferring water among the FC countries. However, the cost of the cleaning process is critical to obtaining acceptable water quality. The cost of tanker conversion also is a vital constraint. Many companies in the FC cannot afford to invest tens of millions of dollars to refit oil tankers for water transportation without receiving compensation.

Israel and Turkey signed an agreement in 2004 that allowed Israel to import 50 MCM/year of fresh water from the Manavgat River system in Turkey for the next 20 years.

The net cost of water imports was estimated at US$0.73 to US$1.36 per $m^3$. That cost covers the tankers, bags and loading and unloading terminals (Yedioth, 2004; Friedman, 2004). The total minimum flow recorded was 60 cubic meters per second (i.e., 1892.16 MCM per year). In other words, a volume of more than 1,892 MCM per year is available from the Manavgat River (Friedman, 2004).

Many studies indicate that political conflict will be the main limiting factor for water-importation. Political uncertainty limits multi-national projects. Strong collaborative institutions, at both national and regional levels, will be required for transboundary basin water agreements (Swedish Ministry for Foreign Affairs [SMFA], 2001). There is hope, that, through transboundary cooperation, local stakeholders' participation and policy-makers' regional analysis, the conflict can be recognized and that people can solve disputes. Political conflicts will limit water imports over the coming decades, but importing water as food products (virtual water) is as an efficient option (Table 17). The potential volumes of water from importation in 2030 will be 140 MCM (Table 17).

Table 17. Potential Volume in 2030 and Costs in 2008 of Different Methods of Water Importation in the FC

| **Methods** | **Potential volume (MCM/yr)** | **Cost ($/$m^3$)** |
|---|---|---|
| Importing water | Low | - |
| Virtual water | High | - |
| Combined all methods | 140 | 1.55 |

Source: Friedman (2004) and Yedioth (2004).

### 5.6. Water Conservation (i.e., Demand Management)

Water conservation increases water supply and can expand water availability and improve water quality. The main constraint for water conservation in the FC countries is that consumers, water authorities are unorganized. There are many water losses and other forms of waste in the FC. There is a lack of national and international water conservation plans to address the many example of water loss through wasteful processes. For example, farmers in the FC consider the cost of adopting new irrigation techniques as a part of a water-conservation system to be high. That belief tends to discourage adaptation of more efficient irrigation systems (Helming, 1993). The farmers have neither appropriate nor adequate incentives to consume water in an efficient way.

Water conservation through water demand-supply management can take many forms, from provisions to diminish losses to technical measures that will improve the efficiency of water consumption. Rationing programs to increase public awareness together with incentives may also promote water conservation. A water-conservation management plan for the Jordan basin region will likely need to incorporate both supply- and demand-oriented measures to maximize economic and environment efficient (Berkoff, 1994).

Many studies in the FC examined water conservation as an option for water supply. Alsharif et al. (2008) evaluated the relative efficiencies of water supply systems in the Palestinian Territories (West Bank and the Gaza Strip) using data envelopment analysis (DEA) (Box 3). Improvements in management of domestic water (i.e., conservation) can mitigate water-shortage. The study also found excessive water loss in the Palestinian Territories

> Box 3. Data Envelopment Analysis (DEA)
>
> DEA is a tool or approach described by Charnes and Cooper (1994) that is used in situations to measure efficiency. This technique is basically a linear program used for measuring the relative performance of an organization where the presence of multiple inputs and outputs makes comparison difficult. DEA uses the input and output information to construct efficiency frontiers. In other words, DEA is a nonparametric method for the estimation of production frontiers. It is used to empirically measure productive efficiency of decision-making units (DMUs).
>
> Source: Charnes and Cooper (1994).

from an inefficient water supply infrastructure. Repairing the faulty infrastructure would increase conservation in the Palestinian Territories water-supply systems (Alsharif et al., 2008).

Strategies to address water scarcities by shifting demand for water have been used in Israel (Arlosoroff, 2004). This strategy can make additional quantities of water available for consumption. Demand management strategies include water pricing, the reuse of sewage effluents, water conservation, virtual water and desalination of seawater to increase water availability (Arlosoroff, 2004).

Hussein and Al-Jayyousi (1999) also present's options to meet the water demand by reassessing tariff systems to prompt water conservation. The authors suggested limiting groundwater usage and raising the tax on the groundwater extractions to enhance water conservation. Many efforts should be done to improve stakeholder engagement and increase the awareness of water consumption. Public awareness campaigns have to be activated to provide information about water conservation.

The average cost of all water conservation measures is about $0.85/m$^3$ and the projected potential quantity of water that can be obtained is about 10 MCM (Arlosoroff, 2004). By 2030, the projections for water conservation in the FC could be 50 MCM (Arlosoroff, 2004). By 2030, the challenges of inappropriate pricing mechanisms and the lack of public awareness could be solved resulting in more water from conservation (Table 18).

Table 18. Potential Volume in 2030 and Costs in 2008 of Different Methods of Water Conservation in the FC

| **Methods** | **Potential volume (MCM/yr)** | **Cost ($/m$^3$)** |
|---|---|---|
| Education | High | - |
| Fixtures –water saving shower head- | High | - |
| Price | High | - |
| Government regulations | High | - |
| Combined all methods | 60 | 0.85 |

Source: Arlosoroff (2004).

Success of a water-management plan will require government involvement to provide appropriate leadership, incentives and mechanisms for water conservation. There is a high priority to have a strong third-party provision for regulating the equilibrium between water supply and demand for each sector. Public awareness programs are also an essential component of water conservation in FC. Consumers, service providers and policy-makers will need to work together to advance understand the water-supply situation. More scientific research which can provide more information about the costs and benefits of water conservation would also be useful.

### 5.7. Summary

The scientific literature identifies a wide range of supply -augmentation options. Three supply-augmentation options have promise in the FC: 1) desalination of brackish water, 2) reducing evapotranspiration and 3) water conservation. These three options have the lowest marginal costs among all options reviewed. MC of reducing evapotranspiration was $0.83/m$^3$, for water conservation was $0.85/m$^3$ and for brackish desalination was $0.54/m$^3$. Options for reducing evapotranspiration and for much gain from water conservation are limited. Additional research is needed to address technical and economic constraints.

Political disputes and prohibitive costs are a barrier to supply-augmentation options. In addition to being expensive, water transportation in the region will require efforts to build cooperation and trust among the water-exporting and importing countries. There are health and environmental risks of untreated or inadequately treated wastewater. Untreated wastewater may contain harmful pathogens (viruses or bacteria). Safe, effective procedures are necessary for traditional wastewater treatment to be seen as a realistic, health-risk mitigation option in FC countries.

The potential volume of water that could be added by each method varies (Table 19). Marginal Cost (MC) also varies for each option. The following plan considers only the MC of each supply-augmentation option to prioritize choices. Further analysis involving AFC, ATC and AVC will be necessary as plan components are implemented.

The more challenging the constraints, the higher the marginal cost (Table 19 and Appendix B). The plan assumes a perfect market where Price (P) =Marginal Cost (MC). The cost of water-supply augmentation options for different prices is adjusted to 2008 (Table 19). Desalination was the lowest marginal cost option to reduce water scarcity. Total water supply in 2010 was about 300 MCM from all sources. By 2030, the total water supply is expected to increase by about 630 MCM (Figure 10).

### 5.8. Conclusion

With continuing population growth and an increasing gap between water supply and demand, supply-augmentation options, such as water importation, wastewater treatment, desalination of brackish water and seawater, water storage in dams and water conservation can help address the water-scarcity problem.

Table 19. Water-Supply Augmentation Cost, Potential Volume (MCM) for Different Years and Constraints for Each Option

| **Supply augmentation options** | **Average prices (2008)* ($/M$^3$)** | **Expected Prices 2030** | **Potential Volumes (MCM)** | | **Constraints** |
|---|---|---|---|---|---|
| | | | **2010** | **2030** | |
| Brackish desalination | 0.54 | ↓ | 30 | 170 | High cost and ecological impact |
| Sea water desalination | 1.70 | ↓ | | | |
| Water importation | 1.55 | ↑ | 60 | 140 | Geopolitical, technical, high cost and pollution concern |
| Building storage dams | 1.87 | ↑ | 120 | 280 | High Cost and little of research |
| Wastewater Reuse | 1.23 | ↓ | 80 | 230 | High cost and water quality |
| Water conservation | 0.85 | ↑ | 10 | 60 | Low social incentive, cost and unorganized plan |
| Reducing ET | 0.83 | ↓ | 0 | 50 | Global climate change |

*Prices from different years were adjusted to 2008 using the GDP deflator.
Source: Al-Mutaz (2005); Alrosoroff (2004); Friedman (2004) and Mohesn (2007)

Brackish desalination, reducing evapotranspiration and water conservation are the least costly at this time. FC countries may need to cooperate to overcome water shortages. Supply-augmentation options require transboundry basin-wide support in the region, and regional cooperation is necessary. Policy-makers might start using supply-augmentation options efficiently not only to overcome water shortages, but also to resolve long-standing political conflicts and to re-establish economic growth and stability in the region.

The development of options with high capital investments is further limited by environmental and ecological impacts along with public awareness. The FC countries lack resources and face technological issues to implement most of supply-augmentation options.

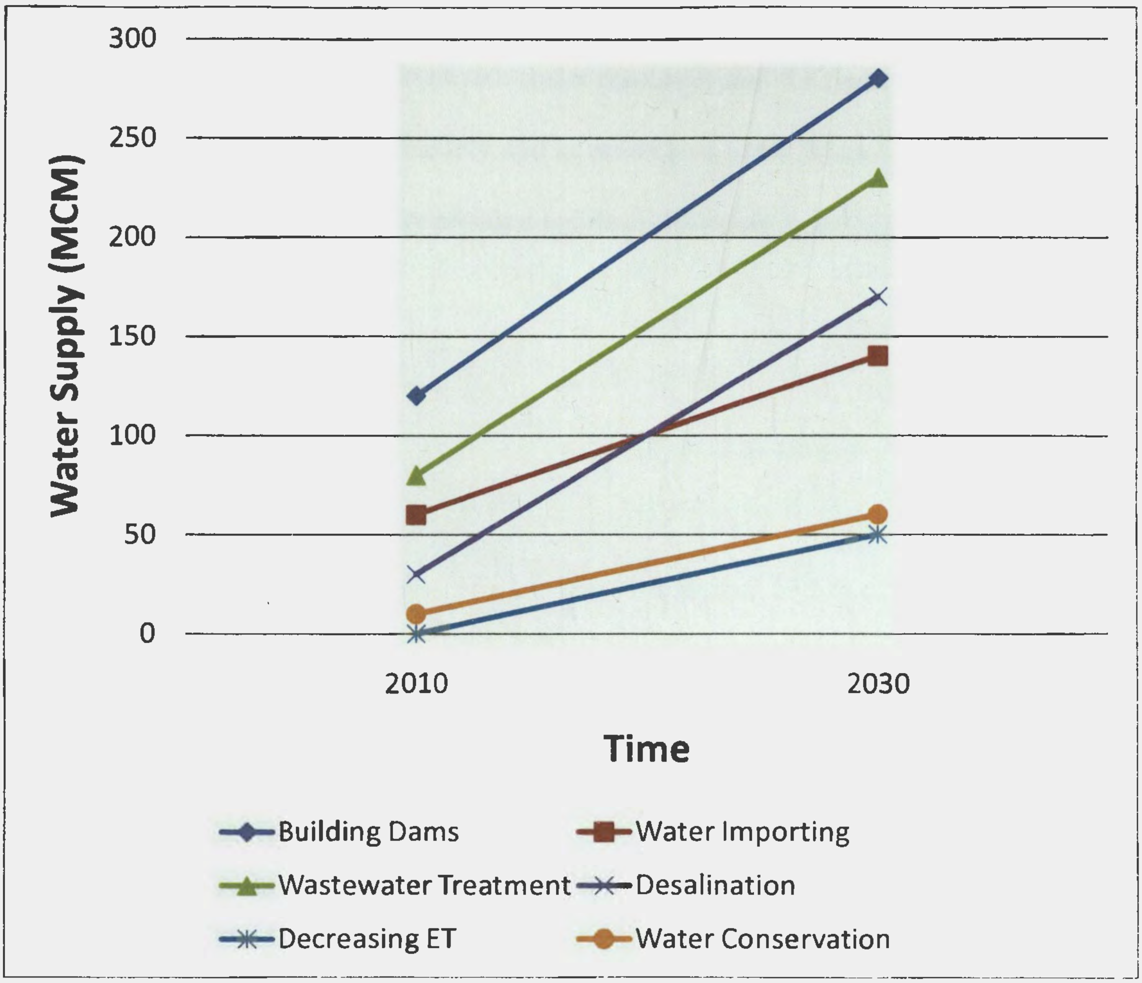



Figure 10. Water-Supply Augmentation Options (MCM) in Different Periods of Time (2010 and 2030) in the FC Countries.

Dams and water importation systems are examples of supply-augmentation options limited by high cost and other political and economical constraints. A mix of water-supply augmentation options will eventually need to be adopted. Most of the literature showed that the major mission given to the engineers was to evaluate the effectiveness and efficacy of various options. The assessment of supply-augmentation options would help extend the process of identifying "packages" of implementation options and help proceed with the plan.

A comprehensive approach is needed. A broad strategy can highlight the need for improving and managing the available water resources and for finding new water-supply options. A strategic plan can feasibly add as much as 630 MCM over the next two decades, helping solve the water-scarcity problem while considering sustainability and water quality for present and future uses.

# CHAPTER 6. WATER SUBSTITUTES

At some point in time, water reallocation (Chapter 4) and supply augmentation (Chapter 5) will have maximized returns from available water and allocated it to the highest value uses. When the marginal cost of an additional unit of water is greater than the marginal benefits, entrepreneurs will find substitutes for some water uses. While there may be no substitute for some uses of water, such as biotic consumption (e.g., human, livestock, wildlife or crops), some non-biotic uses may not require water (e.g., dry cleaning, industrial cooling, or industrial cleaning). People use water for drinking, cooking and washing. Water is also used for producing things such as food, paper, steel and cotton clothes.

A water substitute takes the place or function of water, but is neither water conservation nor virtual water, which are water supply options. Some research on the potential for water substitutes has been completed. This section will review those studies and address potential costs, benefits and constraints associated with water substitutes.

## 6.1 Water Substitutes in Production Activities

Water is used as an input in production. It could be a component of the end product, used for cooling, used for cleaning, or used for other aspects of the production process. Water is not directly demanded, consumers do not care if water or something else is used in place of water during production, as long as the product is supplied. For example, the production of 1 kg of beef requires 16 thousand liters of water, with a great deal of variation in global average consumption of water for beef production (Hoekstra et al., 2009). The demand for water in beef production is a result of derived demand. That is, demand for water is a function of the demand for beef. As the demand for beef increases, demand for inputs to beef production increase as well. The price of inputs to produce beef, potentially include water. Water for animals to drink is not likely substitutable. However, there may be substitutes for the water used along the process of raising the animals, slaughtering the animals, processing the meat, or packaging the meat.

An example of water substitution in industrial cooling comes from Coca-Cola Company in Arizona. Coca-Cola bottlers remove dust and clean beverage containers using air instead of water (Royte, 2010). Another example of a water substitute in production activity is Xeriscaping. It is a landscaping technique which uses native and drought-tolerant plants in order to eliminate the need for water for plant irrigation (EPA, 1993).

Synthetic ice is another example of water substitution. Synthetic ice is a solid polymer (plastic) material intended to substitute for ice used as skating surface (Miller, 2006). Synthetic ice is used where frozen ice surfaces are impractical due to high temperatures and for indoor skating applications (Miller, 2006).

Water substitute in production activities could be a necessary component of water management in the FC. Water threshold availability studies indicate that the region will be in critical situation in time. Further, eventually FC countries will have no additional water to allocate at that point water substitutes will be required.

### 6.2. Water Substitutes in Consumption Activities

There is no substitute for direct consumption of water in biophysical functions, but water substitutes may be found for some consumption activities. In this case, the consumers continue with the activity but a substitute is found for water. An example would be artificial ice for skating from the user's perspective. Another substitution possibility is consumers substituting a good or service that does not use water as an input for a good or service that is dependent on water. In this case, consumers switch activities. An example of this would be skiing on artificial turf instead of water skiing, or racing go-karts instead of personal water craft.

Car washing is a consumer activity where there may be substitutes for water. Washing a car at home can use 50 gallons (at least 50 gallons), while washing a car at a self-service car wash or professional car washing can use 11 to 14 gallons of water (Brown, 2000). There may be methods to clean automobiles car without using water. Ultrasound cleaners, used at frequencies from 20 to 40 kHz, clean jewelry, lenses, watches, dental and surgical instruments and other industrial parts without water. Ultrasound cleaners depend on the energy released from the collapse of millions of microscopic cavitations near the dirty surface. The bubbles made by cavitations collapse forming tiny jets directed at the surface (Cleaning Technologies Group, 2009). These technologies could be adapted to the neighborhood car wash to substitute for water. Ultrasound car washes may require advances in paints and finishes to facilitate the washing technology.

A substantial portion of household water consumption comes from showers, toilets and tap operations. Showers account for about 25 to 35% of all household consumption. Household water consumption for a shower is estimated at about 5 to 6 gallons per minute. In Islamic religious rites, sand is used as a substitute for water. Sand can be used in place of water for ritual washing. Perhaps a non-water substance will be developed to take the place of water in showers, similar to sand for washing in Islamic religious rites.

The next largest household water-consumption activities are flushing toilets, bathroom faucets and outdoor taps (for lawn watering and driveway car washes). Each flush of the toilet or running a tap operation for 1 minute, consumes 5 gallon of water (EPA, 2010). Air and vacuum pumps are used for toilets in space. Vacuum pumps use air to create suction to remove the waste. Astronauts use a large tube for urination which is connected to the bottom front of the toilet. This tube also carries the urine and holds it in the tank through air circulating (Canadian Space Agency, 2006). Campers have used chemical toilets for decades. Remote military outposts often burn their human wastes. In short, there may be non-water using substitutes for one of the most common of household activities—flushing the toilet.

### 6.3. Summary and Conclusion

At any scale, water is finite during a single time period, although it is renewable and potentially expandable in subsequent time periods. However, eventually reallocation and supply augmentation will full use the available supply. After traditional efforts have reached the point of diminishing returns (i. e., stage III in production function), substitutes may be used to alleviate water scarcity. While, there are no known substitutes for water in some uses such as plant and animal biological life functions, scientists and entrepreneurs will likely find substitutes for some water uses. Substitutes for water have been found in some manufacturing and service industries. Water substitutes will likely play a minimum role in reducing water poverty in the FC area in the next two decades, but will become more likely as water per capita becomes more scarce and the marginal cost of water from traditional sources increases.

# CHAPTER 7. PLAN TO REDUCE WATER POVERTY IN THE FC

A strategic plan is a detailed, organized procedure to guide action and decisions to accomplish specific general goals. Plans detail what needs to be done, how it is to be done and who is involved. Strategic plans guide decision-makers by identifying general tasks and accomplishments to help achieve long term objectives. Strategic plans may also detail short term tactical tasks necessary to meet short-term objectives (Yoe and Orth, 1996; Bryson, 1990).

The S-T-P (Situation/Target/Path) model of planning identifies the problem, assists decision-makers in analyzing and solving the problem and lays out a path for meeting a defined objective(s). The target (i.e., goal) was identified in Chapter (1) and the present situation in the FC was detailed in Chapter 3. The components of the path are developed in this chapter.

Water-policy has addressed both ways to reduce demand for water (Arlosoroff, 2004; Brooks and Wolfe, 2006; Magiera et al., 2006; Scott, 2003, Turton, 1999) and ways to increase supplies of water (Allan, 2001; Beyth, 2007; Brooks, 2007; Mohsen, 2007; Schoenfeld et al., 2007). In the short term, reducing demand requires restrictions and/or incentives. Increasing the water supply in the short term is politically appealing because it eliminates potential resistance to a forced reduction in water use. An integrated and comprehensive strategy would combine both approaches, which should result in a more efficient allocation of water than using only one or the other.

A water plan must also take into consideration national agendas and priorities and government and social institutions (Frederickson, 2003). Water plans in the FC must be adaptive and incorporate the transboundary characteristics of the region, as well as recognize local, national and regional dimensions (Etzioni, 2004). This is especially relevant in the FC with its diverse and unique socio-economic characteristics.

### 7.1. Management Structure

Implementation of a water-resource plan in the FC requires an administrative structure. Such a structure is provided here as an example of the administrative support team needed.

Someone needs to be in charge, notably a director. A director will lead the team and select a technical team of civil engineers, GIS specialists, economists, social scientists, environmentalists and DSS specialists. An administrative staff will support mangers and technical specialist and will include clerical staff, public relations, communications, extension specialists and legal consultants (Figure 11). Water-resource planning teams identify problems, issues, challenges, opportunities, and alternatives and offer recommendations to achieve the stated objectives of mitigating water scarcity in the FC.

The FC Water Plan Director should have a broad background in water resources management, experience in public sector policy, and leadership and team building skills. The director is responsible for all aspects of implementing the FC Water Plan and reports to the Advisory Board. The director would be a full-time employee with an estimated annual compensation package of $100,000 (United Nations, 2010).[5]

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[5] This and subsequent budget data were adapted from United Nations, 2010. The effects of inflation on prices over the 20-year planning horizon could be a factor affecting the allocation of the grants but the study ignored that factor. Also, the study ignored any interest earned if the $100 million grant were received in year 1 (Appendix C).

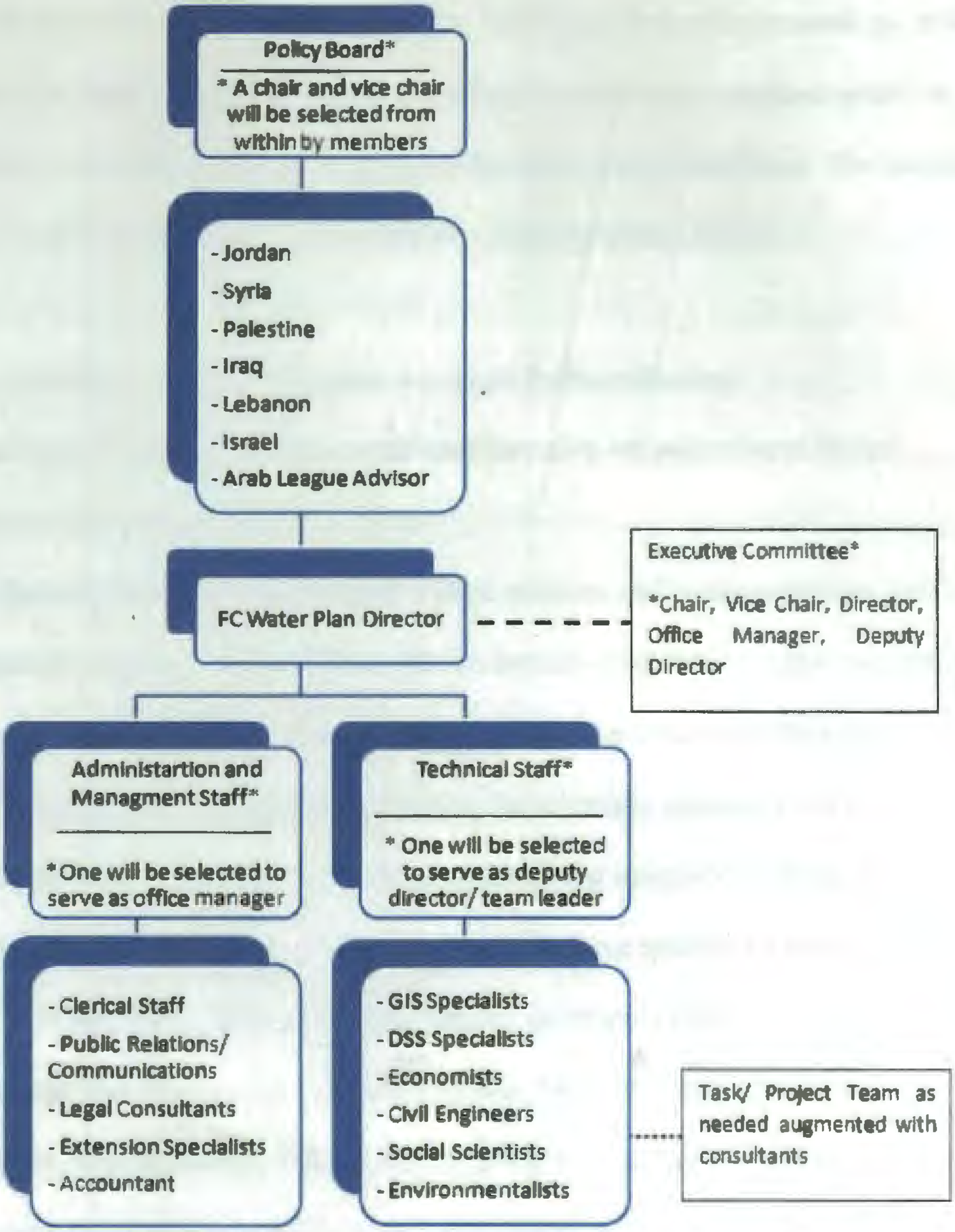


Figure 11. Administration Structure for the FC Water Plan.

An Advisory Board would consist of water ministers from each of the six FC countries or their designee. The Advisory Board has ultimate control over how money is allocated for the water plan and, therefore, will be in charge of making the final call when it comes to decisions. A Board chair and vice-chair would be selected by members of the board. Board members will provide input and oversight to the planning process. Advisory

Board members will serve as long as they hold their respective minister positions in their countries. The Board would meet quarterly. Board member travel expenses would be paid by the Water Plan fund, but they would not be compensated for their time. The estimated annual cost of Board activities will be $25,000 (United Nations, 2010).

7.1.1. Administrative Staff

An office manager will provide oversight for the following:

- Clerical Staff: Clerical staff will provide administrative support to water Board management and technical staff.
- Public Relations/Communications staff: Public relations and communications staff are responsible for ensuring that constituent groups are informed about the planning process. Maintaining transparency through appropriate communication is essential to developing and promoting a positive image of the planning for all public audiences and policy-makers.
- Legal: Legal staff will advise as needed on national and international legal issues.
- Extension Specialist/Outreach: Extension specialists have specialized training and experience in providing disciplinary expertise and developing educational curriculum for outreach programs. Further, an extension specialist has proficiency in program development, implementation and evaluation, group process and facilitating leadership development. Extension Specialists would work closely with technical and communications staff.
- Accounting/Finance: Public sector accountants monitor revenues and expenses and provide reports to ensure efficient use of public funds. Moreover, they analyze, monitor and review budgets and expenditures for the water plan.

7.1.2. A Technical Team

The Technical Team will include professional experts in multiple disciplines as well as data managers and consultants as needed. The Technical Team leader will serve as the Water Plan deputy director. Members include, but are not limited to

- GIS specialist: GIS specialists create and maintain data that can be combined with geographically referenced data. GIS software integrates different types of data including socioeconomic, demographic, administrative, political boundaries, land use patterns and environmental indictors such as water and air quality measurements.
- Decision Support System (DSS) specialist: DSS specialists prioritize data and information requirements and determine how data are organized and presented to provide effective decision support and reporting tools.
- Economist: Economists plan, organize, coordinate, evaluate and perform economic analyses related to water supply reallocation, flood risk management, hurricane and storm damage reduction, drought management and ecosystem restoration studies. Economists also integrate social and economic analysis for evaluation of alternative plans. They also interpret cultural, geographical, historical, sociological, demographic and other factors affecting water resource issues.
- Water engineer: A water engineer is civil engineer who designs and supervises projects involving distribution of freshwater, wastewater and sewage disposal and flood prevention. Water engineers design distribution systems for drinking and non-drinking water and may design water supply networks and storage tanks. Water engineers may also analyze and prepare reports on treatment methods for wastewater and examine water drain systems to manage water quality.

- Social scientist: Social scientists study all aspects of society including the effect of location and politics on culture.

- Environmentalist: Environmental scientists monitor climate and other environmental changes over time. Environmental scientists can monitor river capacity, flows, wildlife and test soil and air for contaminants. An environmentalist's mission is to identify, reduce and eventually eliminate potential environmental hazards.

### 7.1.3. The Water Plan Organization

The organization will be housed in a geographically central location in the FC, perhaps Syria or Jordan. Annual overhead costs (office rent, utilities and insurance) were estimated to be $15,000. The total annual budget for Water Plan management/implementation was estimated to be approximately $612,000 (Appendix C) (United Nations, 2010).

## 7.2. Components of the Path

The objective of this study is to present a draft strategic plan that would reduce water poverty in the FC by 2030. As evidenced by the literature, much has been done on narrowly focused aspects of water poverty and scarcity, yet little progress has been made toward advancing the overall goal. The strategic plan integrates multiple strategies to achieve the stated objective.

The path includes water reallocation (Chapter 4); water supply augmentation (Chapter 5); and water substitutes (Chapter 6). The strategies will be adoptive, integrated and implemented over a 20-year period. Economics will be the primary discipline for evaluating the efficiency of the water reallocation plan. Engineers will assess the effectiveness of the various supply-augmentation options. This path identifies "packages" of options for implementation:

1. Non-traditional shifts in water reallocation within uses (e.g., agriculture) and among users (e.g., agriculture, industry and municipal). The strategic plan assumes a 20% shift in water from agricultural use to municipal and industrial uses over the next 20 years.
2. Innovative supply-augmentation including desalination, water imports, wastewater treatment, wastewater recycling, water conservation, reducing ET and storage.
3. Identification of substitutes for water production and consumption. Ultimately, water substitutes will be required to further minimize water scarcity.

Disciplinary principles and concepts combined with data from the literature are the basis for a water-scarcity mitigation plan in the FC region. The fiscal question was how to allocate $100 million to develop a plan that will identify and develop programs and projects to opertionalize principles into real world solutions to maximize social well-being now and into the future. Water will be allocated to various reallocation programs and projects until optimal economic efficiency is achieved ($MB_1$=$MB_2$=$MB_3$). Supply allocation projects will funded based on the least marginal cost principle until optimal economic efficiency is achieved ($MC_1$=$MC_2$=$MC_3$). Some funds will be allocated to research and development of water substitutes.

### 7.3. Plan Implementation

Current conditions in FC region were described in Chapter 3. Water reallocation tools were identified in Chapter 4; supply augmentation options were in Chapters 5 and potential water substitutes for some water usages in Chapter 6. With a thorough understanding of current conditions and available water resource management tools, the plan can be implemented. Implementation is the process of taking specific actions to achieve plan objectives. Plan implementation is at the heart of making change happen in the organization.

### 7.3.1. Setting up the Organization

An advisory board will set the organization's goals and provide oversight to ensure that the organization meets its mission and operates effectively and in the best interests of the stakeholders (water users and citizens). The plan director will be responsible for plan implementation, finances, organizational operations, community relations and human resources.

The plan director will hire an office manager to supervise the office staff and manage day-to-day office functions. A deputy director will be selected by the director from the technical team. The deputy director will support the executive director in the development and implementation of the strategic planning and assist with policy development, provide leadership and oversee the technical staff. The executive team (director, office manager, and deputy director) will hire additional staff as needed; obtain office space, equipment and draft standard operating procedures (SOP) and internal policies for the Water Plan organization.

### 7.3.2. Developing the Organization's Budget

The budget shows a simulated $100 million 'allocation' would be spent to accomplish the goals and fulfill the mission of the organization. The budget includes revenues and expenses and is flexible as the planning process evolves. Because the path is dynamic, the budget must also be dynamic to meet future fiscal conditions. Potential revenues derived from additional water supplies as well as the associated expenses as a result of increasing the water supply must be included in the budget. The budget should also include cost sharing for projects or programs as well as any funds or grants from regional/international sponsors. The plan will have a hypothetical budget of $100 million.

7.3.3. Selecting Investment Options

After setting aside $612,000/year for administration and management ($12 million per year for 20 years), the remaining $88 million will be distributed to various water management strategies based on the principles of MB and MC detailed on chapters 4 and 5, taking into consideration opportunities and constraints of each option (Table 20).

a. Water Reallocation: Most scientific research on water reallocation does not provide enough data to suggest an operational reallocation strategy. Accordingly, because of the lack of data, the plan assumes $8 million will be dedicated to water reallocation within the agricultural sector and $8 million to water reallocation among the sectors (agriculture, industry and municipality). Funding will support educational programs to increase water users' awareness of efficient use and conservation methods, incentives for farmers to use water resources more efficiently, subsidize small farmers and support research and development activities to overcome internal and external institutional constraints. Water reallocation efforts will not increase water supply; rather they will increase the benefits derived from current water supplies.

Table 20. Distribution of $100 Million among Water Plan Investment Options

| | A.Adm | B. Reallocation | | C. Supply Augmentation | | | | | | D. Water Substitute | Total Cost |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Within agri. | Among Sectors | Des. | Dam | Water Cons. | Imp. | ↓ ET | W.R. | | |
| Y1 | 0.37 / 0 | 0.8 /0 | 0.8 /0 | 3 /0 | 0.1 /0 | 1.5 /0.5 | 0.1 /0 | 0.1 /0 | 1.4 /0 | 0.04 /0 | 8.21 |
| Y2 | 0.612 / 0 | 0.8 /0 | 0.8 /0 | 3 /0 | 0.12 /0 | 1.5 0.5 | 0.13 /0 | 0.15 /0 | 1.4 /0 | 0.04 /0 | 8.552 |
| Y3 | 0.612 / 0 | 0.8 /0 | 0.8 /0 | 3 /0 | 0.15 /0 | 1.5 0.5 | 0.17 /0 | 0.23 /1.5 | 1.4 /0 | 0.07 /- | 8.732 |
| Y4 | 0.612 / 0 | 0.8 /0 | 0.8 /0 | 3 /0 | 0.2 /0 | 1.5 0.5 | 0.2 /0 | 0.32 /1.5 | 1.3 /0 | 0.1 /- | 8.832 |
| Y5 | 0.612 / 0 | 0.7 /0 | 0.7 /0 | 1.2 /8.75 | 0.25 /0 | 0.6 / 3 | 0.25 /5 | 0.7 /2 | 0.75 /9.375 | 0.12 /- | 5.882 |
| Y6 | 0.612 / 0 | 0.6 /0 | 0.6 /0 | 1 /8.75 | 0.35 /0 | 0.5 /3 | 0.3 /5 | 0.75 /2 | 0.7 /9.375 | 0.13 /- | 5.542 |
| Y7 | 0.612 / 0 | 0.5 /0 | 0.5 /0 | 0.9 /8.75 | 0.48 /0 | 0.45 /3 | 0.35 /5 | 0.85 /2.2 | 0.6 /9.375 | 0.15 /- | 5.392 |
| Y8 | 0.612 / 0 | 0.45 /0 | 0.45 /0 | 0.85 /8.75 | 0.6 /0 | 0.425 /3 | 0.4 /5 | 1.1 /2.7 | 0.5 /9.375 | 0.2 /- | 5.587 |
| Y9 | 0.612 / 0 | 0.4 /0 | 0.4 /0 | 0.75/ 8.75 | 0.75 /0 | 0.37 /3 | 0.5 /5 | 1.1 /2.81 | 0.35 /9.375 | 0.25 /- | 5.482 |
| Y10 | 0.612 / 0 | 0.35 /0 | 0.35 /0 | 0.6/8.75 | 1/ 0 | 0.3 /3 | 0.6 /5 | 0.85 /2.95 | 0.28 /9.375 | 0.3 /- | 5.242 |
| Y11 | 0.612 / 0 | 0.3 /0 | 0.3 /0 | 0.5 /8.75 | 1 /20 | 0.25 /3 | 0.6 /5 | 0.75 /3 | 0.25 /9.375 | 0.35 /- | 4.912 |
| Y12 | 0.612 / 0 | 0.28 /0 | 0.28 /0 | 0.45 /8.75 | 0.75 /20 | 0.23 /3 | 0.5 /5 | 0.7 /3.1 | 0.21 /9.375 | 0.4 /- | 4.412 |

Table 20. (Continued)

| | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Y13 | 0.612 / 0 | 0.26 /0 | 0.26 /0 | 0.4 /8.75 | 0.6 /20 | 0.2 /3 | 0.4 /5 | 0.3 / 3.28 | 0.2 /9.375 | 0.45 /- | 3.682 |
| Y14 | 0.612 / 0 | 0.26 /0 | 0.26 /0 | 0.4 /8.75 | 0.6 /20 | 0.2 /3 | 0.4 /5 | 0.3 / 3.28 | 0.2 /9.375 | 0.45 /- | 3.682 |
| Y15 | 0.612 / 0 | 0.21 /0 | 0.21 /0 | 0.3 /8.75 | 0.35 /20 | 0.15 /3 | 0.3 /5 | 0.3 /3.28 | 0.15 /9.375 | 0.6 /- | 3.182 |
| Y16 | 0.612 / 0 | 0.18 /0 | 0.18 /0 | 0.25 /8.75 | 0.25 /20 | 0.13 /3 | 0.25 /5 | 0.3 /3.28 | 0.13 /9.375 | 0.65 /- | 2.932 |
| Y17 | 0.612 / 0 | 0.17 /0 | 0.17 /0 | 0.21 /8.75 | 0.2 /20 | 0.1 /3 | 0.2 /5 | 0.3 /3.28 | 0.1 /9.375 | 0.75 /- | 2.812 |
| Y18 | 0.612 / 0 | 0.05 /0 | 0.05 /0 | 0.08 /8.75 | 0.15 /20 | 0.04 /3 | 0.17 /5 | 0.3 /3.28 | 0.04 /9.375 | 0.9 /- | 2.392 |
| Y19 | 0.612 / 0 | 0.05 /0 | 0.05 /0 | 0.08 /8.75 | 0.12 /20 | 0.04 /3 | 0.13 /5 | 0.3 /3.28 | 0.04 /9.375 | 1 /- | 2.422 |
| Y20 (2030) | 0.612 / 0 | 0.05 /0 | 0.05 /0 | 0.08 /8.75 | 0.1 20 | 0.04 /3 | 0.1 /5 | 0.3 /3.28 | 0.04 /9.375 | 1 /- | 2.372 |
| **Total Cost** | **12** | **8** | **8** | **20** | **8** | **10** | **6** | **10** | **10** | **8** | **100/ 630** |
| **Total Water Gain** | **0** | **0** | **0** | **140** | **160** | **50** | **80** | **50** | **150** | **-** | **630** |

b. Supply Augmentation: The scientific research on water-supply augmentation options offers some data to operationalize the decision-making process associated with supply-augmentation. The decision-maker will use the switch point concept to switch among supply-augmentation options. The least marginal cost supply augmentation option will receive the first funding among supply-augmentation options. Desalination of brackish water has the least MC of $0.54/m$^3$. The capital investment costs and O&M costs for desalination plants were addressed in the scientific literature; about $20 million will be allocated to cover capital investment and operational costs of desalination efforts. Funding will be also used to mitigate ecological and environmental impacts of desalination. At some point the MC of brackish water desalination ($0.54/m$^3$) will start increasing and be not the least MC. A switch to another water-supply augmentation option with a lower MC than desalination MC will be made.

The next least marginal cost options were reducing evapotranspiration, water conservation and wastewater treatment with MC of $0.83/m$^3$, $0.85/ m$^3$ and $1.23/ m$^3$, respectively. $10 million will be allocated for each option, in the absence of workable cost curve data. Evapaotranspiration efforts will focus on research and development, such as supporting efforts to develop technology that will help to reduce evaporation. Water conservation efforts will focus on educational programs to increase consumers' awareness of efficient water use practices. The $10 million funding will also support research and development activities and for conservation activities.

The plan will also fund construction and operation of wastewater treatment plants over 20 years. The funds for wastewater treatment plants have to take risk management into consideration. Risk management involves the risk to human health and the risk of unsatisfactory wastewater treatment.

Construction of dams and water importation had the highest MC, $1.87 and $1.55 respectively. However, $6 million was budgeted for water importation and $8 million for construction of new dams. Funds will cover capital investment and operations for 20-year period for both water importation projects and construction cost for dams. The remaining balance of $100 million will be for research and development related to water storage and dam construction and maintenance.

c. Water Substitutes: Additional research is needed to find substitutes for non-biological water usage. Up to $8 million will be dedicated to identifying efficient, effective substitutions for water in production and consumption activities such as industrial cleaning techniques (cooling) and dry-cleaning applications.

7.3.4. Evaluation/Adaptive Management

Adaptive management monitors the output of a project or plan and modifies plan activities as conditions change. Knowing that uncertainties exist, adaptive management gives decision-makers the flexibility to alter the plan to meet evolving conditions. The water plan will be refined and modified as conditions and technology change. Each of the initial financial allocations is only an estimate to get started. As the planning team is organized and more details are available about each option, the allocations may shift. The possible shifts will be to take advantage of better information, improved technologies, or political circumstances.

Plan evaluation is an important component of strategic planning. The plan evaluation measures/monitors the extent to which the goals and objectives of water management are met and informs stakeholders and funding entities of progress and adaptations. Periodic evaluation of the water plan will insure appropriate modifications of the tasks/options/choices. Moreover, it helps identify areas for improvement and ultimately helps realize goals. The evaluation process facilitates clear communication, and a transparent plan is critical for attracting and retaining support from stakeholder groups.

Each objective in the plan must be evaluated for sustainability and is also an important consideration in the planning, design and construction of water improvement projects. Cost-sharing arrangements, project revenues, water fees and reallocation strategies must be evaluated for sustainability. Sustainability is the potential for long-term maintenance of a plan which has environmental, economic and social dimensions. Plans that lack sustainability do little to address the long-term resolution of water scarcity in FC. Additionally, each task and each project will be evaluated to ensure appropriate sustainability.

### 7.3.5. Sensitivity Analysis

Sensitivity analysis is used to assess how sensitive the outcomes of stochastic or deterministic models are with respect to changes in input values and assumptions. The veracity of outcomes from case studies, such as this, are often better characterized by developing alternative scenarios to demonstrate the magnitude of change in outcomes. Clearly, sensitivity analysis can help present a true picture of the potential gain or loss in the quantity of water per capita under a given set of assumptions.

The principal scenario starts with current water availability in 2010 of 300 MCM for a population of 62 million, for an average of 1,100 m3/year/capita (Chapter 5). This scenario projects steady annual gains totaling 620 MCM over 20 years (2030). Assuming population growth of 3.04% /year would result in 2,270 m3/year/capita of water in the FC. This scenario depicted the FC countries moving up in the Water Poverty Index, as was the overall goal of the plan.

An alternative scenario would be a 'stay even' point. Maintaining 1,100 m3/year/capita in the FC over 20 years, with a predicated population increase of 3.04% would require an additional 159 MCM per year for a total 459 MCM per year. Any outcome less than the 'stay even' scenario will result in less water available per capita and will lower the Water Poverty Index.

Another potential scenario would be a projected increase in water supply of half of the principal scenario. If the total water gain by the end of 20 years was half of the projected 620 MCM, or 310 MCM, the total available water per capita will be about 1,135 m3/year/capita in the FC. The outcomes have a little affect on Water Poverty Index.

Water poverty in the FC over the next two decades is most sensitive to three factors. The first factor is the price of water. The second factor is change in the total available water. The third factor is change in water use efficiencies. Changes in any one or any combination of the three factors could either increase or decrease available water per capita in the FC.

#### 7.3.6. Target Accomplished

Water poverty is an ever-evolving issue that may never be fully resolved. Socio-economic conditions or other unforeseen events may impact either or both re-allocation and supply augmentation options identified in the plan. Changing conditions may lead to the need for a reevaluation of the plan and its strategies and programs in order to meet the water needs in FC countries.

## 7.4. Summary and Conclusion

Water poverty in the FC will likely be a long-term issue. The plan and the process must be adaptive, sustainable and integrated among multiple disciplines to meet the objectives. The strategic plan to allocate the budget among the water-reallocation option, supply augmentation and substitution has to incorporate the role of each policy board, executive committee, management staff, technical group and consultant in making decision. Programs, plans and strategies must be adaptive.

# CHAPTER 8. SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

This chapter presents the summary, conclusions, recommendations and policy implications. The summary will provide an overview of the study. The conclusion will detail key findings. The recommendations and policy implications section will address public policy issues and provide recommendation on specific issues and provide insight advice for decision-makers.

## 8.1. Summary

As the population in the FC region grows, the demand for water resources will also grow. The challenge for FC countries is to meet this demand given scarce water resources. Strategies to deal with water shortages in the FC depend on local conditions, including topography, water-scarcity threshold, available financial resources, and technical and institutional capacity. A mix of strategies that manages demand, reallocates water resources, increases supply and identifies water substitutes to reduce long-term water scarcity for the next two decades is needed.

The agricultural sector will likely continue to be the dominant user of water in the FC countries. However, intense competition for quality water among the municipal and industrial sectors is expected to potentially reduce the amount of freshwater allocated to agriculture in the future. Even with more efficient use of water for agriculture uses, FC countries are expected to become increasingly dependent on non-conventional water resources to augment water supplies for agriculture in order to ensure food security for the region.

A strategic plan is an important tool that helps decision-makers ensure that social, economic, environmental and technical issues and limitations are considered in the management and development of FC water resources. A strategic plan identifies existing water supplies, water supply augmentation options and water substitutes in order to mitigate water scarcity over the next two decades. An integrated strategic plan optimizes society's investment among water reallocation options, supply augmentation and substitution, while also identifying internal and external constraints. A plan that incorporates adaptive management principles is a useful tool for the FC's decision-makers and also addresses water scarcity, both now and in the future. Ultimately, if successful an integrated strategic plan should increase social welfare from water use in the FC.

## 8.2. Conclusions

Alleviating water poverty will require an extraordinary effort and immediate action from the decision-makers in the FC countries. Expanding populations in the FC will add to the challenge of reducing water scarcity. Water poverty however can be reduced by good planning and adequate financial support. Water poverty can also be addressed by more efficient use of new and innovative water sources.

Much scientific literature attempts to address the water-scarcity problem in the FC by using various economic, engineering and policy tools, none of which are adequate on their own to address water-scarcity in the FC. Individual tools from various disciplines must be integrated to solve issues of water scarcity in FC. Additional analytical and empirical research in the field of economics, engineering and water policy is needed to close the gap between scientific theory and real world implementation.

Regional political, legal, cultural and institutional support from FC countries is needed to address water shortages. Without strong cooperation among all countries socio-economic considerations may hamper efforts to address water scarcity in the region. The fact that water is absolutely vital may however force the creation of what could be a powerful coalition of academic, business and financial institutions, political regulations and societal leaders. Regional cooperation will be critical to ensure the effective adoption of water demand management. In addition to regional cooperation, the FC countries will need to devote considerable resources for development and maintenance of water infrastructure.

### 8.3. Recommendations and Policy Implications

A comprehensive assessment of the socioeconomic dimensions of the strategic plan for water should be conducted. A portfolio of socioeconomic interventions should be developed to support the water-management concepts detailed in the plan. These interventions should be designed to mitigate the complex political, social, economic and environmental characteristics of the region.

In order for a strategic plan to be useful, there must be public support for the planning projects. The process must be open and accessible to all stakeholders. The strategic plan has to engage the management and technical staff in the implementation process.

All public districts will create monitoring and transparent mechanisms to ensure that the strategic plan is on track. The decision-makers can prepare a draft procedure that addresses all the significant items. The planning team has to keep digging to find more funds and support from international/national agencies. In other words, more funds and grants are needed to provide financial assistance to pay for the water plan. The funds will be used to pay the direct planning costs and to recover the administrative costs.

The planning process begins with the collection and analyses of information from many disciplines related to water management including: economics, engineering, hydrology and political science. No one field of study will be able to effectively address, mitigate or ultimately solve water scarcity issues in FC. Additional research is needed to integrate research from the various disciplines.

Immigration policies and economic development strategies in the FC and their effect on water poverty should be examined. Liberal immigration policies and economic development, especially unsustainable development, will further strain existing supplies. An evaluation and potential modification of immigration policies and a check on rapid urbanization may reduce the long-term water resources pressure.

To address water poverty in the FC an integrated water plan is required that takes into consideration, available water supply, water use and demand, financial constraints, political and cultural constraints. A collaborative effort among various technical and academic disciplines, as well as regional cooperation among countries and various political, regional and cultural institutions is needed. When used properly, strategic planning can be an important and valuable tool to assess current water use trends, evaluate future needs and identify alternatives that will insure the region's water needs are met.

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## APPENDIX A

Table A.1. Basic Statistics and Water Sources and Uses in Iraq

| Items | Year | Amount | Unit |
|---|---|---|---|
| Area of the country | 2005 | 43,832,000 | Ha |
| Cultivated area | 2005 | 6,010,000 | Ha |
| Total population | 2005 | 28 807 000 | inhabitants |
| Population density | 2005 | 65.7 | inhabitants/km$^2$ |
| Population economically active in agriculture | 2005 | 651,000 | inhabitants |
| Gross Domestic Product (GDP) (current US$) | 2000 | 25,860 | million US$/yr |
| value added in agriculture (% of GDP) | 2000 | 5 | % |
| Precipitation (long term average) | - | 216 | mm/yr |
| Internal renewable water resources (long-term average) | - | 35.2 | $10^9$ m$^3$/yr |
| Total actual renewable water resources | - | 75.61 | $10^9$ m$^3$/yr |
| Dependency ratio | - | 53.45 | % |
| Total actual renewable water resources per inhabitant | 2005 | 2,625 | m$^3$/yr |
| Total dam capacity | 2000 | 139,700 | $10^6$ m$^3$ |
| Total water withdrawal | 2000 | 66,000 | $10^6$ m$^3$/yr |
| Water withdrawal for irrigation + livestock | 2000 | 52,000 | $10^6$ m$^3$/yr |
| Water withdrawal for municipalities | 2000 | 4,300 | $10^6$ m$^3$/yr |
| Water withdrawal for industry | 2000 | 9,700 | $10^6$ m$^3$/yr |
| Water withdrawal per inhabitant | 2000 | 2,632 | m$^3$/yr |
| Surface water and groundwater withdrawal | 2000 | 64,493 | $10^6$ m$^3$/yr |
| Produced wastewater | - | - | $10^6$ m$^3$/yr |
| Treated wastewater | - | - | $10^6$ m$^3$/yr |
| Reused treated wastewater | - | - | $10^6$ m$^3$/yr |
| Desalinated water produced | 1997 | 7.4 | $10^6$ m$^3$/yr |
| Reused agricultural drainage water | 1997 | 1500 | $10^6$ m$^3$/yr |
| Area of Euphrates-Tigris Basin | 2005 | 879,790 | km$^2$ |
| Area of Iraq in Euphrates-Tigris Basin | 2005 | 407,880 | km$^2$ |

Source: FAO, 2009.

Table A.2. Basic Statistics and Water Sources and Uses in Israel

| Items | Year | Amount | Unit |
|---|---|---|---|
| Area of the country | 2008 | 2,077,000 | Ha |
| Cultivated area | 2005 | 392,000 | Ha |
| Total population | 2005 | 6,725,000 | inhabitants |
| Population density | 2005 | 323.8 | inhabitants/$km^2$ |
| Population economically active in agriculture | 2005 | 64,000 | inhabitants |
| Gross Domestic Product (GDP) (current US$) | 2007 | 161,820 | million US$/yr |
| value added in agriculture (% of GDP) | 2005 | 1.8 | % |
| Precipitation (long term average) | - | 435 | mm/yr |
| Internal renewable water resources (long-term average) | - | 0.75 | $10^9$ $m^3$/yr |
| Total actual renewable water resources | - | 1.78 | $10^9$ $m^3$/yr |
| Dependency ratio | - | 57.87 | % |
| Total actual renewable water resources per inhabitant | 2005 | 265 | $m^3$/yr |
| Total dam capacity | - | - | $10^6$ $m^3$ |
| Total water withdrawal | 2004 | 1,954 | $10^6$ $m^3$/yr |
| Water withdrawal for irrigation + livestock | 2004 | 1,129 | $10^6$ $m^3$/yr |
| Water withdrawal for municipalities | 2004 | 712 | $10^6$ $m^3$/yr |
| Water withdrawal for industry | 2004 | 113 | $10^6$ $m^3$/yr |
| Water withdrawal per inhabitant | 2004 | 296 | $m^3$/yr |
| Surface water and groundwater withdrawal | 2004 | 1,552 | $10^6$ $m^3$/yr |
| Produced wastewater | 2005 | 450 | $10^6$ $m^3$/yr |
| Treated wastewater | 2005 | 283 | $10^6$ $m^3$/yr |
| Reused treated wastewater | 2002 | 262 | $10^6$ $m^3$/yr |
| Desalinated water produced | 2007 | 140 | $10^6$ $m^3$/yr |
| Reused agricultural drainage water | - | - | $10^6$ $m^3$/yr |
| Area of Jordan River Basin | 2005 | 18,500 | $km^2$ |
| Area of Israel in Jordan River Basin | 2005 | 6,830 | $km^2$ |

Source: FAO, 2009.

Table A.3. Basic Statistics and Water Sources and Uses in Jordan

| Items | Year | Amount | Unit |
|---|---|---|---|
| Area of the country | 2005 | 8,878,000 | Ha |
| Cultivated area | 2005 | 270,000 | Ha |
| Total population | 2005 | 5,703,000 | inhabitants |
| Population density | 2005 | 64.2 | inhabitants/$km^2$ |
| Population economically active in agriculture | 2005 | 194,000 | inhabitants |
| Gross Domestic Product (GDP) (current US$) | 2007 | 15,830 | million US$/yr |
| value added in agriculture (% of GDP) | 2007 | 3 | % |
| Precipitation (long term average) | - | 94 | mm/yr |
| Internal renewable water resources (long-term average) | - | 0.682 | $10^9$ $m^3$/yr |
| Total actual renewable water resources | - | 0.937 | $10^9$ $m^3$/yr |
| Dependency ratio | - | 27.21 | % |
| Total actual renewable water resources per inhabitant | 2005 | 161 | $m^3$/yr |
| Total dam capacity | 2007 | 275 | $10^6$ $m^3$ |
| Total water withdrawal | 2005 | 940.9 | $10^6$ $m^3$/yr |
| Water withdrawal for irrigation + livestock | 2005 | 611.2 | $10^6$ $m^3$/yr |
| Water withdrawal for municipalities | 2005 | 291.3 | $10^6$ $m^3$/yr |
| Water withdrawal for industry | 2005 | 38.4 | $10^6$ $m^3$/yr |
| Water withdrawal per inhabitant | 2005 | 165.0 | $m^3$/yr |
| Surface water and groundwater withdrawal | 2005 | 847.6 | $10^6$ $m^3$/yr |
| Produced wastewater | - | - | $10^6$ $m^3$/yr |
| Treated wastewater | 2005 | 107.4 | $10^6$ $m^3$/yr |
| Reused treated wastewater | 2005 | 83.5 | $10^6$ $m^3$/yr |
| Desalinated water produced | 2005 | 9.8 | $10^6$ $m^3$/yr |
| Reused agricultural drainage water | - | - | $10^6$ $m^3$/yr |
| Area of Jordan River Basin | 2005 | 18,500 | $km^2$ |
| Area of Jordan in Jordan River Basin | 2005 | 7,470 | $km^2$ |
| Area of Jordan in Euphrates-Tigris River Basin | 2005 | 220 | $km^2$ |

Source: FAO, 2009.

Table A.4. Basic Statistics and Water Sources and Uses in Lebanon

| Items | Year | Amount | Unit |
|---|---|---|---|
| Area of the country | 2005 | 1,040,000 | Ha |
| Cultivated area | 2005 | 328,000 | Ha |
| Total population | 2005 | 3,57, 000 | inhabitants |
| Population density | 2005 | 343.9 | inhabitants/$km^2$ |
| Population economically active in agriculture | 2005 | 35,000 | inhabitants |
| Gross Domestic Product (GDP) (current US$) | 2007 | 24,000 | million US$/yr |
| value added in agriculture (% of GDP) | 2007 | 6 | % |
| Precipitation (long term average) | - | 823 | mm/yr |
| Internal renewable water resources (long-term average) | - | 4.800 | $10^9$ $m^3$/yr |
| Total actual renewable water resources | - | 4.503 | $10^9$ $m^3$/yr |
| Dependency ratio | - | 0.79 | % |
| Total actual renewable water resources per inhabitant | 2005 | 1,259 | $m^3$/yr |
| Total dam capacity | 2007 | 225.65 | $10^6$ $m^3$ |
| Total water withdrawal | 2005 | 1,310 | $10^6$ $m^3$/yr |
| Water withdrawal for irrigation + livestock | 2005 | 780 | $10^6$ $m^3$/yr |
| Water withdrawal for municipalities | 2005 | 380 | $10^6$ $m^3$/yr |
| Water withdrawal for industry | 2005 | 150 | $10^6$ $m^3$/yr |
| Water withdrawal per inhabitant | 2005 | 366 | $m^3$/yr |
| Surface water and groundwater withdrawal | 2005 | 1,096 | $10^6$ $m^3$/yr |
| Produced wastewater | 2001 | 310 | $10^6$ $m^3$/yr |
| Treated wastewater | 2006 | 4 | $10^6$ $m^3$/yr |
| Reused treated wastewater | 2006 | 2 | $10^6$ $m^3$/yr |
| Desalinated water produced | 2006 | 47.3 | $10^6$ $m^3$/yr |
| Reused agricultural drainage water | 2001 | 165 | $10^6$ $m^3$/yr |
| Area of Jordan River Basin | 2005 | 18,500 | $km^2$ |
| Area of Lebanon in Jordan River Basin | 2005 | 670 | $km^2$ |

Source: FAO, 2009.

Table A.5. Basic Statistics and Water Sources and Uses in Syria

| Items | Year | Amount | Unit |
|---|---|---|---|
| Area of the country | 2005 | 18,518,000 | Ha |
| Cultivated area | 2005 | 5,742,000 | Ha |
| Total population | 2005 | 19,043,000 | inhabitants |
| Population density | 2005 | 102.8 | inhabitants/km$^2$ |
| Population economically active in agriculture | 2005 | 1,690,000 | inhabitants |
| Gross Domestic Product (GDP) (current US$) | 2007 | 38,080 | million US$/yr |
| value added in agriculture (% of GDP) | 2007 | 20 | % |
| Precipitation (long term average) | - | 252 | mm/yr |
| Internal renewable water resources (long-term average) | - | 7.132 | $10^9$ m$^3$/yr |
| Total actual renewable water resources | - | 16.797 | $10^9$ m$^3$/yr |
| Dependency ratio | - | 72.29 | % |
| Total actual renewable water resources per inhabitant | 2005 | 882 | m$^3$/yr |
| Total dam capacity | 2007 | 19,654 | $10^6$ m$^3$ |
| Total water withdrawal | 2003 | 16,690 | $10^6$ m$^3$/yr |
| Water withdrawal for irrigation + livestock | 2003 | 14,669 | $10^6$ m$^3$/yr |
| Water withdrawal for municipalities | 2003 | 1,426 | $10^6$ m$^3$/yr |
| Water withdrawal for industry | 2003 | 595 | $10^6$ m$^3$/yr |
| Water withdrawal per inhabitant | 2003 | 921 | m$^3$/yr |
| Surface water and groundwater withdrawal | 2003 | 13,894 | $10^6$ m$^3$/yr |
| Produced wastewater | 2002 | 1,364 | $10^6$ m$^3$/yr |
| Treated wastewater | 2002 | 550 | $10^6$ m$^3$/yr |
| Reused treated wastewater | 2002 | 550 | $10^6$ m$^3$/yr |
| Desalinated water produced | - | - | $10^6$ m$^3$/yr |
| Reused agricultural drainage water | 2004 | 2,246 | $10^6$ m$^3$/yr |
| Area of Jordan River Basin | 2005 | 18,500 | km$^2$ |
| Area of Syria in Jordan River Basin | 2005 | 1,910 | km$^2$ |
| Area of Syria in Euphrates-Tigris River Basin | 2005 | 96,420 | km$^2$ |

Source: FAO, 2009.

Table A.6. Basic Statistics and Water Sources and Uses in Palestinian Territories (West Bank +Gaza Strip)

| Items | Year | Amount | Unit |
|---|---|---|---|
| Area of the country | 2005 | 1,167,500 | Ha |
| Cultivated area | 2005 | 388,702 | Ha |
| Total population | 2005 | 6,004,2000 | inhabitants |
| Population density | 2005 | 1,022,1 | inhabitants/$km^2$ |
| Population economically active in agriculture | 2005 | 108,000 | inhabitants |
| Gross Domestic Product (GDP) (current US$) | 2007 | 4,010 | million US$/yr |
| value added in agriculture (% of GDP) | 2000 | 9.5 | % |
| Precipitation (long term average) | - | 709 | mm/yr |
| Internal renewable water resources (long-term average) | - | 0.812 | $10^9$ $m^3$/yr |
| Total actual renewable water resources | - | 0.837 | $10^9$ $m^3$/yr |
| Dependency ratio | - | 35.2 | % |
| Total actual renewable water resources per inhabitant | 2005 | 384 | $m^3$/yr |
| Total dam capacity | 1997 | 0.0 | $10^6$ $m^3$ |
| Total water withdrawal | 2000 | 290 | $10^6$ $m^3$/yr |
| Water withdrawal for irrigation + livestock | 2000 | 174 | $10^6$ $m^3$/yr |
| Water withdrawal for municipalities | 2000 | 101.4 | $10^6$ $m^3$/yr |
| Water withdrawal for industry | 2000 | 14.4 | $10^6$ $m^3$/yr |
| Water withdrawal per inhabitant | 2000 | 219 | $m^3$/yr |
| Surface water and groundwater withdrawal | 2000 | 280 | $10^6$ $m^3$/yr |
| Produced wastewater | - | - | $10^6$ $m^3$/yr |
| Treated wastewater | 1998 | 10 | $10^6$ $m^3$/yr |
| Reused treated wastewater | - | - | $10^6$ $m^3$/yr |
| Desalinated water produced | - | - | $10^6$ $m^3$/yr |
| Reused agricultural drainage water | - | - | $10^6$ $m^3$/yr |
| Area of Jordan River Basin | 2005 | 18,500 | $km^2$ |
| Area of Palestine Territories in Jordan River Basin | 2005 | 1,620 | $km^2$ |

Source: FAO, 2009.

## APPENDIX B

Table B.1. Prices of Supply-Augmentation Options for Different Years

| Supply Augmentation Options | Prices for different years (Nominal) ($\$/M^3$) | | |
|---|---|---|---|
| Brackish desalination | 0.8 (2001) | | 0.650 (2004) |
| Sea water desalination | 1.2 (2001) | | 1.270 (2004) |
| Water importation | 0.95 (1999) | | 1.045 (2004) |
| Building storage dams | 1.29 (1997) | 1.36 (2000) | 1.411 (2004) |
| Wastewater Reuse | 0.75 (2001) | | 1.038 (2004) |
| Water conservation | 0.62 (2000) | | 0.730 (2004) |
| Reducing ET | 1.3 (1976) | 0.8 (1988) | 0.65 (2004) |

Source: Davenport et al. (1976); Gay (1988); FAO (2008); Al-Mutaz (2005); El-Sadek (2010); Friedman (2004); Yedioth (2004); Arlosoroff (2004) and Mohsen (2007)

## APPENDIX C

Table C.1. Average Salary per Year for the Administration Staff and Technical Team Involved in Water Plan Project

| **Administration staff** | **Avg. Salary/year** |
|---|---|
| Secretary | 10,000 |
| Public relations | 40,000 |
| Legal consultants | 50,000 |
| Office manager | 100,000 |
| Accountant | 30,000 |
| Extension specialist | 50,000 |
| Office rent +utilities | 15,000 |
| Travel expenses | 25,000 |
| **Total** | **320,000** |
| **Technical team** | **Avg. Salary/year** |
| GIS specialist | 35,000 |
| DSS specialist | 30,000 |
| Economists | 60,000 |
| Water engineering | 55,000 |
| Social specialist | 42,000 |
| Environmentalist | 70,000 |
| **Total** | **292,000** |
| **Overall Total** | **612,000** |

Source: United Nations (2010).

## APPENDIX D

Table D.1. The Ashkelon Plant's Average Base Total Water Price

| Cost item | $/m$^3$ | % of total water price |
|---|---|---|
| Base fixed price | 0.31 | 58% |
| Base variable price | | |
| Energy | 0.14 | 26% |
| Membranes | 0.28 | 5.4% |
| Filters | 0.50 | 0.9% |
| Chemicals | 0.21 | 4.1% |
| Post-treatment | 0.90 | 1.8% |
| Others | 0.17 | 3.2% |
| **Subtotal** | **0.22** | **42%** |
| **Base total water price** | **0.53** | **100** |

Source: Dreizin (2006).

Table D.2. The Israeli Government's Total Assumed Project Costs

| Item | Annual costs or allowance | Unit costs | % of total water price |
|---|---|---|---|
| **Unit** | **\$/year** | **\$/m3** | **%** |
| Initial investments | | | |
| Administration and supervision | $0.1\times10^6$ | 0.01 | 0.2 |
| Out-of-plant infrastructure | $2.0\times10^6$ | 0.20 | 3.5 |
| Subtotal | $2.1\times10^6$ | 0.21 | 3.7 |
| Annual running costs | | | |
| Chlorination | $0.2\times10^6$ | 0.02 | 0.4 |
| Product pumping | $3.1\times10^6$ | 0.31 | 5.4 |
| Infrastructure O&M | $0.2\times10^6$ | 0.02 | 0.4 |
| Supervisory and administrative | $0.2\times10^6$ | 0.02 | 0.3 |
| **Subtotal** | **$3.7\times10^6$** | **0.37** | **6.5** |
| Allowances for costs related to government assumed project risks | | | |
| Necessary idling of plant capacity | $1.0\times10^6$ | 0.1 | .8 |
| Uninsured events of Force Majeure | $0.6\times10^6$ | 0.06 | 1.0 |
| Costs related to termination due to default by Seller | $1.5\times10^6$ | 0.15 | 2.5 |
| **Subtotal** | **$3.1\times10^6$** | **0.31** | **5.3** |
| **Total** | **$8.9\times10^6$** | **0.89** | **15.5** |

Source: Dreizin (2006).

Table D.3. The As-Samra Wastewater Treatment Plant Cost of Treatment ($/m³)

| Items | Cost ($/m$^3$) |
|---|---|
| Salary | 166700 |
| Electricity | 600000 |
| Water | 10000 |
| Spare parts | 14300 |
| Chemicals and chlorine | 7200 |
| Sludge disposal | 0 |
| Fuel and oil | 10720 |
| Pesticides | 14300 |
| Others | 77350 |
| **Total costs** | **900570** |

Source: Al-Zu'bi, 2007

Table D.4. Costs of Monolayers Application to Reduce Evaporation Between 6% and 20% for a Water Body of 75 $km^2$

| Items | Costs ($) |
|---|---|
| Product cost | 9.45 million |
| Application cost | 600,000 |
| Storage facility costs | 602,000 |
| Transport costs | 551,000 |
| Salary/Office costs | 1.247 million |
| **TOTAL annual costs** | **12.45 million** |

Source: Barnes (2008).