An-Najah National University

Faculty of Graduate Studies

DEVELOPMENT OF SUSTAINABLE MANAGEMENT OPTIONS FOR THE WEST BANK WATER RESOURCES USING WEAP

By

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DEDICATED TO MY LOVELY FAMILY, TO ALL WITH LOVE

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ABSTRACT

Palestinians are living under conditions of repressed demand as result of the limitations on supply and restrictions on new water resources development due to the Israeli imposed military control over Palestinian water resources. The West Bank lacks proper water infrastructure resulted in huge losses in the delivery of water or unaccounted for water. Moreover, there is a significant shortage of capital for new infrastructure. The prevailing system of uncoordinated water resources management in the West Bank cannot sustain the ever-increasing water needs.

The study methodology consists of three components (1) data gathering and review (2) stakeholders field survey that determined key planning issues and questions needed and (3) WEAP model that aided to evaluate water resource management options for the West Bank.

The results obtained showed that water demand varies significantly according to the assumed political situation, and underlined the importance role of water management aspects. Also the results revealed that an additional amounts more than 700 MCM is needed to satisfy water needs and development, otherwise the gap between demand and supply will grow dramatically if current supply conditions continued. The results confirmed that WEAP can be applied as a decision support system (DSS) tool for the water resource management in the West Bank.

CHAPTER ONE

INTRODUCTION

1.1. IMPORTANCE OF THE STUDY

Water is needed in all aspects of life. The general objective is to make certain that adequate supplies of water of good quality are maintained for the entire population of this planet, while preserving the hydrological, biological and chemical functions of ecosystems, adapting human activities within the capacity limits of nature and combating vectors of water-related diseases. Innovative technologies, including the improvement of indigenous technologies, are needed to fully utilize limited water resources and to safeguard those resources against pollution. (UN, 1999)

The prevailing system of uncoordinated water resources management in the West Bank cannot sustain the ever-increasing water needs. Fast growing population, rapid urbanization, food security polices and the expansion of development and economic activities exert pressure on available water resources. Israeli military occupation restricting access to water created a consistent challenge in providing a continuous supply of clean fresh water and sanitation, since Israel has controlled water utilization development in the West Bank. In addition to the uncertainties of climate change which require integrated water management to handle water availability different situations. Sustainability, equity, public health, environmental protection, and economics are key factors.

Within the limits of water availability and/or accessibility, it appears that some water users are not able to meet all their requirements. This encourages the adaptation of the methodology of Water Resource Management which offers the best means of reconciling competing demands with supplies, integrates the various needs against the available water resources, helps us achieve a sustainable development, and ensures a better balance between efficiency, sustainability and equity needs in water allocations.

1.2. Objective

The objective of the work is to evaluate management options for West Bank water resources using Water Evaluation and Planning System (WEAP). This model will help to identify water resource management options under different scenarios which in turn will help to identify and implement effective solutions to many water-related problems in the West Bank. Also this work will test WEAP capabilities as management tool.

1.3. Methodology

To achieve the objectives outlined for this study, the following activities were performed.

- Data collection to define the current situation of the water system.
- Review of available data and water management previous studies
- Assessment of the water system state addressing the different aspects
- Building a conceptual water management model and obtaining its output
- Conducting a field questionnaire aimed to identify the community priorities and attitudes towards different water management options.
- Defining alternative water resources management options for the West Bank.
- Forecast the behavior of the water system state, on the basis of assumed or envisaged scenarios of water availability and demands.
- Evaluate the impacts of the actions, by observing and analyzing the results.

CHAPTER TWO

LITERATURE REVIEW

2.1. General

Planning, developing, and managing water resources to ensure adequate, inexpensive and sustainable supplies and qualities of water for both humans and natural ecosystems can only be successful if such activities address the causal socioeconomic factors, such as inadequate education, population pressures and poverty.(Loucks,2005)

Water management must be undertaken using an integrated approach that can achieve social equity, sustainable environment, and the economic efficiency, makes identifying and implementing effective solutions much easier, avoids poor investments and expensive mistakes ensuring maximum returns both social and economic on investments, and allocates water strategically improving the efficiency in water use (GWP, 2004)

Integrated Water Resources Management (IWRM) is defined as" a process, which promotes the coordinated development and management of water, land and related resources, in order to maximize the resultant economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems" (GWP, 2000)

2.2. IWRM Basic Principles

Dublin Statement on Water and Sustainable Development, International Conference on Water and Environment, 1992, addressed four guiding principles

- Fresh water is a finite and vulnerable resource, essential to sustain life, development and the environment.
- Water development and management should be based on a participatory approach, involving users, planners and policy-makers at all levels.

- Women play a central part in the provision, management and safeguarding of water.
- Water has an economic value in all its competing uses and should be recognized as an economic good. (Loucks, 2005)

2.3. MANAGEMENT INSTRUMENTS:

Management Instruments are the elements and methods that enable and help decision makers to make rational and informed choices between alternative actions, selecting, adjusting and applying the mix appropriate to the given circumstances.

- Water resources assessment: Understanding resources and needs including the collection of data.
- Planning: combining development options, water uses and human interaction, and modeling of data from all relevant domains putting into mind social, economic and environmental needs
- Supply and demand management: using water more efficiently that balances supply and demand, focusing on the better use of existing water withdrawals or reducing excessive use rather than developing new supplies.
- Social change instruments: encouraging a water-oriented civil society.
- Conflict resolution: managing disputes, ensuring sharing of water.
- Regulatory instruments: allocation and water use limits. Regulation in this context covers water quality, service provision, land use and water resource protection
- Economic instruments: using value and prices for efficiency and equity. Economic tools involve the use of prices, subsidies, and other market-based measures to provide incentives to all water users to use water carefully, efficiently and avoid pollution.

2.4. WATER RESOURCES MANAGEMENT IN THE WEST BANK

The Palestinian Water Authority (PWA) and the National Water Council (NWC) are in charge of implementing any water management strategy. The PWA is the central water authority. It is responsible for strategic planning, monitoring and oversight, policy implementation, regulation, water rights negotiations, ensuring the equitable utilization and sustainable management of Palestinian water resources. The local ministries, utilities, and water users associations are responsible for the actual implementation of the PWA national water plan. While the PWA is effectively the primary water agency, the NWC is officially the highest body within the Palestinian Authority regarding water issues.

Water supply management is shared by Israeli Authorities and the Palestinian Water Authority (PWA). The proposed water projects must be approved by the Joint Water Committee (JWC)[1]; a procedure that obstructs and delays water development projects, since they are subjected to Israeli approval.

The bad economic situation restrains water development projects, since that Palestinian economy is highly dependent on donors and can't afford by itself development projects; in addition to that projects are unsustainable due to the inefficient implementation of "full cost recovery" principle.

Conveyance between districts does not exist due to the absence of national water distribution grid, many communities haven't water piped network among many others that haven't sewerage networks, lack of storage facilities, and high rate of losses magnifies the problem resulting in a very poor infrastructure, besides the repeated Israeli aggressions on the infrastructure causing huge damage.

[1]JWC was established as part of the OsloΠ agreement and it is composed of equal number of representatives from each side of Palestinians and Israelis

Accelerating Water need rates exert huge pressure on the present available water supply which is restricted by Israeli military laws; this resulted in the growing competition on water resources between sectors. Palestinian agriculture is not subsidized by the government and therefore farmers pay high price for their water resulted in limiting the productivity of agriculture.

There is a significant lack of water management due to political constrains, economical factors, and others that restricts development. This encourages the adaptation of the methodology of Water Resource Management which offers the best means to moderate the situation, integrating various needs against available resources, helping to achieve a sustainable development, and ensuring better balance between efficiency, sustainability and equity needs in water allocations.

2.5. PREVIOUS WATER STUDIES IN WEST BANK

Numerous studies was carried out in order to assess and evaluate water availability, and to develop demand supply system. Following are some studies that are done that can serve and enrich this study.

Article 40 (Water Resources) of the Oslo Accords

Article 40 of Oslo Π Agreement, signed on September, 1995, is the basis for water sector planning and project implementation. This binding agreement regarding water and wastewater became the basis for water sector planning during the “interim period” and until the final agreement was reached. The original plan states that the interim period should not exceed 5 years from the date of the signing of Oslo 2. It states “recognizes the Palestinian water rights in the West Bank.” These rights will be settled in the permanent status agreement after the final negotiations.

Middle East Regional Study on Water Supply and Demand Development (1996, 1997)

The main objectives of this regional study is to develop specific proposals for the provision of additional water resources on the basis of a comprehensive demand forecast, and to develop a concept for a coordinated future management of all regional water sectors. The study was carried out by Palestinian, Jordanian, and Israeli study teams in three phases. It defined the regional net water gap after full utilization of all available conventional resources, and analyzed the various options to bridge the gap. (GTZ[2], 1996, GTZ, 1997)

Comprehensive Planning Framework for Palestinian Water Resources Development (1997)

The report provides a framework for development and utilization of water resources in West Bank and Gaza Strip through the year 2040. It presents "the rationale and details of alternative plans relating to several possible scenarios for meeting water demands. Information and data discussed in this study include estimates of the total water supply, baseline and projected water demand, and renewable water resources available for development (CDM/Morganti[3], 1997)

Regional Plan for the West Bank Governorates (1998):

Water and Wastewater Existing Situation: This study, developed by the Ministry of Planning and International Cooperation (MOPIC), provides comprehensive, descriptive and quantitative information concerning the existing situation of water resources, water supply, water quality, wastewater collection, and wastewater treatment at a governorate level of the West Bank. (MOPIC, 1998)

[2] Deutsche Gesellschaft für Technische Zusammenarbeit GmbH
[3] Camp Dresser & McKee International Inc. Team

Water Sector Strategic Planning Study (2000)

The study builds upon the resource analysis and supply and demand estimations presented by CDM/Morganti. It provides a comprehensive database of projects to be implemented in order to meet anticipated water demand through 2020. In addition, this study asserts specific goals, objectives, policies, and priorities recommended for adoption by the Palestinian water sector. (Carl Bro International, 2000)

National Water Plan (2000):

The National Water Plan (NWP) is a strategic document developed to provide guidance for development of the Palestinian water sector. The document provides important insight to the Palestinian vision for water sector growth. It includes descriptions of the legal and institutional framework, the tariff structure, the basis for water rights, general management strategies, and a detailed investment. (PWA, 2000)

West Bank Integrated Resources Management Plan (2003)

This study provides an overall strategy and vision for water sector development integrating all available resources and requirements of all water sectors stakeholders. The study represents a guideline for the water sector development. It outlines PWA goals, objectives and polices for the water sector, and provides master planning detail to guide water infrastructure development. (CH2M HILL[4], 2003)

[4] CH2M HILL is a global project delivery firm providing strategically integrated services to public and private sector clients in water resources, water and wastewater facilities design, construction and operations, and environmental, telecommunications and transportation services, as well as related infrastructure

SUSMAQ[5] (Sustainable Management of the West Bank and Gaza Aquifers, Management Options Report, 2003)

This study aims to understand the behavior of sustainable yield of the West Bank and Gaza aquifers under different economic, demographic and land use scenarios, and evaluate the alternative groundwater management options. It focuses on groundwater as a principle source of water in Palestine. It didn't refer to Jordan River as a source of surface water, the Palestinian have the right to make use of it. (British Geology Survey. 2003)

Liquid Assets (An Economic Approach for Water Management and Conflict Resolution in the Middle East and Beyond, 2005)

The study provides an important concept based on the value and economics of water and describes how that mode of thinking can lead to a powerful optimizing tool for water management and the analysis of water policy and infrastructure. It forms an economic approach for water management and conflict resolution in the Middle East and beyond. (Fisher, 2005)

2.6. WATER RESOURCES MANAGEMENT MODELING

Modeling of water conditions in a given area is a simplified description of the real system to assist calculations and predictions used to estimate the amount of water that is needed to meet the existing and projected demands under potential availability and demand scenarios, and determine what interventions are necessary, as well as when and where, and their cost. Models can represent the important interdependencies and interactions among the various control

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[5] A partnership project between Palestinian Water Authority and University of Newcastle and the British Geological Survey funded by the United Kingdom's Department for International Development

structures and users of a water system; in addition they can help identify the decisions that best meet any particular objective and assumptions.

The two principal approaches to modeling are simulation of water resources behavior based on a set of rules governing water allocations and infrastructure operation; and optimization of allocations based on an objective function and accompanying constraints. Simulation models address what if questions. Their input data define the components of the water system and their configuration and the resulting outputs can identify the variations of multiple system performance indicator values. Simulation works only when there are a relatively few alternatives to be evaluated. Optimization models are based on objective functions of unknown decision variables that are to be maximized or minimized. The constraints of the model contain decision variables that are unknown and parameters whose values are assumed known. Constraints are expressed as equations and inequalities.

The DSS supports the user to assess the functionality and performance of the water system within the entire region of application as well as individual points of interest. (Loucks, 2005)

2.7. Water Management Models

Different models are developed for water resources management. There are two basic types of optimization approaches: hydrology inferred optimization models that optimize allocations based on hydrologic specifications and economic optimization models that optimize allocations based on economic considerations. Other criteria, such as equity or environmental quality can also be used. In this study a model that optimizes allocation based on equity rather than economic considerations was adopted, keeping in mind the economic and environmental considerations. Following are some models with a brief description of their suitability to achieve our needs from modeling.

Water Evaluation and Planning System (WEAP): WEAP is a general multi-purpose, multi-reservoir simulation program which determines the optimal allocation of water for each time-step according to demand priorities and supply preference. It operates at a monthly time step on the basic principle of water balance accounting.

The model can represent any water resource system incorporating natural inflows, precipitation, evaporation, and evapotranspiration as input data. Operational features that can be represented include storage and release of water by reservoirs, physical discharge controls at reservoir outlets, water flow in channels, consumptive demands, and hydropower releases. These operational features can be specified as steady-state or time-varying.

An intuitive graphical interface provides a simple yet powerful means for constructing, viewing and modifying the system and its data. In addition, WEAP allows users to develop their own set of variables and equations to further refine and adapt the analysis to local constraints and conditions with possible data exchange with other software such as excel (SEI, 2005)

The Water Allocation System Model (WAS): It is an annual steady state model with extraction from water sources limited to annual renewable amounts. Seasonal variation and multiyear issues are not modeled. It is assumed that each source of supply has an annual renewable and a constant extraction cost per cubic meter up to that amount. Different sources can be drawn on the same water resource (e.g. the same river or aquifer). Agricultural demands are treated in a very simple means. WAS model can be applied to regions larger or smaller than an actual country and optimizes allocation based on economic considerations. It treats demand as a function of price by representing demand by the demand curve (Fisher, 2005)

Interactive River and Aquifer Simulation (IRAS): This tool is a surface water resource simulation tool, based on water balance accounting principles that can test alternative sets of conditions of both supply and demand. The river system is represented by a network of nodes and links, with the nodes representing aquifers, gauges, consumption sites, lakes, reservoirs, wetlands, confluences, and diversions. The model can simulate up to 10 independent or interdependent water quality factors at a submonthly time step.

Through data interfacing, IRAS can link to various external modules such as rainfall-runoff and to economic and ecological impact prediction programs. Used in long-range planning to evaluate the performance or impacts of alternative designs and operating policies of regional water resource systems, ranging from simple to complex systems. It has more significant water quality modeling ability than WEAP, but does not include a detailed demand modeling environment. Strengths include modeling capability of groundwater, natural aquatic systems and water quality, includes wetland analysis. (Wurbs, 2005)

MODSIM_DSS: is a simulation model that can be obtained free of charge. The model can simulate physical operation of reservoirs and water demand. The data sets can be developed for daily, weekly, and monthly time steps.

It is a generalized river basin Decision Support System and network flow model developed at Colorado State University designed to meet the growing demands and pressures on river basin managers. It has been linked with stream-aquifer models for analysis of the conjunctive use of groundwater and surface water resources, as well as water quality simulation models for assessing the effectiveness of pollution control strategies. It can be used with geographic information systems for managing the intensive spatial data base requirements of river basin management. Results of the network optimization are presented in useful graphical plots. (http:// modsim.ergr.colostate.edu/modsim.html/)

SPATSIM: is an integrated hydrology and water resource information management and modeling system. It makes use of ESRI Map Objects and the Delphi programming language to create a data management environment with a spatial information front end and a relational database structure to provide access to a wide range of different types of hydrological and water resource information. The package includes many utilities for importing data, viewing, graphically displaying and editing data, sharing data with other users and further processing data to create new information. It also provides access to a wide range of linked models and data analysis procedures that are typically used in water resource assessments (rainfall-runoff models, design floods, reservoir water balance models) and ecological water requirement assessments. The software is available from the Institute for Water Research -Rhodes University– South Africa at a cost of 170 US $ (Wurbs, 2005)

WaterWare: is object-oriented, fully web-enabled and Internet based, supporting the integration of databases, GIS, simulation and optimization models, and analytical tools into a common, easy-to-use framework, time series analysis, reporting functions, an embedded system for estimation, classification and impact assessment tasks, and a hypermedia help- and explain system.

Real-time data management, simulation and optimization modeling, with data assimilation, forecasting, and reporting, and support for operational management can be provided with a real-time rule-based system. Auxiliary tools manage user requirements and stakeholder preference structures. (www.ess.co.at)

Water Rights Analysis Package (WRAP) simulates management of the water resources of a river basin or multiple-basin region under a priority-based water allocation system. The model facilitates assessment of hydrologic and institutional water availability and reliability for specified water use requirements. Basin-wide impacts of water resources development projects and management strategies may be evaluated. The software package is generalized for application to any river/reservoir system, with input files being developed for the particular river basin of concern. (www.ceprofs.tamu.edu)

MITSIM provides capabilities to evaluate both the hydrologic and economic performance of alternative river basin development plans involving reservoirs, hydroelectric power plants, irrigation areas, and municipal & industrial water supply diversions. A river/reservoir/use system is conceptualized as a collection of arcs and nodes. A variable computational time interval is used. The model assesses system reliability in meeting demands. Economic benefits and costs can also be evaluated. Benefits are divided into long-term benefits and short-term losses. Optional displays of net economic benefits and benefit-cost ratios for the entire river basin and/or sub-regions within the basin can be included in the output. (Wurbs, 2005)

AQUARIUS is an object-oriented modeling system for allocating the water resources of a river basin based on mathematical programming with an economic objective function. The computations are based on solving a quadratic objective function subject to a set of linear constraints. Economic benefit functions are reflected in the objective function. A monthly time step is used. (Wurbs, 2005)

STELLA is a general-purpose modeling package designed to simulate time varying or otherwise changing systems characterized by interrelated components. The user builds a model for a particular application using the operations and functions that are provided, and designs the tabular and/or graphical presentation of simulation results.

Developing a model using STELLA is by combining four types of icons or objects: stocks, flows, converters, and connectors. Stocks accumulate flows and are used as state variables to reflect dynamic time-varying characteristics of the system. Numerical integration methods are used to solve the mass or volume balance at each stock. The value or amount associated with a stock can change in each time period in response to flows into and out of the stock. For example, if a reservoir system is being modeled, stocks can represent reservoir storage, which is a time-varying function of STELLA flow objects representing stream inflows, water supply diversions, reservoir releases, and evaporation. Converters are used to store mathematical expressions and data. Connectors provide a mechanism to indicate the linkages between stocks, flows, and converters. STELLA provides a number of built-in functions used in developing the logic and mathematics for the particular application. (www.iseesystems.com)

Operational Analysis and Simulation of Integrated Systems (OASIS) with OCL is a tool that enables parties with diverse and often conflicting goals to work together to develop operating policies and solutions that mutually satisfy their diverse objectives. It is capable of modeling any water system, from small and simple to large and complex. OASIS' is a combination of a graphical user interface and OCL™ (Operation Control Language) enables data to be entered as a series of easily stated rules and constraints. (www.hydrologics.net)

Performing a simple comparison between the preceding models, it was decided to use WEAP, since WEAP posses a convincing level of capability. Moreover, David R. Purkey, PhD Senior Hydrologist used NHI's Model Evaluation Tool to test and evaluate some models and had identified a set of three models that seems to have the desired attributes, among of which WEAP which is identical to what we sought for the model (Purkey, 2006)

2.8. Water Evaluation and Planning System (WEAP)

2.8.1. Background

The WEAP model was developed by the Stockholm Environment Institute (SEI) and can be downloaded from www.weap21.org . It is a general multi-purpose, multi-reservoir simulation program which determines the optimal allocation of water for each time-step according to demand priorities and supply preference. It operates at a monthly time step on the basic principle of water balance accounting.

The model provides a comprehensive flexible and user-friendly framework for planning and policy analysis. WEAP has an integrated approach to simulating both the natural inflows and engineered components (reservoirs, groundwater pumping) of water systems. This allows the planner access to a comprehensive view of the factors that must be considered in managing water resources for present and future use .This enables us to predict the outcomes of the whole system under different scenarios, and carry out comparisons between the different alternatives to evaluate a full range of water development and management options. (SEI, 2005)

2.8.2. WHY TO USE WEAP?

Based upon the following criteria, WEAP was selected to perform water resources management modeling, since it meets the criteria requirements:

- Able to simulate and assess the current state, competition among water users
- Priority-based water allocation system.
- Available Technical support
- Ease of use
- Capable to build and compare scenarios
- Capable to simulate: Internal hydrology, groundwater utilization, surface-groundwater interactions, and wastewater treatment.
- Integrate the modeling technology into the economical, social and political components of the planning and management process.
- Get stakeholders involved in management procedure through interactive data-driven model to increase public awareness and acceptance.
- Capable to create rolling plan that can be updated according to user need.
- Giving interactive control over data input, editing, model operation and output display.
- Able to integrate with spatial data stored in GIS
- Capable to explain the relationship between various human activities and the hydrology by generating representative outputs.
- Generate output that can be easily used by other software (e.g. excel)
- Variable time step.
- Model licensee is affordable.

2.8.3. WEAP CAPABILITIES

Database Tool: WEAP provides a system for maintaining water demand and supply information with an interactive control over data input, editing, model operation and output display

Scenario Generation and Analysis Tool: The Current Account of the water system under study is created. Then, the reference scenario is established based on a variety of economic, demographic, hydrological, and other trends. Then one or more policy scenarios are developed with alternative assumptions about future developments. The scenarios can address a broad range of "what if" questions. These scenarios may be viewed simultaneously in the results for easy comparison of their effects on the water system.

Policy analysis and Decision Support System Tool: WEAP evaluates a full range of water development and management options. This approach places development objectives at the foundation of water analysis, and allows an evaluation of effects of improved technologies on these uses, as well as effects of changing prices on quantities of water demanded. In addition, priorities for allocating water for particular demands or from particular sources may be specified by the user. This approach can help identify the decisions that best meet any particular objective and assumptions and supports decision makers to assess the functionality and performance of the water system.

Environmental Effects: WEAP can account for the requirements of aquatic ecosystems. It can provide a summary of the pollution pressure different water uses impose on the overall system. Pollution is tracked from generation through treatment and outflow into surface and underground bodies of water.

2.8.4. WEAP APPLICATIONS

There are many case studies that are supported by WEAP Applications all over the World that can be downloaded from the site (www.weap21.org), such as:

Israeli/Palestinian Dialogue (1999-2000): WEAP was used to represent alternative water development and allocation scenarios in a process involving both Israeli and Palestinian participants. Results were used in a workshop in which government, academic and stakeholder representatives jointly explored alternatives for water sharing in the region

Decision Support System for Sustainable Water Supply Planning for US Utilities (USA) (2002-2005): This research focuses on developing a decision support system (DSS) for three urban water utilities in the U.S. to facilitate long-term management of water supplies in balance with water demands.

Effects of Climate Change on Ecosystem Services in California (2001-2004): WEAP is used to better understand the combined effects of climate change and other stressors on the goods and services provided by aquatic ecosystems in the San Francisco Bay Watershed. Through a series of scenarios with varying climate, demographics and land use, WEAP is used to identify and evaluate the likely impacts of climate change and other stressors on the provision of aquatic ecosystem services such as water for agriculture, recreation, hydropower generation, water for municipal and industrial use, habitat function and health, biodiversity, and water purification

CHAPTER THREE

DESCRIPTION OF THE STUDY AREA

3.1. GEOGRAPHY AND TOPOGRAPHY

The West Bank, Palestine is a territory of 5,774 km^2; 130 km long, 40-65 km in width , located 32' 00 N, 35'15 E , It is located west of Jordan River whi.ch forms the border with Jordan. Figure 1 shows the Location of the West Bank.

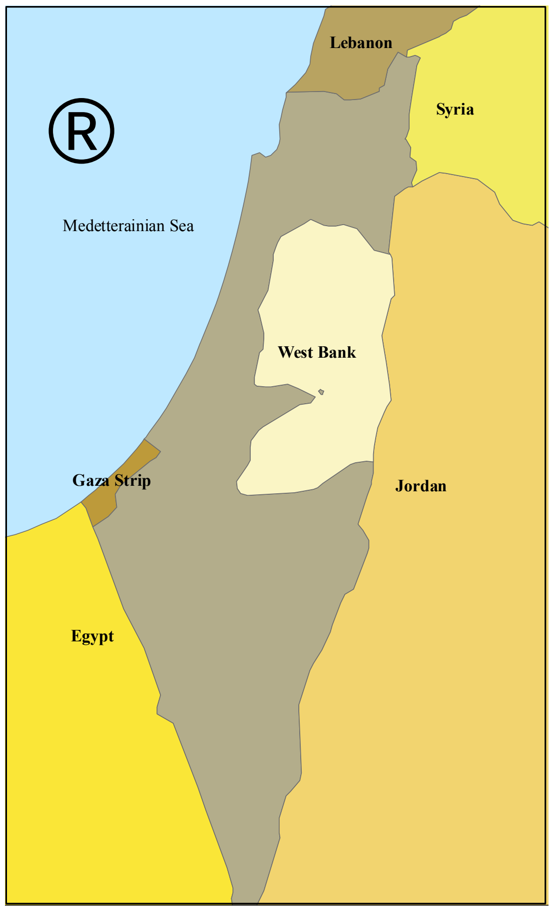

Figure 1: Location of the West Bank

The topography of the West Bank is characterized by a great variation in elevations ranging between 1020 m above sea level and 375 m below sea level. It is divided into four major geomorphologic parts: Nablus Mountains, Jerusalem Mountains, Hebron Mountains and the Jordan valley. The mountains extend over the length of the central parts of the West Bank from Jenin in the north to Hebron in the south. The drainage and valley systems originate from the mountain range and extend either eastwards or westwards. The summits of these mountains delineate watershed lines and the water divide separating the western and the eastern basins in Palestine coincide with the summits of these mountains

The Jordan Valley is part of a long and deep depression of the earth's crust, widely known as the Jordan Rift, running along the edge of the country separating it from Jordan. The Valley is characterized by a semi-tropical climate with hot summer and warm winters. However, this region would be desert-like without access to water. (ARIJ, Agenda21)

3.2. SOIL AND GEOLOGY

The West Bank is mostly composed of limestone hills that are 700 to 900 meters high (See Figure 2), brown lithosols and loessial arid brown soils cover the eastern slopes. Soil cover is generally thin, and fertile soils are found in the plains.

Figure 3 explains the structural geology of the West Bank, which is dominated by a series of regional, parallel, southwest-northeast trending folds dissected by faults associated with the Jordan Rift Valley. The fault turns towards the northwest near Jericho. Some faults in West Bank act as conduits and some others represent barriers to groundwater flows. Dolomitization has assisted in developing joints that were subsequently widened by solution, which increases the potential of the aquifers and their permeability. The percent of water infiltrated to the groundwater basins depends on many factors such as topography, soil types, rock formations, the rainfall and rainfall intensity. It was estimated to be about 25% of rainfall. (Rofe and Raffety, 1965)

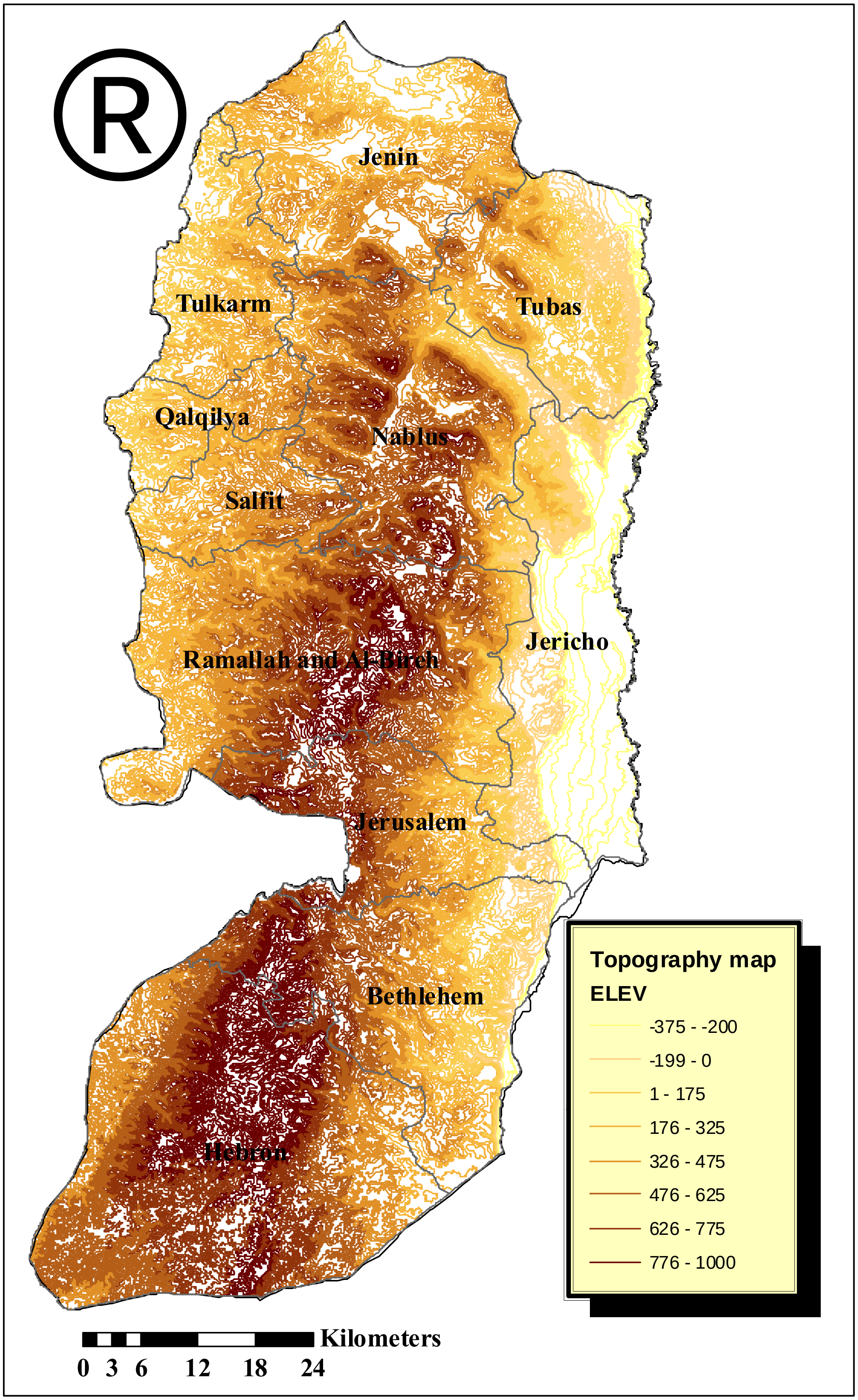

Figure 2: West Bank Topography Map (GIS shapefile is obtained from Water and Environmental Studies Institute (WESI**)**

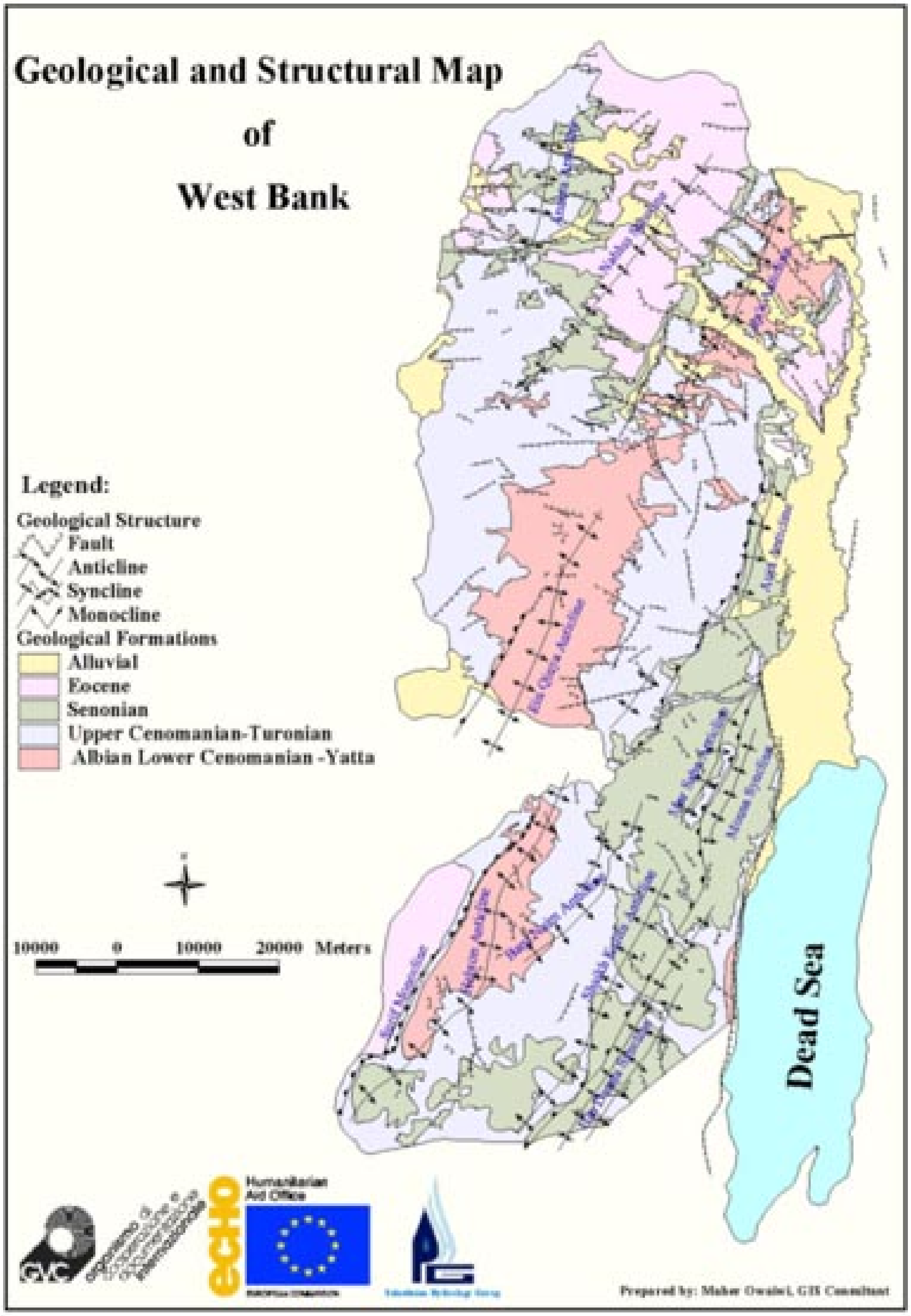

Figure 3: Geological and structural map (Source: PHG modified after ARIJ, 2000)

3.3. SOCIAL AND ECONOMIC CHARACTERISTICS OF THE WEST BANK

3.3.1. DEMOGRAPHY

Population of the West Bank is estimated at 2.3 million capita at the end of year 2003(PCBS, 2003), distributed into 11 governorates. Hebron Governorate has the highest percentage of population of 13.9% of the total population, while, Jericho Governorate has the lowest percentage of population of 1.1%. Population average natural increase rate is about 3.2%. The Figure below shows the different West Bank governorates population and population densities

District	Population	Area km^2	Density ($pers./km^2$)
Jenin	253,965	583	436
Tubas	46,453	417	111
Tulkarm	167,770	272	617
Nablus	326,752	627	521
Qalqilia	93,413	166	563
Salfit	61,830	206	300
Jericho	42,057	855	49
Ramallah	277,898	593	469
Jerusalem	395,607	355	1114
Bethlehem	174,033	659	264
Hebron	520,479	1041	500
Total	2,360,257	5774	409

Figure 4: West Bank Governorates (GIS shapefile obtainrd from WESI)

According to the official list of localities adopted by PCBS[6] and the ministry of local governments, there are 648 localities within the West Bank. The localities are distributed by type to 45 urban, 582 rural, and 21 refugee camps. In addition to twenty localities within the east part of Jerusalem which were annexed by Israel in 1967 and treated as one locality. (PCBS, 2003) Figure 5 shows the distribution of localities according to their governorates.

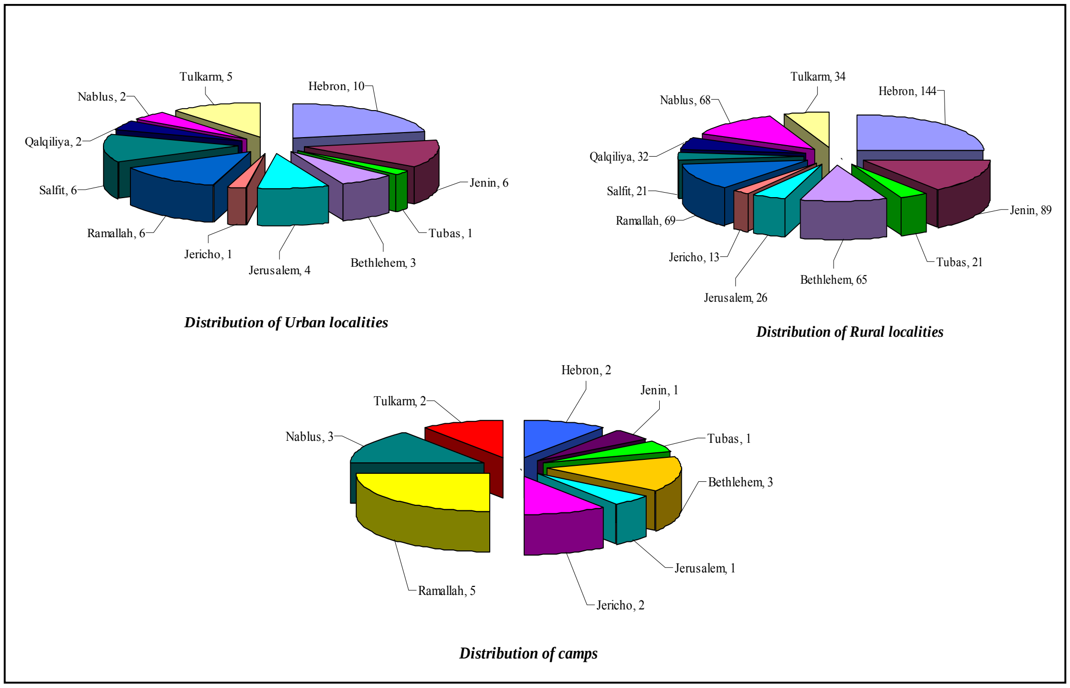

Figure 5: Distribution of localities according to governorates

3.3.2. Social and Economic Aspects

Water resources development in Palestine should go beyond the mere allocation of certain quantities of water; it should rather be concerned with the end goal, which is improving the quality of life for Palestinian people. (Assaf,2005).The Lack of effective government operating under the rule of law in a safe and

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[6] Palestinian Central Bureau of Statistics

secure environment that provides for economic development and supports adequate level of living for its people, resulted in a high rate of poverty.

Palestinian economic development has historically been constrained, and per-capita national income is in the range of “lower middle income” countries. Palestinian economy compared to other developing economies is to a large extent dependent upon wage labor, remittances from abroad which played a large role in the total income, and work in Israel. The results of PCBS survey indicate that the rate of the total diffusion of poverty among Palestinian households in the West Bank is 30.9 percent in December 2003. More significant is the fact that about 1 out of 4 poor households were suffering from deep poverty; unable to meet the minimum requirement for food, clothing and housing. (www.pcbs.gov.ps)

Historically, agriculture has played a more dominant role in the overall Palestinian economy. Despite that Palestinian agriculture trade has been influenced greatly by political status. Agriculture provides 14% of the Palestinian GDP. About 19-22% of the Palestinian labor force are employed in agriculture. (PASSIA, , 2002)

People can be ‘water poor’ in the sense of not having sufficient water for their basic needs because it is not available. People can also be ‘water poor’ because they are ‘income poor’; although water is available, they cannot afford to pay for it. Water Poverty Index (WPI) provides a simple and easy to use indicator for the water sector. The idea of a WPI is to combine measures of water availability and access with measures of people’s capacity to access water. WPI for the West Bank is estimated 39.5 percent (Bushnaq, 2004). This indicates that the country is experiencing a serious water scarcity. So, there is a need to integrate all the water needs of the environment into water management strategies.

3.4. CLIMATE

The West Bank is characterized by Mediterranean climate with hot, dry summers and wet cold winters with short transitional seasons. The eastern and southern parts of the region have a semi-arid to arid climate. In the Jordan rift valley climate is arid all year long and can be classified as desert climate.

The rainy season usually begins as early as September and ends in April. The area experiences extreme seasonal variations in climate. Characteristics of the Middle East in general is a high variability of precipitation; both temporary and spatially. In Nablus, for example, a minimum of less than 316 mm/yr (1952) and a maximum of more than 1387 mm/yr (1992) has been recorded, while the average is about 617 mm/yr (see Figure 6).

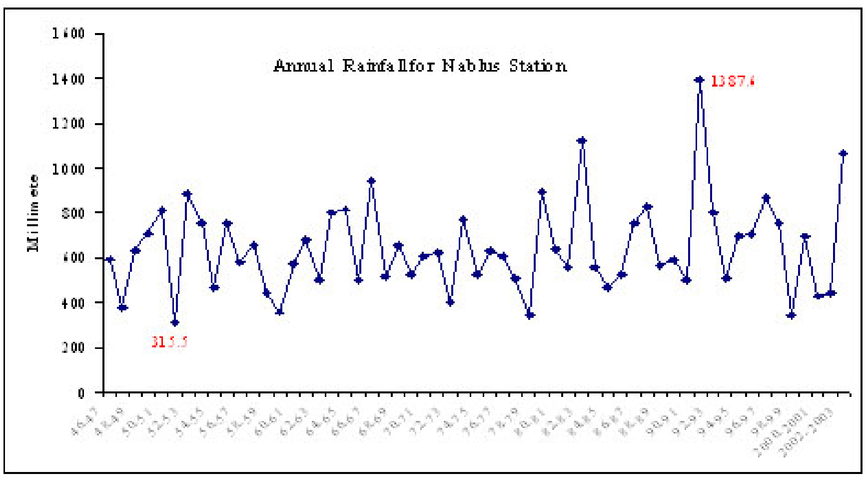

Figure 6: Annual Rainfall for Nablus Station

Figure 7 shows Rainfall distribution in the West Bank. The semi coastal region receives the highest rainfall of around 700 mm/yr; whereas the Jordan valley receives the lowest rainfall at average less than 100 mm/yr. Monthly average rainfall for each district is tabulated in Table 1

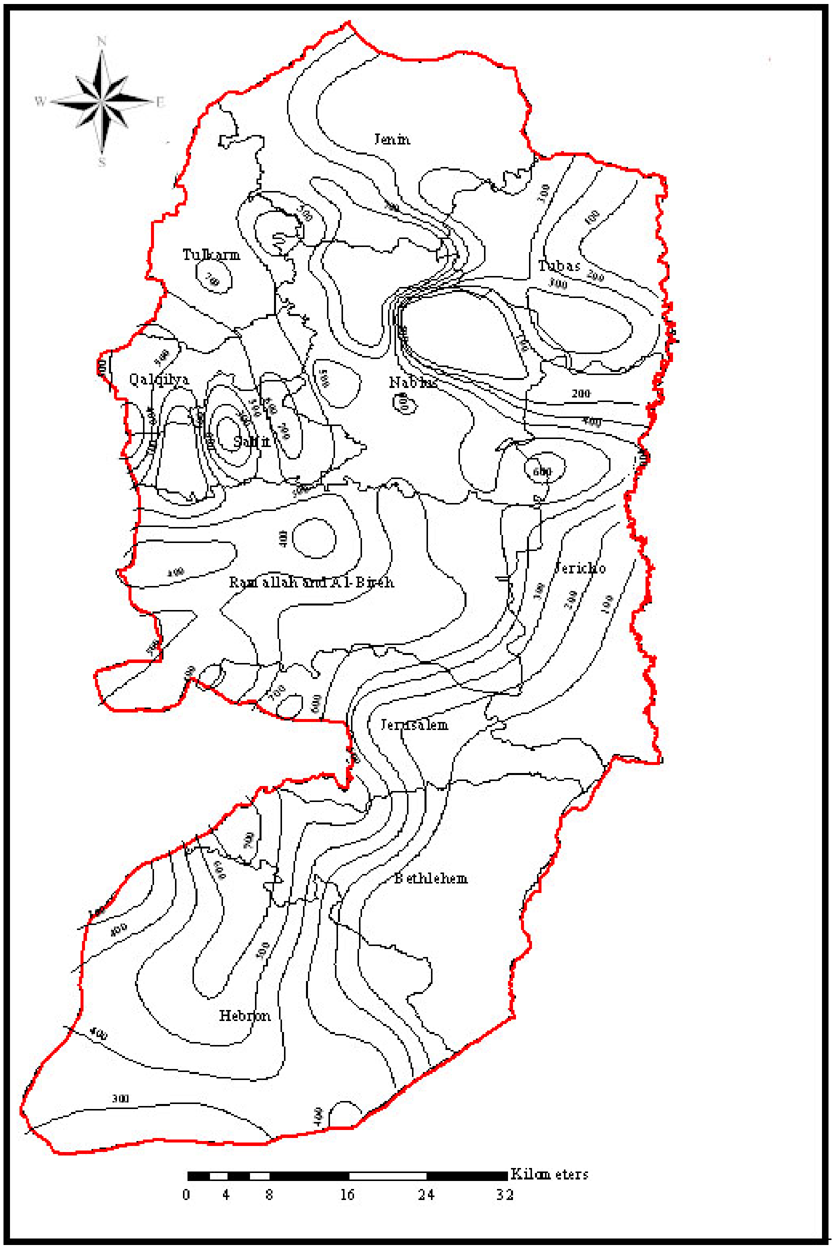

Figure 7: West Bank Rainfall contours (GIS shapefile is obtained from WESI)

Maximum mean daily temperature in Jerusalem is 30° C in August and minimum mean daily temperatureis 6° C in January. For the Dead Sea the corresponding figures are 39°C and 12° C. (EXACT[7], 1998)

[7] Executive Action Team,Middle East Water Data Banks Project

Potential evapotransporation (ET) exceeds rainfall rates most of the year and increases from west to east. In the western slopes, ET is estimated at 1900 mm/yr, and on the eastern slopes it is more than 2350 mm/yr. (see Figure 8). Monthly average reference evapotranspiration (ET_0) for districts is calculated using CROPWAT program and tabulated in Table2, ET_0 is automatically calculated when climatic data (temperatures, humidity, wind speed, sunshine) are entered using InputData, Climate, Enter/Modify keyboard. (Clarke, 1998)

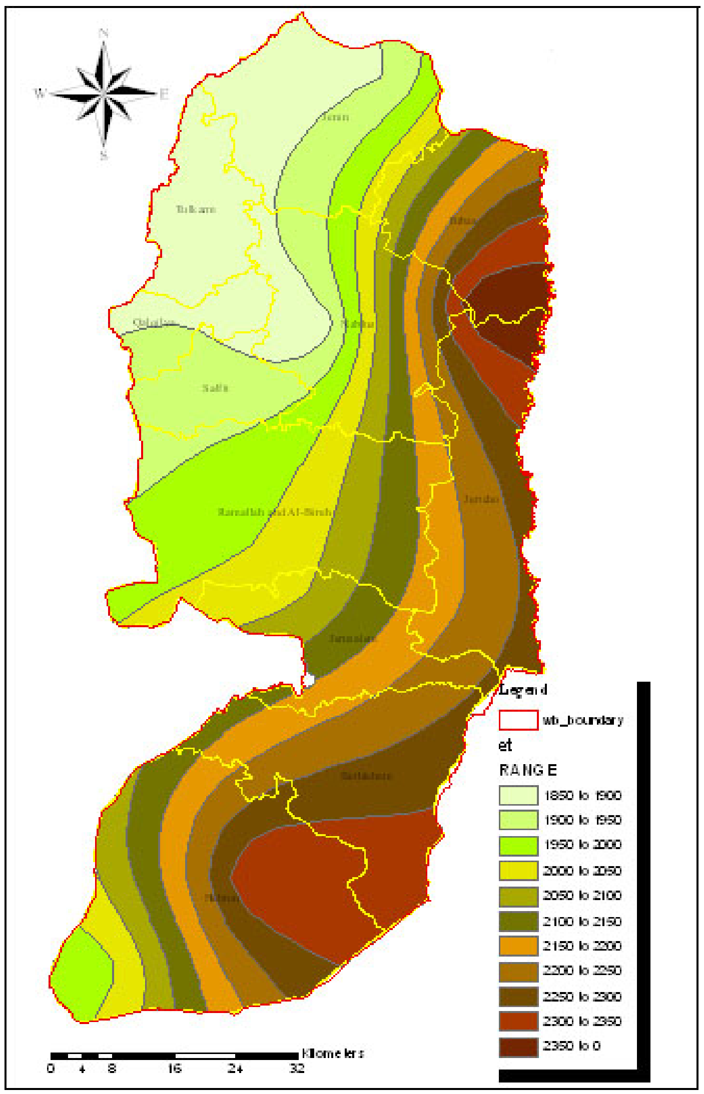

Figure 8: West Bank Potential Evapotranspiration (GIS shapefile is obtained From WESI)

Table 1: Monthly Average Rainfall (mm)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Jenin	131.23	101.07	78.76	24.33	9.16	0.00	0.00	0.00	2.51	36.21	64.29	122.33	569.87
Tubas	85.70	65.94	60.37	17.61	8.62	0.00	0.00	0.00	0.73	16.96	49.37	75.05	380.35
Tulkarm	161.47	114.84	84.01	24.18	10.31	0.00	0.00	0.00	1.73	31.10	73.31	149.47	650.42
Nablus	145.08	113.52	91.93	22.78	10.93	0.27	0.00	1.40	1.98	40.23	67.02	121.72	616.86
Qalqilya	158.41	113.13	91.38	25.32	10.14	0.00	0.00	0.00	1.06	32.37	78.41	136.20	646.43
Salfit	158.82	124.22	96.58	27.01	7.71	0.00	0.00	0.00	3.54	28.58	75.17	137.80	659.44
Ramallah	145.58	120.39	92.27	27.03	10.12	0.00	0.00	0.00	5.76	39.02	71.77	123.69	635.63
Jericho	35.79	31.18	24.21	6.43	0.48	0.00	0.00	0.00	1.18	94.53	19.99	32.46	246.25
Jerusalem	134.38	100.67	83.92	31.19	2.88	0.00	0.00	0.00	0.00	192.33	66.99	95.89	708.25
Bethlehem	125.66	88.18	74.60	32.52	7.64	0.00	0.00	0.00	0.00	168.93	40.20	87.97	625.71
Hebron	132.99	95.43	68.72	25.77	8.19	9.70	0.00	0.00	1.48	48.23	53.59	95.98	540.09

Table 2: Monthly Average Reference Evapotranspiration (mm)

District	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Jenin	66.55	71.88	122.05	180.98	239.78	256.79	267.34	242.19	194.69	142.88	97.16	70.87	1953.1
Tubas	75.36	93.67	156.44	184.04	245.10	270.70	333.76	305.02	235.09	147.15	92.66	61.20	2200.2
Tulkarm	66.25	73.48	117.75	164.85	216.03	240.21	256.07	231.26	182.28	142.09	92.32	65.78	1848.3
Nablus	73.57	82.54	130.92	188.54	237.18	244.82	257.95	248.44	205.42	162.41	105.73	69.81	2007.3
Qalqilya	68.36	75.82	121.50	170.10	222.91	247.86	264.22	238.63	188.08	146.61	95.26	67.88	1907.2
Salfit	71.47	80.19	127.18	183.15	230.41	237.83	250.58	241.34	199.56	157.77	102.71	67.82	1950.0
Ramallah	74.76	88.32	130.20	212.40	277.92	259.92	257.04	236.64	193.68	136.20	92.16	98.64	2057.8
Jericho	68.50	84.80	146.00	221.10	279.00	300.60	318.70	291.10	229.20	160.60	94.80	64.20	2258.6
Jerusalem	74.50	85.35	134.33	192.31	254.56	273.04	279.63	254.91	208.25	155.35	108.11	79.12	2099.4
Bethlehem	78.16	88.34	152.14	205.91	263.53	282.56	290.91	272.38	210.42	171.34	104.21	80.33	2200.2
Hebron	76.01	87.00	141.18	205.88	258.48	260.53	276.07	256.13	220.01	177.77	114.48	76.48	2150.0

3.5. Water Resources

3.5.1. Surface Water Resources

Surface water resources in the West Bank consist of the Jordan River and wadis runoff

The Jordan River is the only permanent river which can be used as a source of surface water in Palestine. The Jordan River is 360 km long. The average annual flow of this river is about 1485 MCM. The Jordan River initiates from three main springs: The Hasbani in Lebanon, the Dan in occupied Palestine and the Banias in the Syrian Golan Heights to form the Upper Jordan River basin. The water of this basin flows southward through Lake Hula towards Lake Tiberias. (Isaac, 2000) figure 10 shows a schematic map of the Jordan River basin as well as the various surface water sources that contribute to the Jordan's discharge.

As regards to The Jordan River which is considered a shared water resource, Palestinians are denied their right to utilize water resources from the Jordan River due to Israeli military occupation.

Wadis runoff is mostly intermittent and probably occurs when the rainfall exceeds 50 mm in one day or 70 mm on two consecutive days. There are 33 main wadis in the West Bank. Total wadis runoff is estimated at 198.9MCM/yr, among which 122.8 MCM/yr flow toward the Mediterranean Sea, 21.8 MCM/yr toward the Dead Sea, and 24.3 MCM/yr discharge into Jordan River (CH2M HILL, 2003). In addition, there are small scale wadis that discharge a total flood volume that may reach 15 MCM/yr during very seasons (Isaac, 2000). Streams flowing from the West toward the Jordan Valley recharge shallow aquifers such as Wadi Al Qilt, Auja, Al Faria (Assaf, 1991 cited in Isaac, 2000). Figure 9 shows West Bank major wadis and their catchments.

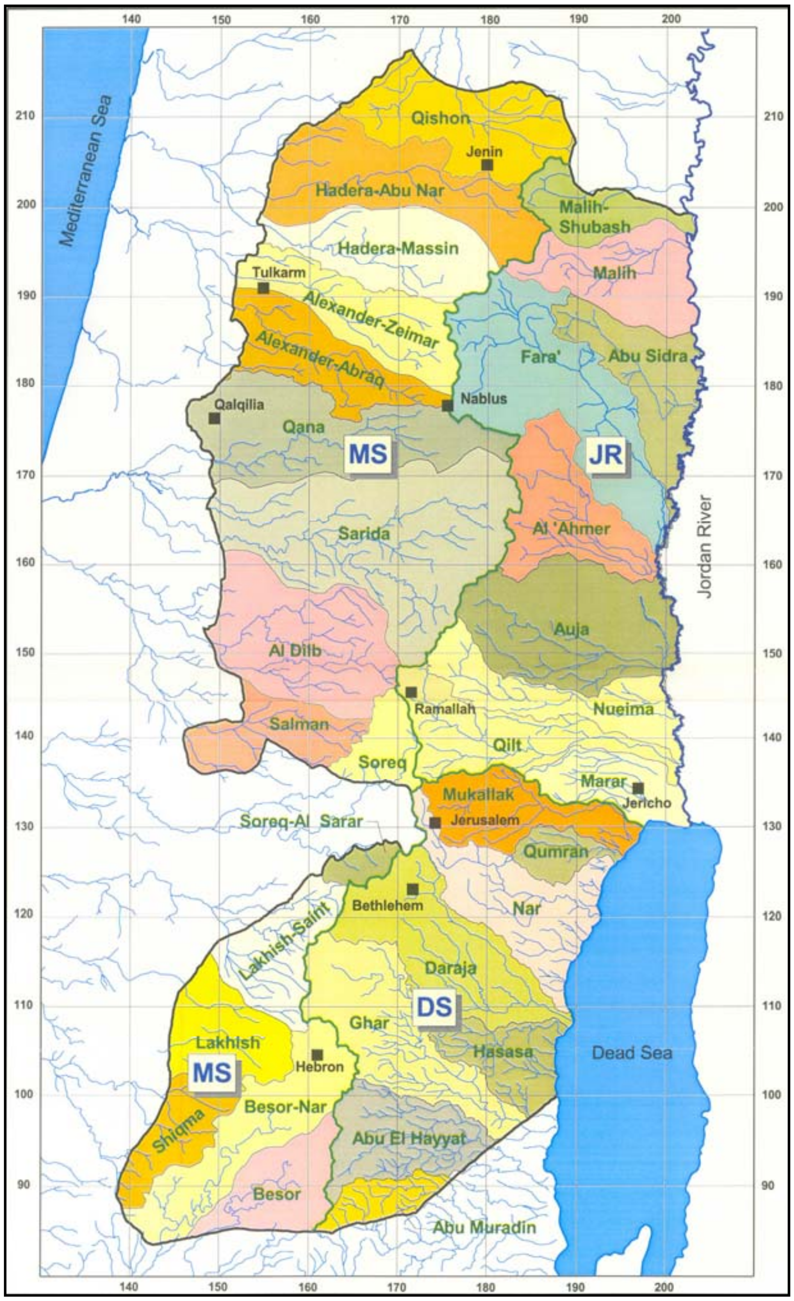

Figure 9: West Bank Catchments and Hydrography (Source: CH2M HILL, 2003)

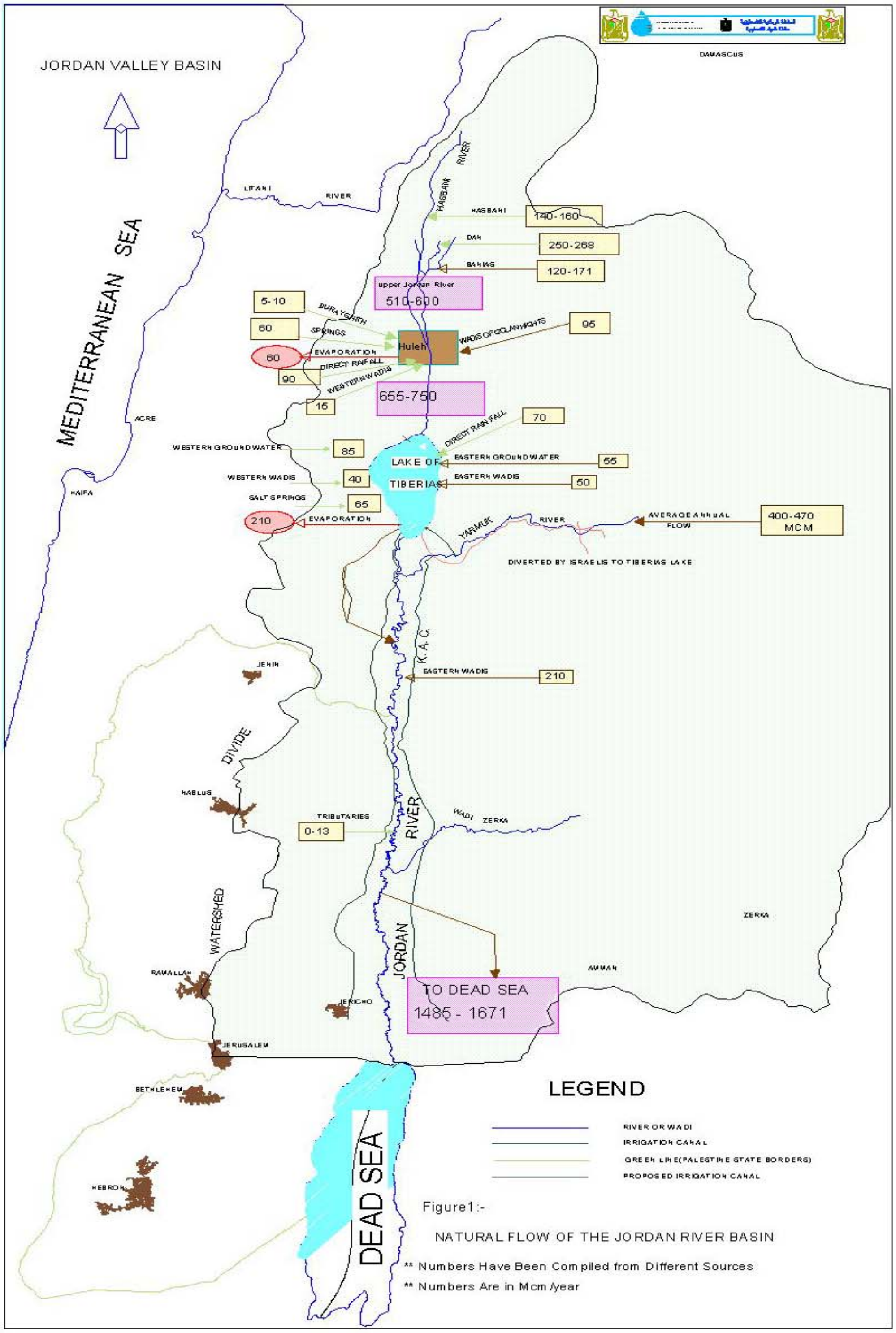

Figure 10: Water Balance in the Jordan River before Utilization (Source: Palestinian Water Authority PWA)

3.5.2. GROUNDWATER RESOURCES

Groundwater is the major source of fresh water supply in the West Bank. Most of the aquifer rock formations are comprised of carbonate rocks mainly limestone, dolomite, chalk, marl, and clay. The groundwater basins are recharged directly from rainfall on the outcropping geologic formations in the West Bank Mountains. The West Bank aquifer system, see figure 11, is classified to:

The Western Aquifer Basin: Eighty percent of the recharge area of this basin is located within the West Bank boundaries. Precipitation recharges the groundwater system in the West Bank at an average volume of 362 MCM/yr, and flows in a general westward and northward direction.

The Northeastern Aquifer Basin: It is a generally flat area with low rolling hills in the northernmost part of the Mountain Belt with no obvious topographic features that delineate its boundaries. Groundwater system in the West Bank is recharged by precipitation at an average volume of 145 MCM/yr, and flows generally in a northeast direction.

The Eastern Aquifer Basin: It lies entirely within the West Bank territory. Groundwater is recharged by precipitation at an average volume of 172 MCM/yr, and flows generally in a southeastward direction toward the Jordan Rift Valley which forms the eastern boundary of the basin (EXACT, 1998)

Although the fact that over 90% of the recharge originates in the Palestinian lands, Palestinians have water control (quantities that are available for utilization) only of 15 % of groundwater resources (PWA data base, 2003)

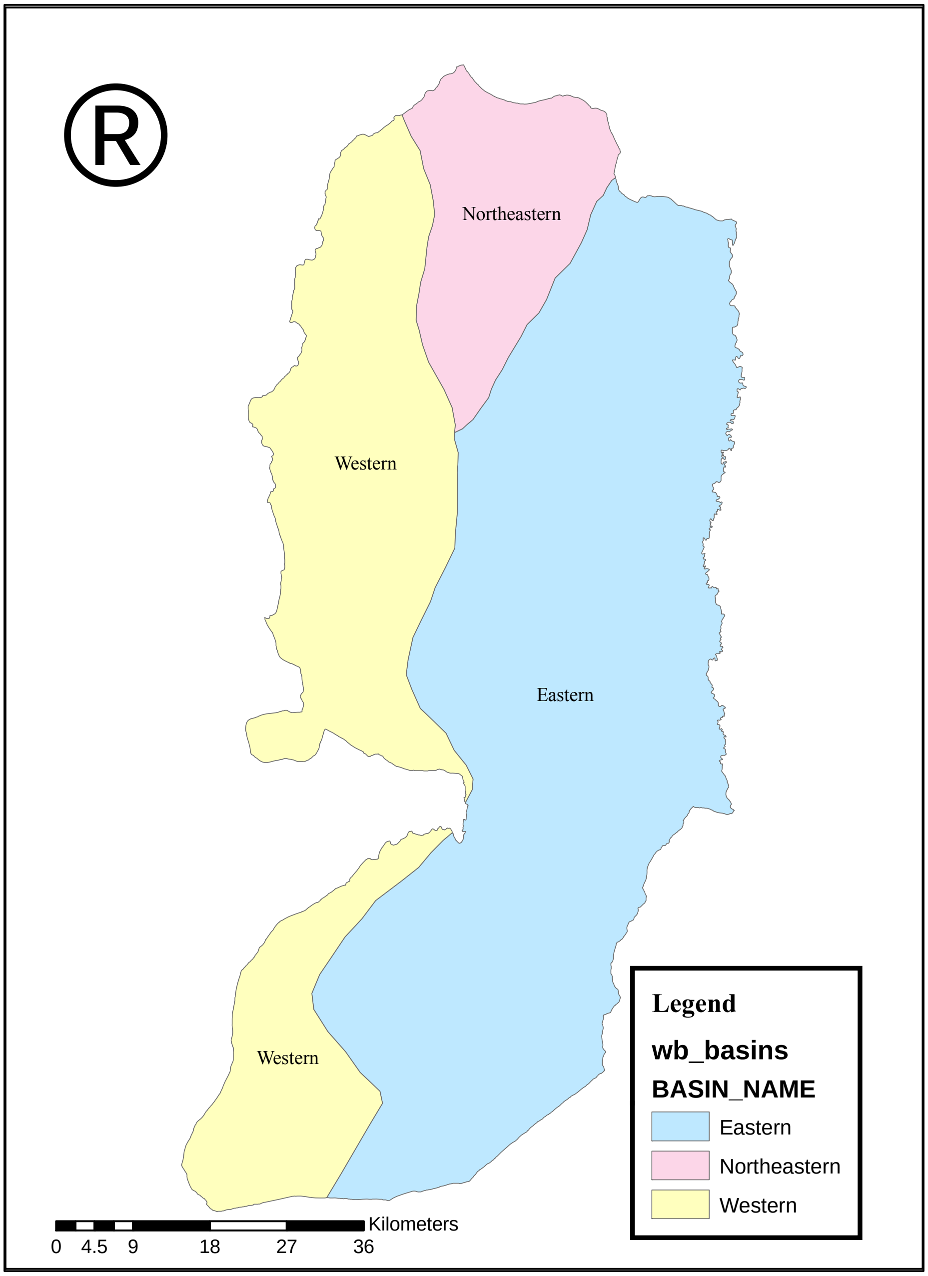

Figure 11: West Bank Groundwater basins (GIS shapefile is obtained From WESI)

3.6. LAND USE PATTERNS

Land use patterns are greatly influenced by topography, climate, and political situation. These factors are strongly affecting the distribution of cultivated areas, urbanization, road construction and other uses. Figure 12 shows the land use patterns in the West Bank.

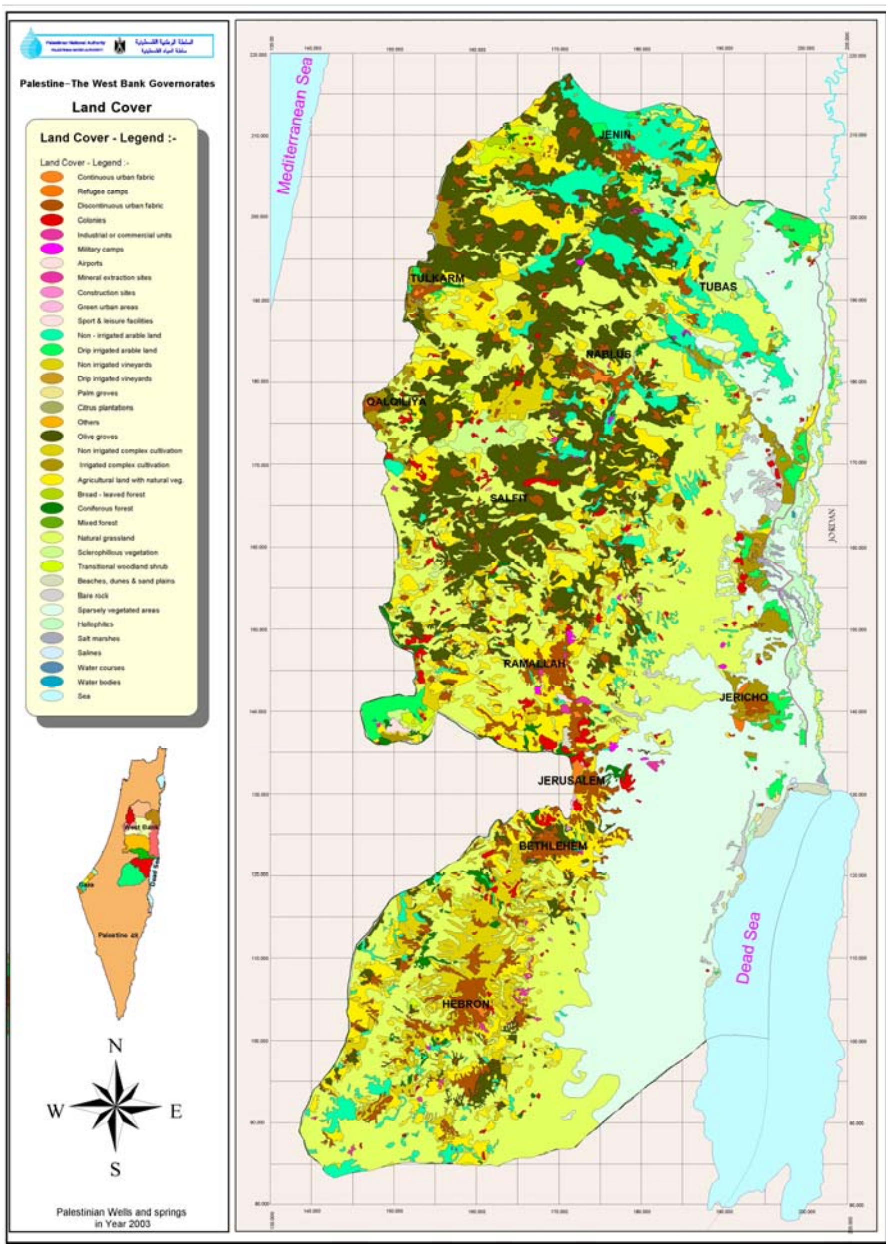

Figure 12: Land Use Patterns in West Bank (source: PWA)

Conflicts over water allocation between Palestinians and Israelis had limited economic development and restricted the expansion of agricultural land and industrial activities.

During the period 1967 through 1995 a mix of economic and political considerations shaped Palestinian agricultural practices. In irrigated agriculture, economic issues forced Palestinians to shift from fruit trees to high cash value crops such as vegetables. In rain-fed farming, Palestinians shifted from field crops to olives, because the income from field crops is low, Olives do not require a lot of work, and the planting of olives indicates that the land is cultivated, which protects it from the Israeli assaults. As a result, the country has moved away from agricultural food security. Palestine has not been self-sufficient in producing field crops and livestock products, mainly red meat and milk.

Agriculture is divided into rain-fed and irrigated cultivation. Rain-fed cultivation forms the largest cultivated area, using more than 90% of the total cultivated land. Annual production is generally affected by the dominant climatic conditions by rainfall, reflecting substantial variation between the various years. Almost 92.7% of the total irrigated areas in the West Bank are concentrated in the two agro-ecological areas, the semi-coastal region and the Jordan Valley. Vegetables constitute 67% of the total irrigated areas. Fruit trees form about 26.5%, while field crops constitute 6.5%. Cultivation of fruit trees is the major sector of plant production mainly olives. Nearly 97.3% of the fruit trees are cultivated under rain-fed conditions, irrigating the remaining 2.7%. Although irrigated fruit trees occupy limited areas, they contribute approximately 37% to the total fruit tree production. (PCBS, 2003)

CHAPTER FOUR

MODELING DEMAND AND SUPPLY USING WEAP

4.1. Introduction

Palestinian water managers face significant challenges in providing sufficient water supplies to meet Palestinian domestic needs at present and in the future, and to support agricultural and industrial growth. Increasing water demand must be both managed and met. Palestinians must have a model that explains variety of options available to them to manage future water demand and develop supplies. Modeling becomes an essential tool in water management. It plays a significant role in fulfilling the core tasks of water management.

The major steps used in WEAP to generate water management options under different scenarios for the West Bank are:

- Identification of time frame and system components and configuration.
- Establishing the current accounts that provide a snapshot of actual water demand resources and supplies for the system
- Establishing the reference scenario that represents the changes that are likely to occur in the future, in absence of any new policy measure.
- Building scenarios based on different sets of future trends and factors that affect demand supply
- Evaluating the scenarios with regard to criteria including adequacy of water resources, costs, benefits, and environmental impacts

4.2. Model Algorithm

In order to verify the model, the algorithms behind the different scenarios were reviewed. A summary of Input - Output data is explained in figure 13 below.

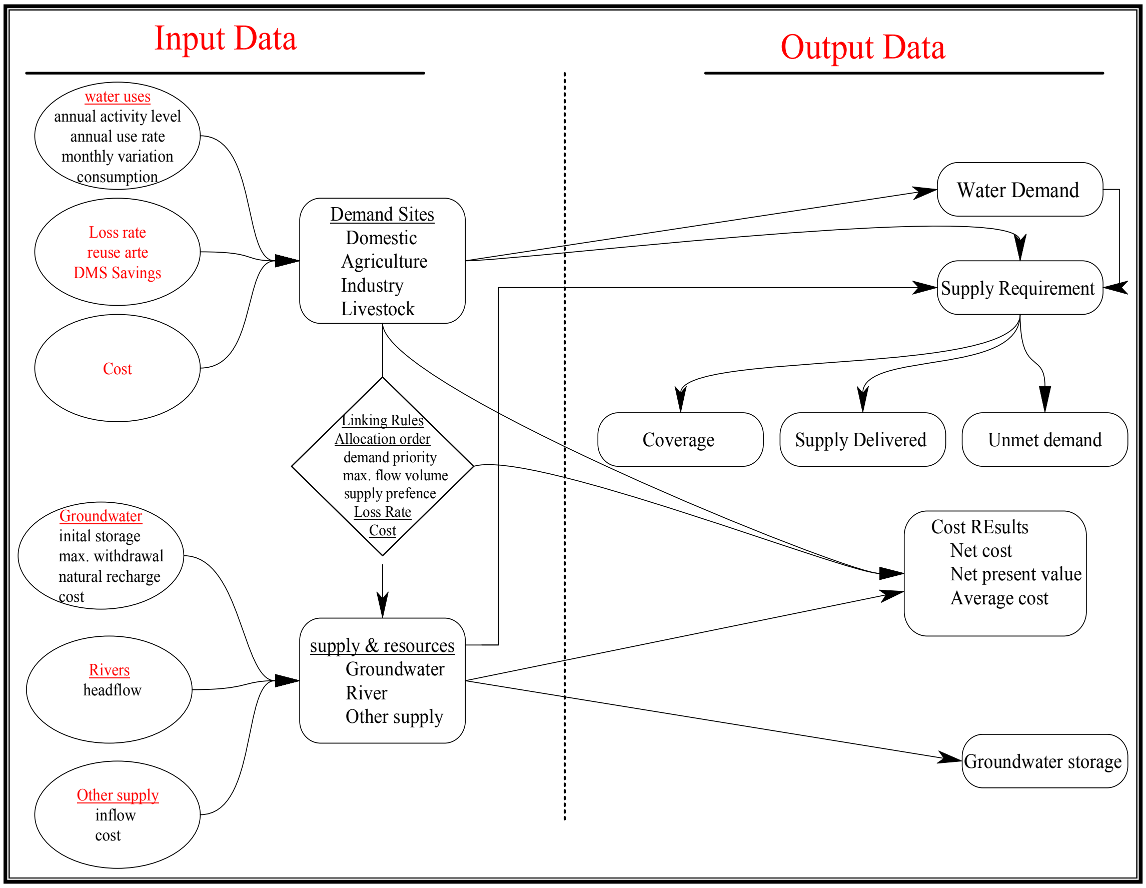

Figure 13: West Bank WEAP Model Input-Output Data

WEAP operates on the basic principle of water balance for every node and link in the system on a monthly time step subject to demand priorities, supply preferences, mass balance and other constraints. Mass balance equations are the foundation of WEAP monthly water accounting: total inflows minus total outflows equal to net change in storage if any. Every node and link in WEAP has a mass balance equation and some have additional equations which constrain their flows (e.g., outflows from an aquifer cannot exceed its maximum withdrawal, link losses are a fraction of flow, etc.).

Annual demand in WEAP: The monthly demand represents the amount of water needed by the demand site for its use on monthly basis .A demand site's (DS) demand for water is calculated as the sum of the demands for all the demand site's bottom-level branches (Br).

$$Annual\ Demand = Total\ Activity\ Level \times Water\ Use\ Rate \ \cdots\cdots\cdots \ (1)$$

Monthly Supply Requirement: The supply requirement is the actual amount needed from the supply sources. The supply requirement takes the demand and adjusts it to account for internal reuse, demand site management strategies for reducing demand, and internal losses. These three adjustment fractions are part of the input data for the model.

$$MonthlySupply\mathrm{Re}quiremnt = \frac{MonthlyDemand \times (1 - \mathrm{Re}use\ Rate) \times (1 - DSM\ Savings)}{1 - Loss\ Rate} \ \cdots\cdots\cdots \ (2)$$

Supply and resources: Given the monthly supply requirement established from the definitions of the system demand and the definitions of Hydrology, the Supply and Resources section determines the amounts, availability and allocation of supplies.

Transmission Links: Transmission links deliver water from supply nodes to satisfy final demand at demand sites. In addition, they deliver wastewater outflows from demand sites and wastewater treatment plants to other demand sites for reuse. The amount delivered to the demand site equals the amount withdrawn from the source minus any losses. Losses refer to the evaporative and leakage losses as water is carried to demand sites. This Loss Rate is specified as a percentage of the flow passing through a transmission link

$$Trans.\ Link\ Outflow = Trans.\ Link\ Inflow - Trans.\ Link\ Loss \ \cdots\cdots\cdots \ (3)$$

Constraints are set using a fixed upper bound (Maximum Flow Volume) on the amount of water flowing into the link to model the political, physical, contractual and other limits on the flow from a source to a demand site.

$$Trans.\ Link\ \ Inflow \leq Maximum\ \ Flow\ Volume \qquad \cdots\cdots\cdots\ (4)$$

Priorities for Water Allocation: Competing demand sites and catchments are allocated water according to their demand priorities. These priorities are useful in representing a system of water rights, and are also important during a water shortage, in which case higher priorities are satisfied as fully as possible before lower priorities are considered.

Supply Preference: If a demand site is connected to more than one supply source, choices for supply, that supply is preferred to be used, may be ranked using supply preferences. In the model groundwater is set to be with the highest preference since it is more reliable and better quality.

Using the demand priorities and supply preferences, WEAP determines the **allocation order** to follow when allocating the water. The allocation order represents the actual calculation order used by WEAP for allocating water. All transmission links with the same allocation order are handled at the same time. For example, flows through transmission links with allocation order 1 are computed, while temporarily holding the flows in other transmission links with higher allocation orders at zero flow, and so on.

Return flow links transmit wastewater from demand sites to destinations that are either wastewater treatment plants or receiving bodies of water. The amount that flows into the link is a fraction of that demand site return flow.

A wastewater treatment plant (TP) receives wastewater inflows from one or more demand sites (DS). TP treats wastewater inflows, removes a fraction of the pollution, then returns the treated effluent to one or more receiving bodies of water.

$$Treatment\,Plant\,Inflow(TP) = Demand\,Site\,Return\,Outflow_{DS,TP} \quad \cdots\cdots\cdots \quad (5)$$

A groundwater node's (GW) storage in the first month (m) of the simulation is specified as data.

$$Begin\ Month\ Storage_{GW} = Initial\ Storag_{GW,m} \quad \cdots\cdots\cdots \quad (6)$$

$$Begin\ Month\ Storage_{GW,m} = End\ Month\ Storage_{GW,m-1}\ \ for\ m > 1 \quad \cdots\cdots\cdots \quad (7)$$

$$Storage_{GW,m+1} = Storage_{GW,m} + natural\ recharge + return\ flows \pm surface\,water\,interactions - withdrawals \quad \cdots\cdots\cdots\cdots\cdots \quad (8)$$

4.3. ESTABLISHING THE CURRENT ACCOUNTS IN WEAP

The Current Accounts represent the basic definition of the water system, as it currently exists. In our case, the year 2003 is selected as the current year. The model simulation period is taken from 2003 -2025.

4.3.1. IDENTIFYING CURRENT WATER USES

Existing water uses can be classified to the following: Municipal and industrial (domestic, industrial) water demands, Agricultural demands.

Annual water demands are the requirements for final water services. Activity Levels are used as a measure of social and economic activity, and the water use rate is the average annual water need per unit of activity.

Domestic demand: the population census obtained from PCBS are shown in Table 3

Table 3: Domestic Demand Sites

District	Annual activity level (population)	growth rate (%)
Jenin	253,965	3.2
Tubas	46,453	3.2
Tulkarm	167,770	3.2
Nablus	326,752	3.2
Qalqilia	93,413	3.2
Salfit	61,830	3.2
Jericho	42,057	3.2
Ramallah	277,898	3.2
Jerusalem	145,400	3.2
Bethlehem	174,033	3.2
Hebron	520,479	3.2

Agricultural demands are represented by irrigated agricultural areas obtained from PCBS survey for 2003 are shown in Table 4

Table 4: Agricultural Demand Areas (dunums)

District	Irrigated
Jenin	14,062
Tubas	15,291
Tulkarm	11,941
Nablus	8,235
Qalqilya	8,668
Salfit	834
Ramallah	1,203
Jericho	50,089
Jerusalem	159
Bethlehem	1,958
Hebron	4,566

Industrial demand shares about 7 percent of total municipal and industrial demand. *(CH2MHILLM, 2003)*

4.3.2. Identifying Current Basic Water Needs

Domestic Water Needs

All people, whatever their stage of development and their social and economic conditions, have the right to have access to drinking water in quantities and of a quality equal to their basic needs. (UN, 1977)

In terms of quantity and quality, four basic human needs are identified: drinking water for survival, water for human hygiene, water for sanitation services and modest household needs for preparing food.

Considering drinking water and sanitation needs only suggests that the amount of clean water required to maintain adequate human health is about 100 liters per person per day, and 150 L/c/d is necessary to provide for some average acceptable quality of life.

Irrigation Water Needs

To avoid water crop water stress, rainfall and irrigation must be sufficient to meet the crop's ET requirements. This means that for any period of time during the crop growing season, the net irrigation requirement (NIR) is the amount of water which is not effectively provided by rainfall. NIR is irrigation water which is delivered to the field and available for the crop to use.

Irrigation requirements were estimated using CROPWAT program. Crop requirements are calcaulated after entering the monthly climate data, types of crops, and the planting date. The results are summarized in Table 5

Table 5: Crop requirements (m^3/dunum)

District	Area (dunum)	Water requirement (m^3/du)
Jenin	14,062	540
Tubas	15,291	633
Tulkarm	11,941	498
Nablus	8,235	627
Qalqilya	8,668	534
Salfit	834	489
Ramallah	1,203	623
Jericho	50,089	693
Jerusalem	159	521
Bethlehem	1,958	536
Hebron	4,566	552

4.4. West Bank Water Infrastructure

4.4.1. Water Availability

In this section all potential resources that can be available for future development in Palestine are considered. Maximum potential resources are identified regardless of the political and economic constrains. Constrains will be discussed and taken into consideration while developing scenarios.

Groundwater: Limits to groundwater development are set by the sustainable yield of the aquifers. Sustainable yield is estimated as the annual recharge, since that data is not available and validated.

Table 6: Potential Groundwater Development

Basin	Eastern	Northeastern	Western
Annual Natural Recharge (MCM)	172	145	362

Jordan River: In this context, the Johnston Plan for Middle East water allocation, which was developed in the mid-1950s, introduces 250 MCM to supply the West Bank as presumed Palestinian water rights.

Wadis: Total surface water resource from wadis discharge in the West Bank is estimated to be 168.9 MCM/yr according to CH2MHILL study. It was indicated from previous feasibility analysis of the West Bank development (FORWARD, 1998, cited in CH2MHILL, 2003) that many of small wadis, stormwater could not be captured feasibility. For wadis flowing to Jordan River Valley, only those with an estimated annual discharge greater than 4 MCM/yr and more than 10 MCM for those flowing toward Mediterranean Sea were considered potentially feasible to stormwater capture with efficiency up to 70 percent. Wadis with potential stormwater capture are listed in Table 7 classified according to its flow direction. (CH2MHILL, 2003)

Table 7: West Bank Wadis with Potential Stormwater Capture

Wadi	Average annual runoff (MCM)
Flowing toward Jordan valley	
Faria	6.4
Al Ahmer	4.4
Auja	4.6
Qilt	4.2
Daraja	5.3
Ghar	6.5
Flowing toward Mediterranean Sea	
Al Dilb	16.4
Sarida	22.8
Qana	12.8
Hadera Massin	11.7

Rainfall harvesting: Potential rainwater harvesting can be estimated as the total depth of precipitation multiplied by West Bank built up areas. This potential volume was estimated at 16 MCM/yr.

Wastewater reuse: Potential treated wastewater resource depends on the community capacity and admittance for infrastructure construction, rather than available raw wastewater.

Seawater Desalination: Desalination is an energy-intensive technology that can produce great quantities of freshwater for use in any sector. Seawater desalinated and treated to potable standards can be supplied directly to the end user. Potential desalinated water depends on economic factors.

4.4.2. CURRENT WATER SUPPLY

Clean and sufficient water; for domestic consumption, commercial and industrial development, and agriculture is a requirement for a viable Palestinian state. The existing level of water resource development and sharing of water resources between Israelis and Palestinians does not meet this requirement today and is even less likely to do so as the Palestinian population grows over the next several decades. *(RAND[8], 2005)*

The majority of Palestinian domestic water supply is provided by springs and wells fed by underground aquifers. The total amount of domestic water supply is about 78 Mcm/yr, among of which 46 percent is purchased from Mekorot. Most of this Mekorot water sold to Palestinian is from wells within the West Bank.

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[8] The RAND Corporation is a nonprofit research organization providing solutions that address the challenges facing the public and private sectors around the world.

The amount of water delivered for municipal uses to each district varies significantly, see Table 8. This is due to that water conveyance between districts is not existed due to the absence of a national water distribution grid. Also, the political constraints restrict the development of groundwater.

Table 8: Total municipal Water Supply (MCM

District	Domestic wells[1]	Springs[1]	Agricult. Wells[1]	Imported[2]	Cisterns[3]	Total Supply	Consump. (L/c/d)
Bethlehem	3.440	0.048	0.000	5.162	0.5	9.15	144
Hebron	6.879	0.000	0.000	7.831	2.00	16.71	88
Jenin	2.496	0.157	0.485	2.052	0.9	6.09	66
Jericho	0.000	1.270	0.000	1.042	0.000	2.312	151
Jerusalem	0.062	0.000	0.000	7.025	0.000	7.087	133
Nablus	5.779	2.047	1.202	2.244	0.1	11.372	95
Qalqilia	3.996	0.000	0.000	0.335	0.2	4.531	133
Ramallah	4.764	0.064	0.371	8.668	0.4	14.267	141
Salfit	0.091	0.140	0.120	1.299	0.2	1.85	82
Tubas	0.416	0.180	0.000	0.120	0.00	0.716	42
Tulkarm	6.239	0.000	0.000	0.265	0.7	7.204	118
Total	34.162	3.906	2.177	36.043	4.9	81.188	105

Source of data

1 Palestinian Water Authority Data Base

2 Water Supply_ PWA Report, 2003 (Arabic report)

3 CDM/Morganti, 1997

Figure 14 shows Palestinian wells and springs in the West Bank districts.

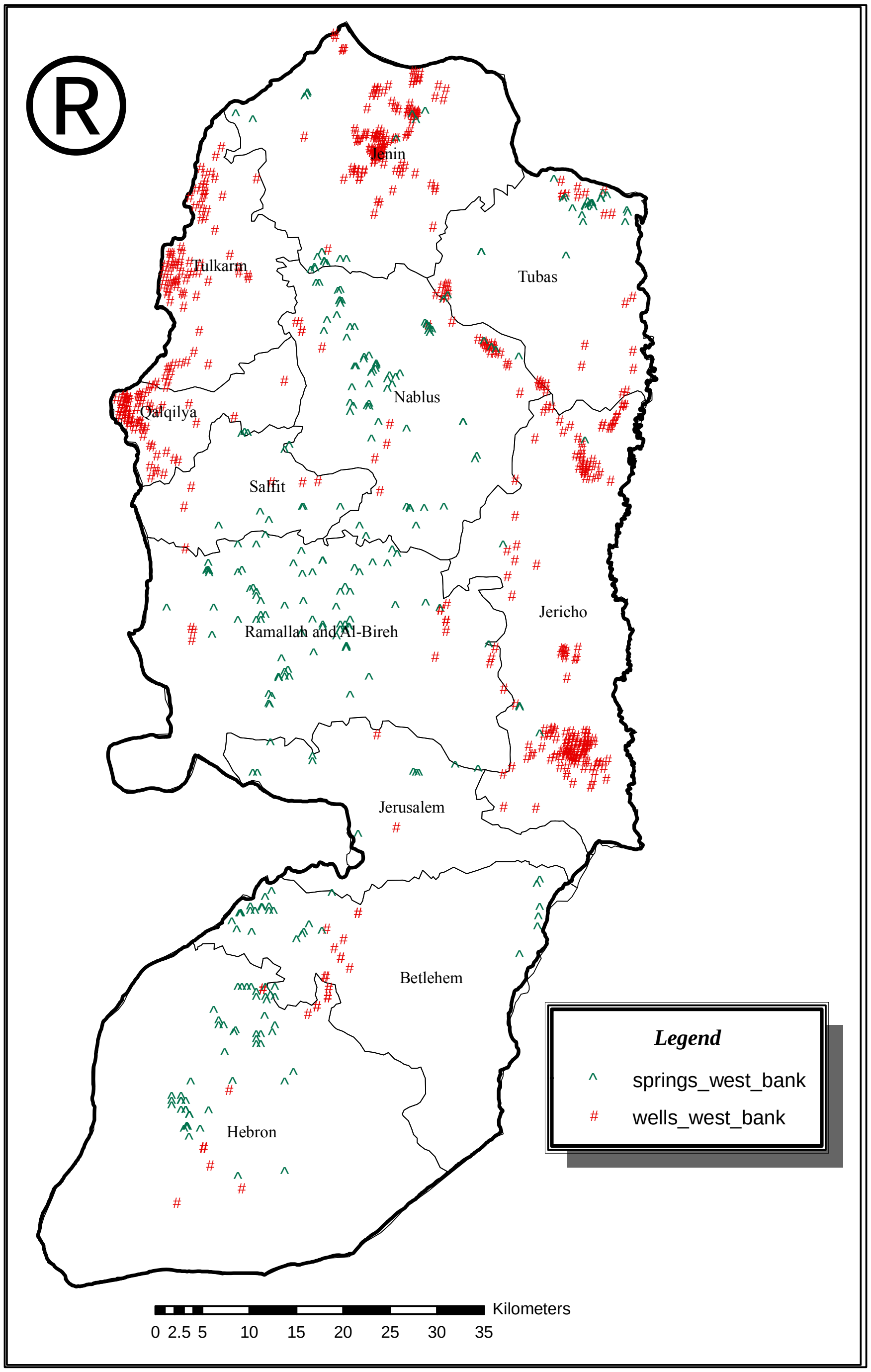

Figure 14: West Bank wells and springs

The current municipal water supply provides only an average of about 100 L/c/d. Taking into consideration the overall losses of about 30% and deducting the water used for industrial uses which accounts for about 7 percent *(CH2MHILLM, 2003)* gives an actual average amount of water consumed per capita of about 59 L/c/d which is far below the World Health Organization's (WHO) per-capita domestic water requirement that amounts to a minimum of 100 L/c/d and an average of 150 L/c/d for small communities.

The agricultural water supply comes from wells and springs, and are shown in Table 9

Table 9: Agriculture Water Supply (Mcm/yr)

District	Springs	Wells	Total
Jenin	0.440	5.250	5.69
Tubas	3.878	2.272	6.15
Tulkarm	0	6.103	6.103
Nablus	7.681	2.556	10.237
Qalqilya	0	5.950	5.95
Salfit	0.120	0	0.12
Ramallah	1.106	0	1.106
Jericho	23.23	9.093	32.323
Jerusalem	1.938	0	1.938
Bethlehem	1.550	0	1.55
Hebron	3.270	0	3.27

Source of data PWA data base, 2003

Delivered water quality in general is good or acceptable according to the standards. Table 10 represents a summary for water quality parameters obtained from a series of wells and springs from each aquifer. Moreover, a study conducted by Ne'mat Qamheieh as part of her master thesis shows that 90% of the West Bank is at low risk of pollution, while 10% is at moderate risk. This indicates that our groundwater resources are safe (Qamhieh, 2006).

Table 10: Quality Parameters for Aquifers (mg/l)

Aquifer	Cl	K	Na	NO3	SO4	TDS
Eastern	196.99	7.93	93.65	30.54	71.67	517.90
North Eastern	77.59	3.68	36.61	52.60	25.33	371.65
Western	65.57	5.40	36.81	41.74	39.08	403.01

Source of data PWA data base, 2003

A summary of average water quality parameters for wells and springs sampling conducted by The Palestinian water Authority (PWA) in 2003 is shown in Table 11 and Table 12. Comparing the results with the Palestinian water health standards; it is clear that water quality from these sources is within the acceptable standards.

Table 11: Water Quality Parameters for selected wells (mg/l)

Governorate	Ca	Cl	EC	HCO3	K	Mg	Na	NO3	SO4	TDS
Bethlehem	57.7	22.6	541.5	244.4	1.8	27.0	12.8	8.1	13.1	208.1
Hebron	56.0	28.8	530.0	252.8	2.0	30.5	14.9	8.4	13.9	241.3
Jenin	101.8	116.1	1010.3	294.6	8.0	33.7	58.9	34.6	30.8	435.3
Jericho	180.4	710.5	3193.3	301.5	28.7	125.1	263.4	32.6	143.9	1113.5
Jerusalem	32.5	24.5	467.5	194.5	1.5	23.5	12.0	11.0	9.0	227.0
Nablus	65.2	59.2	714.2	252.9	1.6	39.2	27.9	27.3	22.7	326.6
Qalqilia	88.8	81.0	1007.2	310.3	8.4	39.3	47.8	66.7	59.7	545.7
Ramallah	54.8	32.2	541.4	245.1	2.9	33.3	15.2	15.1	14.5	261.3
Salfit	_	31.0	_	_	_	_	_	11.0	_	_
Tubas	101.5	141.5	1169.2	249.7	3.2	41.9	69.9	113.4	47.5	518.9
Tulkarm	80.0	80.7	860.3	261.9	5.5	27.1	43.8	51.9	28.0	419.4

Source of data PWA data base, 2003

Table 12*:* Water Quality Parameters for selected springs (mg/l)

Governorate	Ca	Cl	EC	HCO3	K	Mg	Na	NO3	SO4	TDS
Bethlehem	_	42.2	844.6	287.8	10.5	_	29.4	66.8	42.0	363.6
Hebron	81.2	60.8	752.0	275.8	3.1	31.1	44.0	79.7	34.3	383.6
Jenin	88.3	67.8	818.6	232.6	11.5	26.1	36.6	67.9	28.5	383.2
Jericho	66.5	41.9	584.6	225.0	2.4	24.7	16.8	21.2	19.8	272.5
Jerusalem	0.0	48.0	679.0	191.0	2.4	0.0	42.0	37.6	76.2	321.0
Nablus	64.8	44.4	551.2	206.9	2.4	18.4	20.0	23.9	17.7	245.7
Ramallah	66.2	38.3	595.7	236.7	2.0	25.9	21.3	24.8	24.8	292.7
Salfit	96.0	70.9	858.8	246.2	10.6	20.8	34.2	72.8	40.0	442.9
Tubas	121.4	227.4	1382.6	245.5	5.6	51.1	98.2	31.4	71.8	530.4

Source of data PWA data base, 2003

4.4.3. CONVEYANCE, DISTRIBUTION, AND STORAGE

Fragmented transmission links deliver water from surface water, groundwater and other supplies to satisfy demand at demand sites and subject to losses, physical capacity, contractual and other constraints.

Many communities are not connected to a piped water supply. Figure 16 shows the classification of communities to served and un-served by a water network in addition to the percent of population connected to a water source. "Although average water supply coverage levels are relatively high at around 90% of households, there is a significant local variation and average data also conceal problems within systems in terms of the reliability and the quality of service". (SUSMAQ, 2003)

Figure 15 shows water network status as what have been collected through field surveying conducted by Palestinian Hydrology Group for the Water and Sanitation Hygiene Monitoring Project (WASH MP). The Figure shows that only 36 % of the communities having network with a good network, and the others have a bad network. This indicates the high percentage of losses (PHG, 2004)

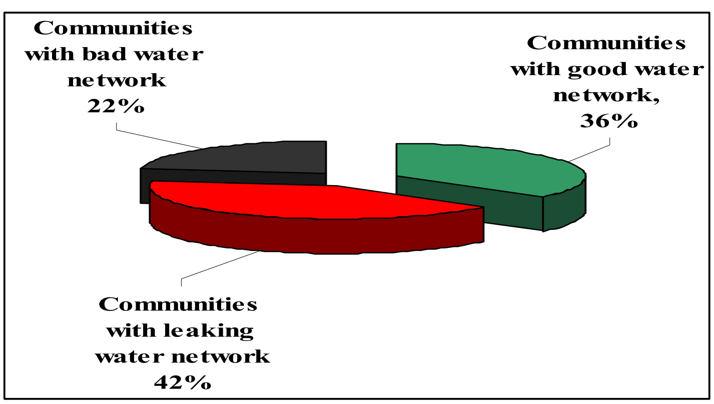

Figure 15: Water Network Status

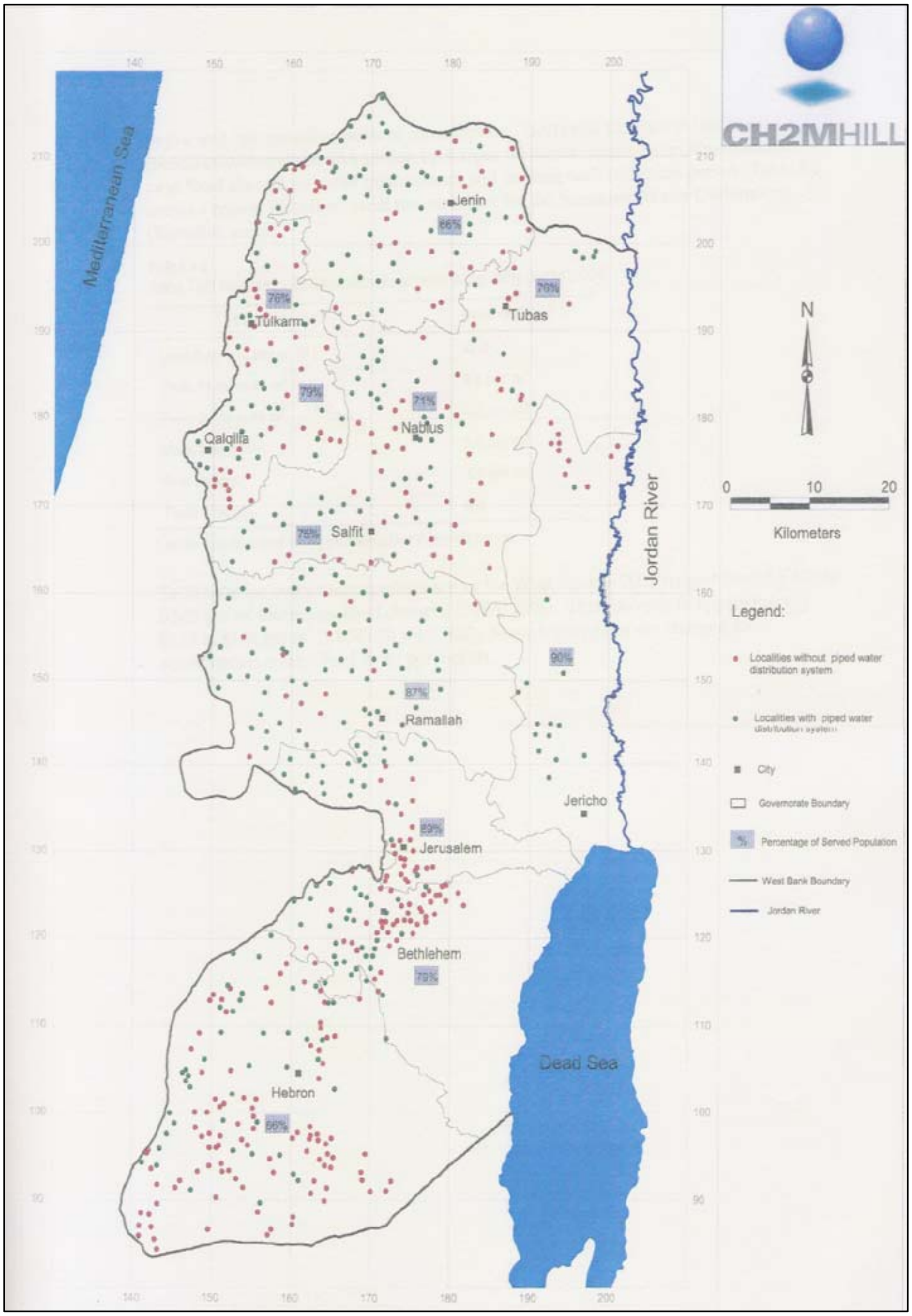

Figure 16: West Bank Localities with and without piped water distribution system (Source: CH2MHILL, 2003)

The transmission losses refer to the evaporative and leakage losses as water is carried by canals and conduits to demand sites and catchments. This loss rate is specified as a percentage of the flow passing through a transmission link. The average estimated loss is due to poor construction, inadequate maintenance, illegal connections and inadequate metering. Table 13 shows these losses for each district obtained from different municipalities.

Table 13: Distribution losses

District	Loss Rate (%)
Bethlehem	30
Hebron	38
Jenin	36
Jericho	20
Jerusalem	25
Nablus	32
Qalqilia	26.5
Ramallah	28.16
Salfit	35
Tubas	31.13
Tulkarm	45

At present, conveyance between districts is not existed due to the absence of national water distribution grid.

Figure 17 shows the conveyance system for the West Bank. However, large service areas are interconnected to multiple water supplies in urban areas, but this is not the case in small rural communities.

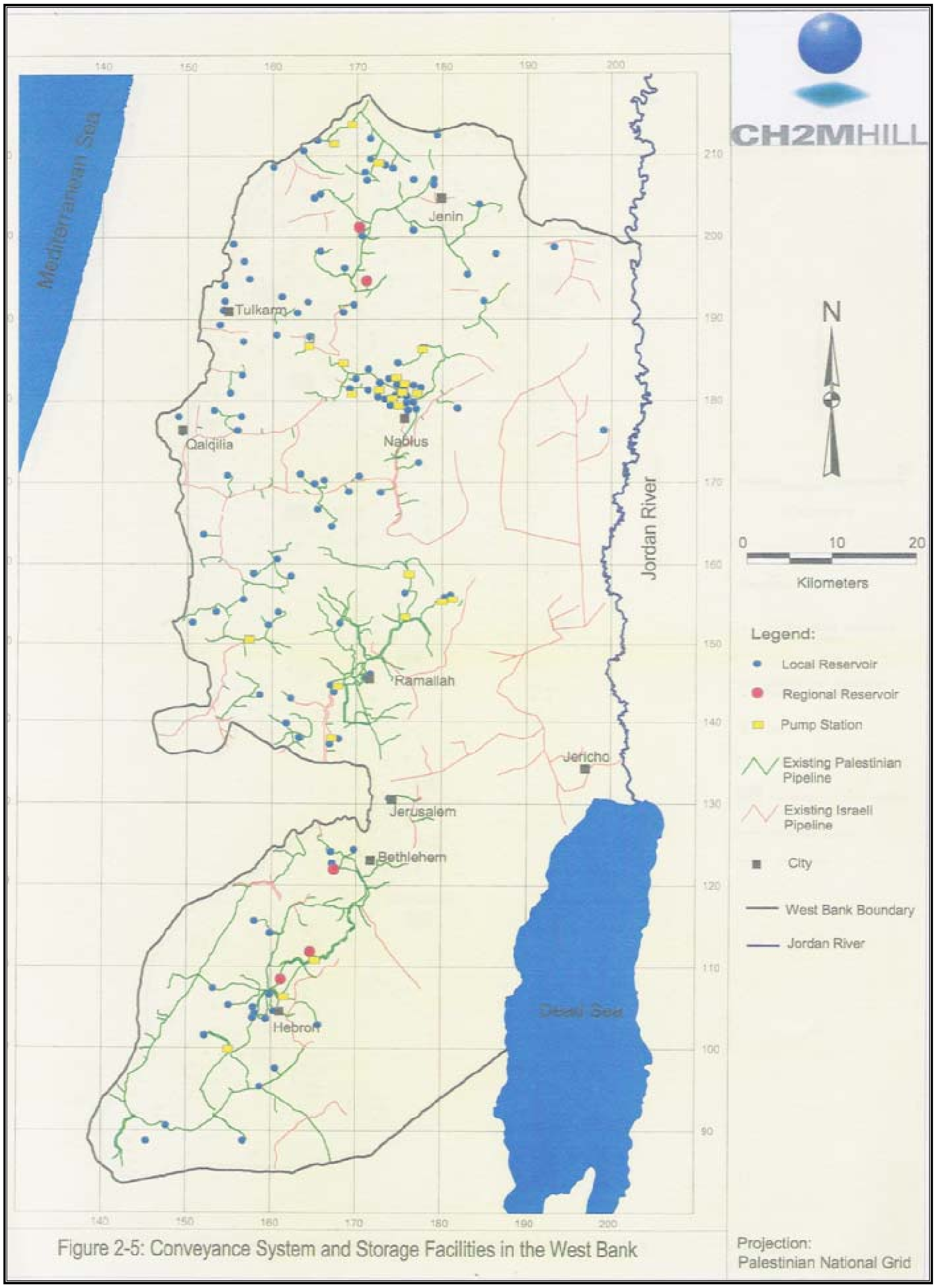

Figure 17: Conveyance System and Storage Facilities in the West Bank (Source: CH2MHILL, 2003)

4.4.4. WASTEWATER FACILITIES

Data obtained from a survey conducted by Applied Research Institute (ARIJ) shows that annual quantities generated from houses accounts 80% of total water consumption. It was found out from the survey that about 28% of populations are connected to public sewerage network while the majority depends upon percolation pits.(www.arij.org)

Agricultural wastewater was assumed to be from 15 percent of total irrigated water (FAO, 1985). The industrial wastewater quantities produced are estimated to be about 80 percent. Wastewater characteristics for some districts of the West Bank are tabulated in Table 15.

Wastewater treatment plants (WWTP) in Jenin, Ramallah, and Tulkarm were built in early 1970's. Effluent quality from these plants is not much better than the influent quality. There has been no maintenance, repairs, and no institutional agency responsible in proper operations. The systems inspected suffer from severe lack of financial support for operation, maintenance, and upgrading. Al Bireh treatment plant is in good conditions and is operating well. Table 14 summarizes basic data of existing WWTP's. (PCBS, 2001)

Table 14: Basic Data of Existing Wastewater Treatment Plants

Location	Type of treatment ponds	Efficiency (%)	Inflow(m^3/d)
Jenin	Aerated Lagoon and Stabilization Pond	Not working	760
Tulkarem	Algal Ponds	15	760
Ramallah	Aerated Lagoon and Stabilization Pond	20	1370
Al Bireh	Activated Sludge and Trickling Filter	90	980
Hebron	Algal Ponds	Not working	1650

Table 15: Characteristics of Raw Wastewater in Each of the West Bank Districts

Parameters	Ramallah	Jenin	Nablus			Tulkarm	Hebron	Bethlehem
			E	W1	W2			
PH	n\a	3.7	6.5	8.8	8.4	6.5	6.0	6.5
COD	1390.0	1557.0	1338.0	3250.0	2000.0	738.0	2736.0	2724.0
BOD	525.0	619.0	560.0	650.0	1150.0	575.0	520.0	660.0
TSS	1290.0	640.0	840.0	300.0	140.0	350.0	1794.0	688.0
Chloride	3500.0	n\a	9300.0	n\a	n\a	n\a	3540.0	1080.0
Phosphate	13.1	n\a	47.0	n\a	n\a	n\a	133.5	45.6
Phosphorus	n\a	15.6	15.6	10.3	10.0	4.0	413.8	141.4
Nitrates	n\a	n\a	201.9	140.0	112.0	0.0	33.4	249.9
Nitrate N	79.0	n\a	45.9	n\a	n\a	n\a	7.6	56.8
NH3-N	n\a	85.3	n\a	n\a	n\a	76.0	n\a	n\a
Sodium	n\a	n\a	840.0	n\a	n\a	102.0	839.0	411.0

1. All concentrations are in ppm except the pH. n/a: not available. E: Main eastern outlet. W1: Main western outlet, the sampling time is 10:10. W2: Main western outlet, the sampling time is 1:30.

2. Source: Environmental protection of the shared Israeli - Palestinian mountain aquifer; The University of Michigan - School of public health- Department of environmental and industrial health; Final Report; April 2000

4.4.5. Cost Estimates

All cost estimates will be based on the available cost estimates in the WSSPS Investment Program and West Bank Integrated Water Resources Management Plan. Assessments were based on actual cost of some projects that had been recently executed. Table 16 shows a summary of the estimated unit costs for the different actions. These estimates are based on the 2003 dollar value

Table 16: Capital, operating and maintenance Costs ($ /m^3)

Management Action	Capital	O&M
Development of new wells	0.43	0.54
Distribution networks	0.17	0.02
Rehabilitation of existing irrigation system	0.27	0.1
Rehabilitation of existing distribution network	0.33	0.13
Rainfall harvesting by cisterns	0.7	0.21
Consumer actions	0.15	0.11
Desalination of brackish water	0.23	0.59
Wadis Utilization	0.49	0.02
Wastewater reuse	1.09	0.76
Desalination of Sea Water	0.23	0.97
Importing by Sea bags	0.03	1.85
Importing by pipeline	1.07	0.16

4.4.6. Water Tariffs

At present each municipality has its own water tariff structure. The most have minimum block rate that has a constant fee regardless of the consumption. There is no distinguishing between different water users except for Salfit. Table 17 shows the tariff structure for the major cities obtained through personal interviews.

Table 17: West Bank Districts Tariff system

District	Tariff blocks	Tariff (NIS)
Bethlehem	m^3	4
Hebron	Less than or equal 10 m3 More than 10 m3	4 NIS/m3 5 NIS/m3
Jenin	Less than or equal 50 m3 More than 50 m3	4.34 NIS/m3 6.2 NIS/m3
Jericho	Less than or equal 150 m3 151 – 250 m3 More than 250 m3	1 NIS/m3 2 NIS/m3 3 NIS/m3
Jerusalem	N/A	
Nablus	Less than or equal 10 m3 11 – 15 m3 16 – 20 m3 21 – 40 m3	3.72 NIS/m3 5.58 NIS/m3 7.44 NIS/m3 7.75 NIS/m3
Qalqiliya	Less than or equal 5 m^3 6 – 39 m^3 40 – 69 m^3 70 – 99 m^3 More than 100 m^3	20 NIS 0.5 NIS/m3 0.8 NIS/m3 1.55 NIS/m3 2.55 NIS/m3
Ramallah	Less than or equal 10 m3 11 – 20 m3 20 – 40 m3 More than 40 m3	42 NIS 3.8 NIS/m3 4.0 NIS/m3 5.2 NIS/m3
Salfit	Less than or equal 10 m^3 10 – 30 m^3 30 – 60 m^3 60 – 100 m^3 More than 100 m^3	35 NIS 3.5 NIS/m3 4.0 NIS/m3 4.5 NIS/m3 5.0 NIS/m3
Tubas	Less than or equal 5 m^3 6 – 10 m^3 11 – 20 m^3 21 – 30 m^3 More than 30 m^3	15 NIS 2.5 NIS/m3 3.0 NIS/m3 4.0 NIS/m3 6.0 NIS/m3
Tulkarm	Less than or equal 5 m^3 6 – 30 m^3 More than 30 m^3	17 NIS 2.5 NIS/m3 3.0 NIS/m3

Source: personal interviews

4.5. INPUT PARAMETERS IN WEAP

In order to build up the WEAP model, the current supply and demand data explained above will be entered to be integrated and used inside the software (WEAP). Figure 18 shows a schematic representation of WEAP input basic parameters

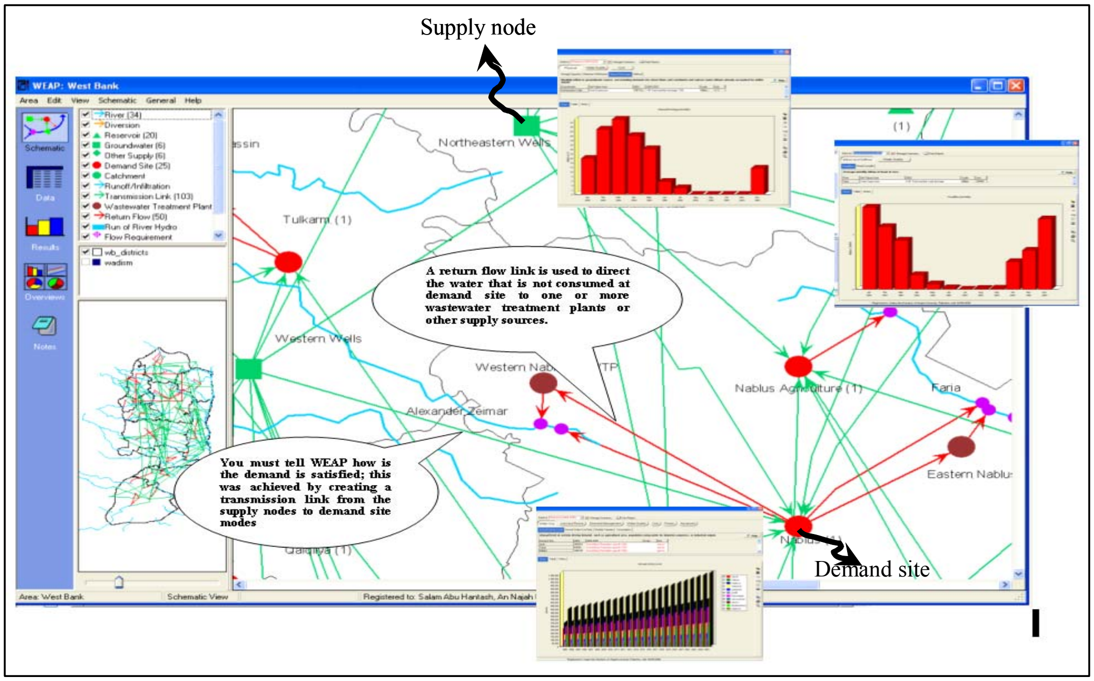

Figure 18: Schematic representation of WEAP input Parameters

Water Demands: Currently three options exist to input and calculate water demand within WEAP: (1) standard water use method (2) FAO crop requirements approach and the (3) direct method.

1. The Standard Water Use Method is the simplest case, the user determines an appropriate activity level (e.g. persons, households, hectares of land) for each disaggregated level and multiples these by an appropriate annual water use rate for each activity.

2. FAO Crop Requirements Approach is typically used to represent agricultural demand nodes. This approach assumes for each demand site a set of simplified hydrological and agro-hydrological processes.

3. Direct Method in which Demands can be directly read into WEAP from a file.

Water demands were entered as 11 municipal demand sites and 11 agricultural demand sites classified according to West Bank districts using the Standard Water Use Method. Figure 19 shows the demand data entry table in WEAP.

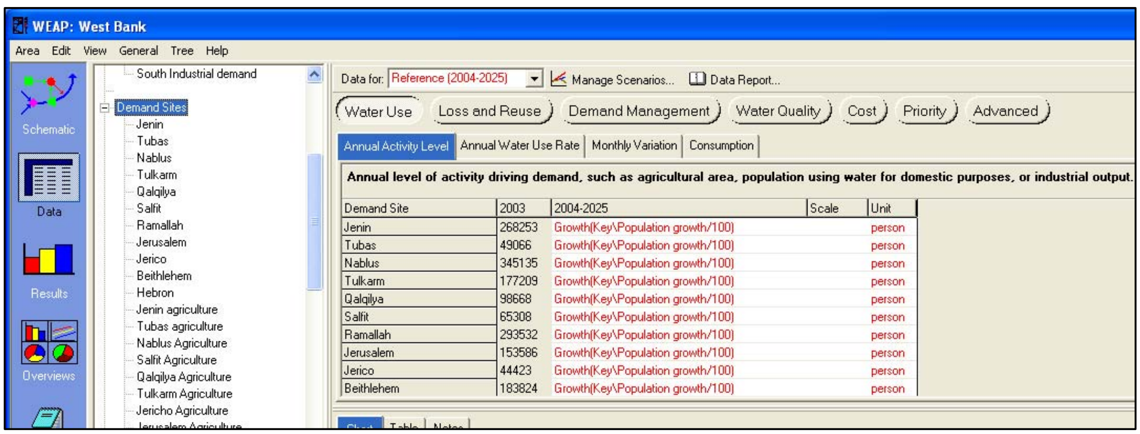

Figure 19: Example of Demand Data Entry Table in WEAP

Supply elements were defined. Data related to groundwater (recharge rates, its initial storage, and the maximum withdrawals allowed according to annual renewal), river and wadis (headflow), other supply parameter used in WEAP to represent supplies other than Groundwater and Rivers such as Cisterns and Mikorot inflows are entered.

There is a need to tell WEAP how is the demand is satisfied; this was achieved by connecting a supply resource to each demand site through creating a transmission link from the supply nodes to demand site modes. Transmission links carry water from local and river supplies, as well as wastewater from demand sites and wastewater treatment plants, to demand sites, subject to losses and physical capacity, contractual and other constraints.

Primarily, WEAP allocates water according to the demand priority associated with each demand site. The sites with the highest priorities get water first, followed by sites with lower priorities as availability allows.

Each demand site with multiple sources can specify its preference for a source, due to economic, environmental, historical, legal or political reasons, by entering supply preference for each source linked to each demand site.

You can restrict the supply from a source, to model contractual or physical capacity limitations, or merely to match observations by entering the maximum flow volume on transmission link rules/maximum flow volume in WEAP.

The transmission losses refer to the evaporative and leakage losses as water is carried by canals and conduits to demand sites and catchments. This Loss Rate is specified as a percentage of the flow passing through a transmission link.

A return flow link is used to direct the water that is not consumed at demand site to one or more wastewater treatment plants or other supply sources.

Entering all related data and integrating them into WEAP, the West Bank conceptual model is shown in Figure 20

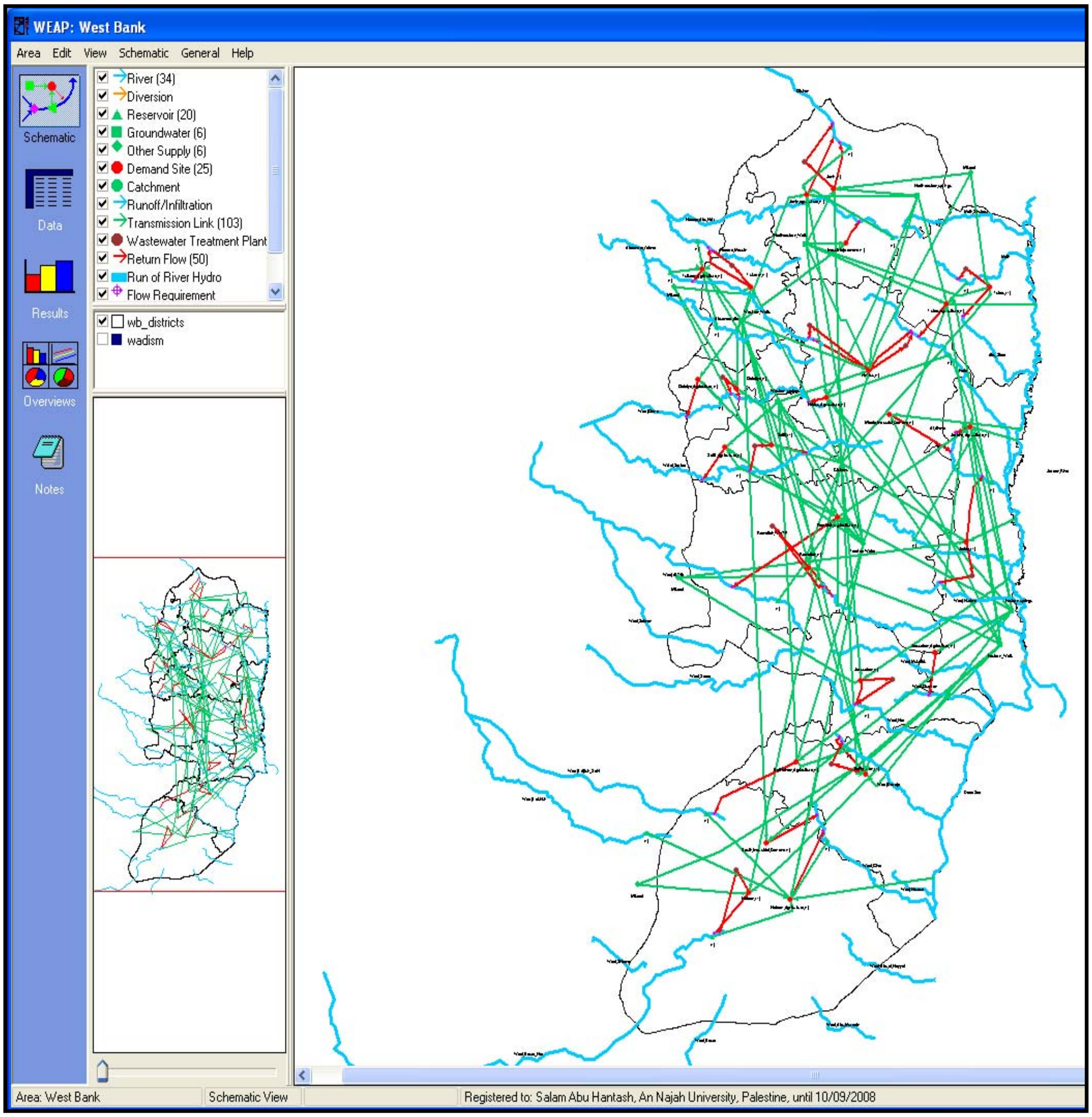

Figure 20: West Bank Conceptual WEAP model

CHAPTER FIVE

DEVELOPMENT OF MANAGEMENT OPTIONS AND SCENARIOS

5.1. INTRODUCTION

Scenarios are self-consistent story-lines of how a future system might evolve over time in a particular socio-economic setting and under a particular set of policy and technology conditions. Using WEAP, scenarios can be built and then compared to assess their impacts. All scenarios start from a common year, for which the model Current Accounts data are established.

The scenarios can address a broad range of "what if" questions. Scenarios in WEAP encompass any factor that can change over time, including those factors that may change because of particular policy interventions, and those that reflect different socio-economic assumptions.

5.2. ESTABLISHING THE REFERENCE SCENARIO

5.2.1. DEMAND PROJECTIONS

This scenario represents the changes that are likely to occur in the future, in absence of any new policy measure. Base case scenario is with population growth at a rate of 3.2 (PCBS, 2003), with existing water allocation and polices and very slight improvement in irrigation practices.

Historic water demand in the West Bank has been artificially constrained by non market forces. As a result, historic demand figures can't be used to forecast future demand (UNESCO, 2005). Current water allocation between Palestine and Israel aggrieves Palestinian water wrights. Present per capita consumption is below WHO standards. So WHO standards will be used to project future demand. Population increase is the major parameter affecting future water needs, not only for domestic uses, but also for other uses such as industrial and commercial uses.

Industrial and Agricultural development in Palestine has been obstructed by Israeli Occupation. The amount of water available for development purposes is insufficient that restricted development to the existing.

5.2.2. Supply Projections

Present water supply has been limited due to severe political constraints and restrictions on developing new water resources and supply infrastructure. Present supplies are not adequate to provide acceptable standards of living and economic development for palestinian. From the political perspective, it is assumed that the water supply quantities will remain static.

5.3. Models Development

Since the historic water demand in the West bank has been artificially constrained by non market forces, domestic water demand will not be calibrated. Instead of the current water supply will be used as the current water demand. By running the model for the reference scenario, Figure 21 shows Palestinian estimated water demand, which is restricted to a minimum that is very far from WHO standards versus recommendations.

Reference scenario results indicate that total water demand will increase from 155 MCM in base year 2003 to 234 MCM at the end of 2025. This increase is due to population growth only.

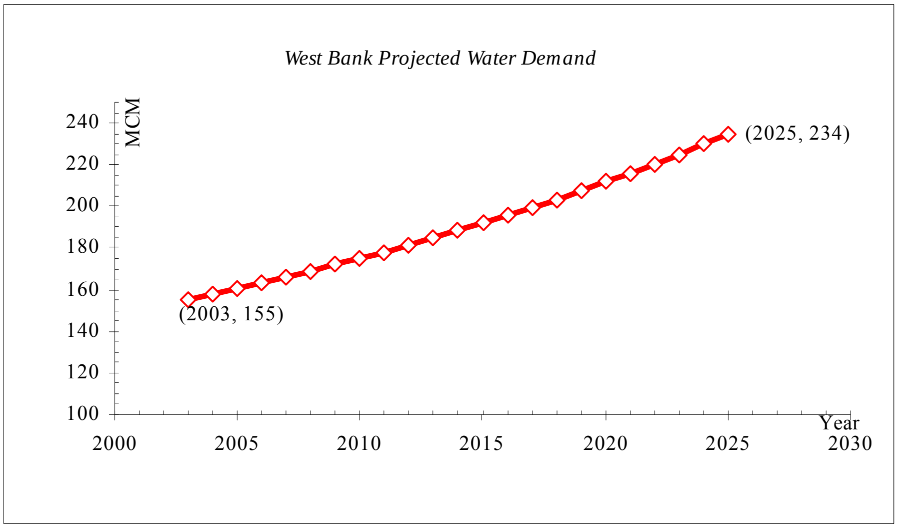

Figure 21: Projected Palestinian water demand for the reference scenario

Unmet demand was predicted at 53.2 MCM in 2005 and increased to 126.17 in 2025 (see Figure 22). This is due to demand increase while the water supply still unchanged due to the Israeli constraints.

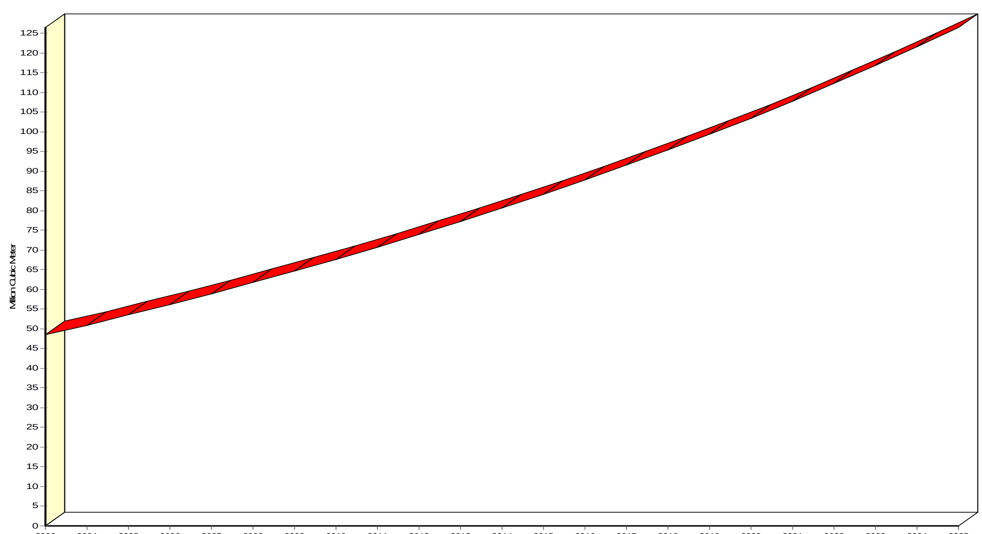

Figure 22: Unmet Demand (Reference Scenario)

Total supplies delivered to different demand sites are shown in figure 23 below, which is at rest according to the Reference Scenario.

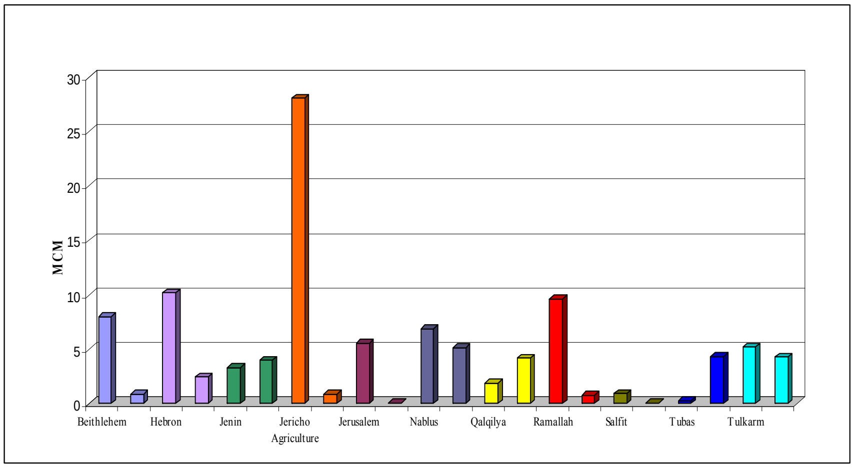

Figure 23: Supply delivered to different demand sites

5.4. MANAGEMENT OPTIONS DEVELOPMENT

In order to develop realistic management options for the West Bank, stakeholder questionnaire developed by Haddad (Haddad, et al, 2006, haddad, 2007) was adopted and distributed to explore Palestinian priorities and concerns related to water uses (Appendix A). It targeted decision makers, researchers, academics and experts, international and local NGO's, farmers, and other stakeholders. One hundred and ninety three questionnaires were returned and properly completed out of 420 distributed to stakeholders, distributed as 51 decision makers, 29 researchers, academics and individual experts, 11 NGO's, 77 farmers, 25 others. This field survey was conducted at the start of the study prior to model simulation runs. Nine groups of questions were listed with a total 107 question distributed as follows:

- Physical and Political Issues (4 questions)
- Environmental Issues (8 questions)
- Water Management Issues (24 questions)

- Institutional Issues (15 questions)
- Socio-Economic Issues (13 questions)
- Agricultural Issues (15 questions)
- Wastewater Reuse (7 questions)
- Data Management and Modelling (13 questions)
- Multiple Choice Issues (8 questions)

The stakeholder survey results came out with the main water resources management decision support questions and issues to be run and found answers through the WEAP simulation runs, as a result of the survey two main factors were identified for better water management in the West Bank

PHYSICAL AND POLITICAL ISSUES

- Israeli imposed and restricted water quotas has limited availability of water to Palestinian (including to farmers)
- Palestinians will have to develop additional (conventional and non-conventional) water resources to meet their future water demands
- Conflicts over water allocation between Palestinians and Israelis are limiting local economic development (including the expansion of agricultural land) and re-shaping political–economic landscapes of the district

AGRICULTURAL ISSUES MANAGEMENT

- I think that the government (PWA, ministry of agriculture or else) should introduce to farmers new agro technologies and on farm water and production management approaches
- I think that the government (PWA, ministry of agriculture or else) should appropriate some of the farms or farming practices and inappropriate others
- I think that existing land uses can be improved through better water and production (plant or animal) management practices

5.4.1. THE ANALYTICAL FRAME: DRIVING FORCES, PRESSURE, STATE, IMPACT

Causal chain analysis traces the cause-effect pathways, associated with each significant water resources problem, from the socio-economic and environmental impacts back to its root causes, is used to target these causes by appropriate policy measures. The most widely accepted framework to help with this task is the Driving forces, Pressure, State, impact, Response (DPSIR).

Applying the DPSIR process to the West Bank study area based on the results obtained from the questionnaire, the following chain was introduced and described as shown in Figure 24 below

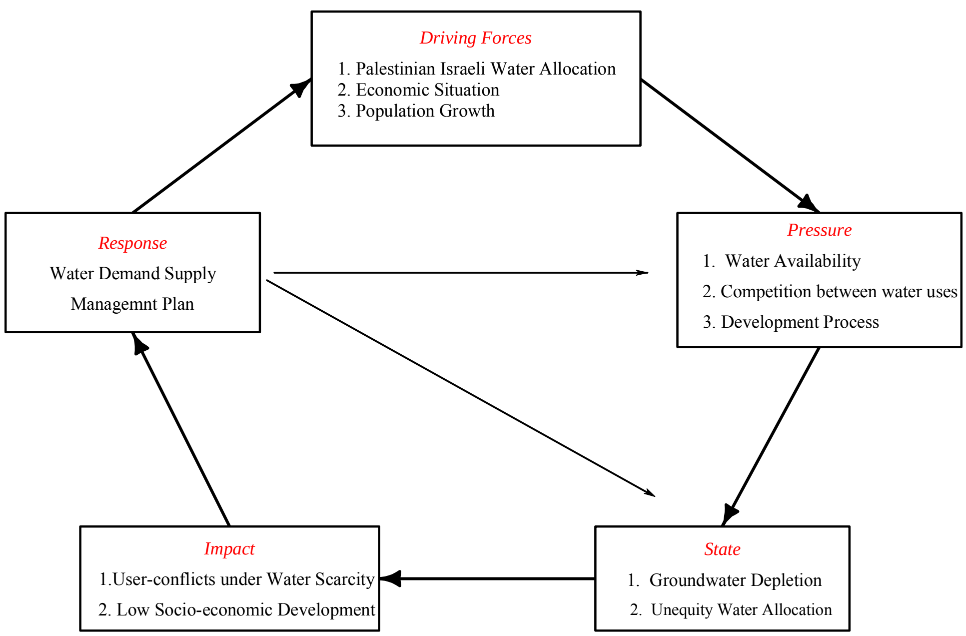

Figure 24: West Bank Driving forces, Pressure, State, Impact (DPSIR**)**

5.4.2. PLANNING CONSTRAINTS AND CRITERIA

Planning criteria were developed to help screening the planning elements and to evaluate the management options in order to obtain the most proper management options. Input parameters taken from the questionnaire target group were used to develop these criteria. The planning criteria main elements are:

- **Economical viability:** Since available funding for water resources development is scarce, it is important that the total cost of a certain water supply alternative to be within Palestinian financial capabilities.
- **Reliability:** It is important to provide significant good quality quantities of water in relation to water demand, and sustain these quantities during the planning period.
- **Equity:** The per capita water domestic supply varies between districts, which is below recommended WHO standards. Water supply options must address the present lack of parity between domestic supplies in the West Bank.
- **Optimizing allocation:** The allocation is based on priority rules, assigned to both demand sites and supply elements. Supply allocation rules express cost, quality and conservation preferences, whereas demand rules reflect social objectives and development priorities.
- **Political Certainty of the Source:** Long term accessibility to the source must be reliable and stable.
- **Institutional arrangements:** It is incumbent upon institutions to be effective, reliable, and efficient in supply management and treatment.
- **Environmental Sustainability:** It is important to maintain sustainable water resources; groundwater abstractions shall not exceed the safe yields to ascertain that aquifers are not over exploited.

- **Public Acceptance:** This criterion refers to public attitudes towards different management options, such as willing to pay additional costs, willing to consume crops irrigated by treated water, acceptance for regulating rules and laws, and any other management options.
- **Fulfillment of Development Needs:** Resources development must be with the maximum benefit for the society related to economic growth due to the expansion of water-reliant economic sectors such as agriculture and industry, and social development.

Based upon the planning Criteria explained above and from the results of the questionnaire; the followings were introduced:

- Priority will be given to supply a minimum domestic demand of 100 l/c/d for all Palestinians as a minimum level.
- Agriculture represents a part of Palestinian economy and culture, provides for a national food security, so a priority in development will be given to support the agricultural sector.
- Groundwater is the most reliable and cost effective source of water for further development, so it will be given the supply preference.
- There is a public acceptance to the reuse of wastewater
- Desalination of Sea Water and importation are considered expensive water source options, so it will not be considered.
- The results of the questionnaire shows that there is a satisfactory level of public awareness to water issues, so demand management option and conservation measures can be implemented .

5.5. POTENTIAL MANAGEMENT OPTIONS

Decisive issues used in developing the scenarios for water management for Tulkarm District (Haddad, et al, 2006) were adopted to be used for the case of the West Bank based on outcome of the stakeholder questionnaire (see Figure 25). The figure shows the most important decisive issues that have significant effects on the various management options. Eight modules were identified and used to develop the scenarios.

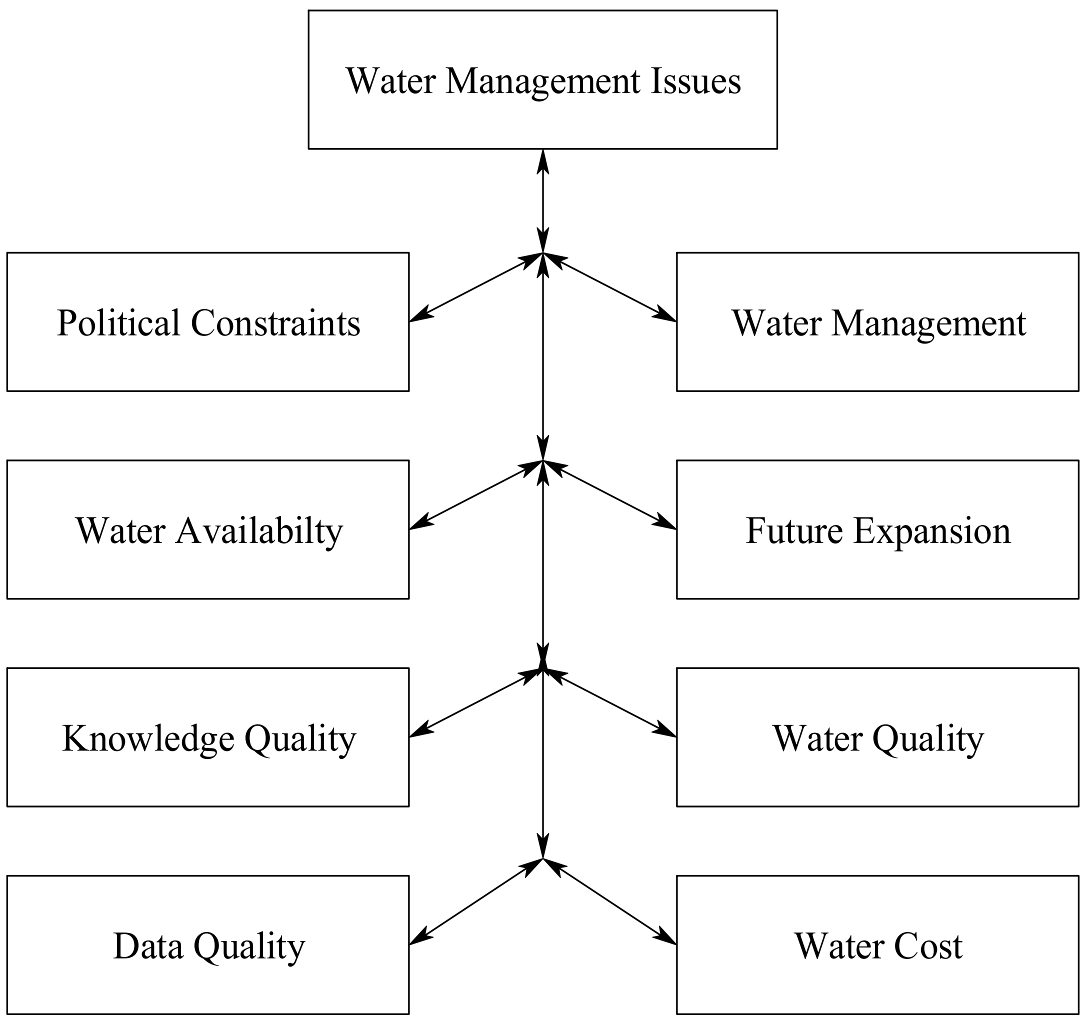

Figure 25: Decisive Issues Used in Developing management Options (Haddad, 2006)

As a result of the analysis of the questionnaire, the political aspects were key factors in developing water resources management options for the West Bank. They have significant effects on the other management options. Accordingly, three main scenarios were developed representing the eight different modules. As such, Figure 26 represents the scenarios development schematic that was used.

- **Scenario 1: Current state of occupation and closures**
- **Scenario 2: Consolidate State when peace process moves on**
- **Scenario 3: Independent State of Palestine**.

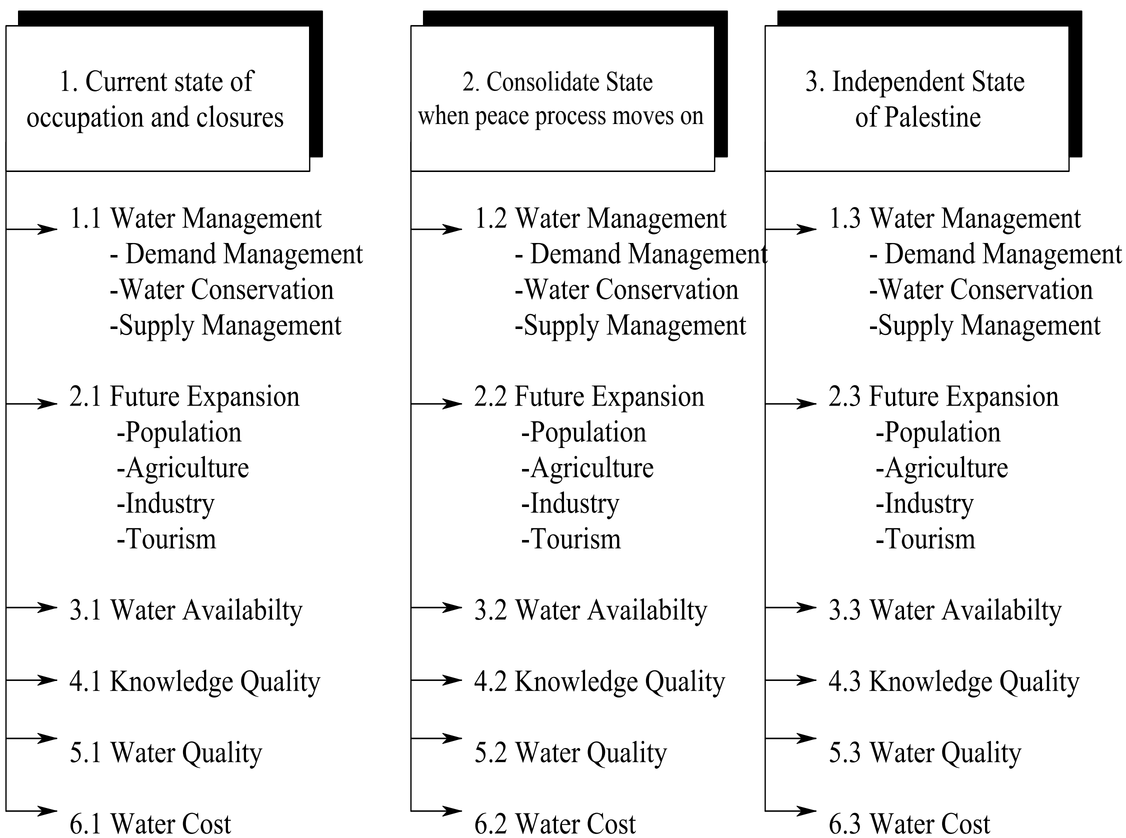

Figure 26: Schematic Representation of Scenarios Development

5.5.1. SCENARIO 1: CURRENT STATE OF OCCUPATION AND CLOSURES

FUTURE EXPANSION MODULE

- Population growth rate 3.2%
- Domestic demand will be at minimum WHO standards. The aim is to provide a sustainable and reliable amount of water to reach 100 L/C/d in an equitable manner for all population in the West Bank to secure health.
- Irrigated areas will still as current
- Industrial demand will remain as current 7 percent of municipal demand.

WATER MANAGEMENT MODULE

1. Demand Management

- Domestic demand will be reduced to be at 100 L/C/d.
- Irrigated areas will still as current.
- Industrial demand will remain as current.

2. Water Conservation: Applying conservation measures and improving water infrastructure was assumed to be reflected in unaccounted for water rates reduction that losses will not exceed 30 percent at the end of 2020.

3. Supply Management: Demand management practices and wastewater treatment and reuse, privatization, farming practices change, institutional aspects and others were not considered due to either economy or political limitations.

WATER AVAILABILITY MODULE: Water available for Palestinian as current

WATER COST MODULE: There will not be any increase in water cost.

WATER QUALITY MODULE: The situation will remain as current

KNOWLEDGE QUALITY MODULE: No effect

5.5.2. Scenario 2: Consolidate State when peace process moves on

Future Expansion module:

- Population projections are assumed as shown in Table 18 to reflect the improvement in the level of living.
- Municipal demand will be at the average WHO standards 150L/C/d.
- Irrigated areas will be projected to achieve 0.12dunum/c at the end of 2020 restricted to total area of irrigable lands, to secure the per capita basic food needs.
- Industrial demand will be increased to reach 10.5 percent of total municipal demand, and tourism will be developed to reach 2.5% of total municipal demand to achieve some reasonable level of economic development

Water Management module:

1. Demand Management (DM)

- Municipal demand will be at the average WHO standards 150L/C/d.
- Irrigated areas will be projected to achieve 0.12dunum/c at the end of 2020 to secure the per capita basic food needs.
- Industrial and tourism demands will be increased to reach 10.5% and 2.5% consequently of total municipal demand.
- Demand management program will be implemented to increase user awareness to use water saving technologies, save water by optimizing its use, and protect it from pollution; It was estimated making use from pervious experiments in communities similar to the West Bank, that water can be saved as much as 25 % (GWP, case studies)

Table 18: Population Projections in the Consolidate State of Palestine while peace moves on

Demand Sites	2003	2003-2007		2007-2015		2015-2020		2020-	
	Population	growth rate	demand	growth rate	Demand (m3/cap/y	growth rate	Demand (m3/cap/y	growth rate	Demand (m3/cap/y
Jenin	253,965	3.20%	20.5	3%	55	2.50%	55	2%	55
Tubas	46,453	3.20%	15.5	3%	55	2.50%	55	2%	55
Tulkarm	167,770	3.20%	41.2	3%	55	2.50%	55	2%	55
Nablus	326,752	3.20%	34.5	3%	55	2.50%	55	2%	55
Qalqilia	93,413	3.20%	46.4	3%	55	2.50%	55	2%	55
Salfit	61,830	3.20%	26.7	3%	55	2.50%	55	2%	55
Jericho	42,057	3.20%	55	3%	55	2.50%	55	2%	55
Ramallah	277,898	3.20%	50	3%	55	2.50%	55	2%	55
Jerusalem	145,400	3.20%	48.7	3%	55	2.50%	55	2%	55
Bethlehem	174,033	3.20%	49.7	3%	55	2.50%	55	2%	55
Hebron	520,479	3.20%	30.3	3%	55	2.50%	55	2%	55

- Agriculture water demand management: Increasing farmer's knowledge and awareness, appropriate new farming practices such as watering at field level, crop reallocation, and crop water allocation reduction techniques, and introduce farmer's new agro technologies and economic incentives; this can save water as much as 13 percent (GWP case Studies).

2. Water Conservation: Applying conservation measures and improving water infrastructure was assumed to be reflected in unaccounted for water rates reduction that losses will not exceed 25 percent at the end of 2020.

3. Supply Management

- Local supplies in this stage are still the only feasible and reliable source of water to meet Palestinian needs and the most cost effective source. The Quantity that will become available for Palestinian use in the future is not defined subjected to the outcome of the final Status Negotiations. Under the terms of article 40 of the Oslo Interim Agreement, the Palestinians are entitled to develop an additional annual supply of 70-80 MCM from groundwater sources above current abstractions.
- Water utilization from wadis is estimated be developed by 42 MCM to be used for agricultural purposes.
- The MOPIC plan for water and wastewater estimated that 4 MCM can be utilized from cisterns by year 2020.
- Water and wastewater network coverage will be expanded to reach 100%.
- Only the wastewater generated by municipalities can be feasibly developed, so 39 MCM/yr of treated water will be used for agricultural purposes.
- Private sector will be engaged in water development activities in the West Bank to achieve development progress. This would enable projects sustainability and ensures more effective water supply management

WATER AVAILABILITY MODULE: Further development of additional 80 MCM form groundwater, 42 MCM from wadis, 4 MCM from cisterns, and 39 MCM treated water.

WATER COST MODULE: There will not be any increase in water cost, improving water tariff system leads to personal demand management practices which can reduce water demand to about 5% (GWP, case studies) included into user awareness assumptions, willingness to pay will increase water project cost recovery which will affect project sustainability.

WATER QUALITY MODULE: It was assumed that all Municipalities will have wastewater collection, treatment and reuse systems and plants. It was also assumed that 39 MCM of collected and treated wastewater will be reused in agriculture.

KNOWLEDGE QUALITY MODULE: Consumer education and awareness level would affect his water use and practices, which could result in water demand reduction. In this case it was assumed that there is an increase in education and awareness to a level that will result in a succeeded efficient demand management program, which can save 25% of domestic demand and 13% of agricultural demand.

5.5.3. Scenario 3: Independent State of Palestine

Future Expansion Module:

- Based on regional equity between Palestinians and Israelis, domestic Demand will be projected as shown in Table 19
- Industrial demand is projected to reach 13% of municipal water demand at the end of 2020.
- Irrigated areas will be increased to achieve the land requirement for national consumption needs which is 0.14 dunum/ capita at the end of 2020.

Water Management Module:

1. Demand Management (DM)

- Water demand practices program will be implemented to increase user awareness of how to save water by optimizing its use, and protect it from pollution; this can save water as much as 25 % and assures equity for all.
- Agriculture water demand management: Increase farmer's knowledge and awareness, appropriate new farming practices such as watering at field level, crop reallocation, and crop water allocation reduction techniques, and introduce farmer's new agro technologies and economic incentives; this can save water as much as 13 percent

2. Water Conservation: Applying conservation measures and improving water infrastructure was assumed to be reflected in unaccounted for water rates reduction that losses will not exceed 20 percent at the end of 2020.

Table 19: Population- Demand Projection Data

Demand Sites	2003	2003-2010		2010-2015		2015-2020		2020-	
	Population	growth rate	Demand	growth rate	Demand (m^3/cap/y	growth rate	Demand (m^3/cap/y	growth rate	Demand (m^3/cap/y
Jenin	253,965	3.20%	20.5	3%	65	2.50%	75	2%	100
Tubas	46,453	3.20%	15.5	3%	65	2.50%	75	2%	100
Tulkarm	167,770	3.20%	41.2	3%	65	2.50%	75	2%	100
Nablus	326,752	3.20%	34.5	3%	65	2.50%	75	2%	100
Qalqilia	93,413	3.20%	46.4	3%	65	2.50%	75	2%	100
Salfit	61,830	3.20%	26.7	3%	65	2.50%	75	2%	100
Jericho	42,057	3.20%	55	3%	65	2.50%	75	2%	100
Ramallah	277,898	3.20%	50	3%	65	2.50%	75	2%	100
Jerusalem	145,400	3.20%	48.7	3%	65	2.50%	75	2%	100
Bethlehem	174,033	3.20%	49.7	3%	65	2.50%	75	2%	100
Hebron	520,479	3.20%	30.3	3%	65	2.50%	75	2%	100

3. Supply Management

- The dependence on Mekorot supply will be terminated, and water supply will be developed by Palestinian there own to satisfy there needs.
- Palestinian will gain their water rights and will develop all their needs which are summarized as follows:

    - Full control over the Eastern Aquifer water resources, since this aquifer is entirely located within the West Bank and is not a shared water resource.
    - Full control over the West Bank groundwater system in the western and northeastern aquifers.
    - Palestinian access to Jordan River and utilization of 250 MCM as what was called for by the Johnston Plan to meet Palestinian needs and development processes.

- Water utilization from wadis will be developed by 66 MCM for agricultural uses.
- The MOPIC plan for water and wastewater estimated that 4 MCM can be utilized from cisterns by year 2020.
- Wastewater generated by municipalities will be treated, 78 MCM/yr of treated water will be used for agricultural.
- Wastewater generated by municipalities will be developed to be used for agricultural purposes can be feasibly developed, so 78 MCM/yr of treated water will be used for agricultural purposes.

WATER AVAILABILITY MODULE: Development of Palestinian needs from aquifers 679 MCM, 250 MCM from Jordan River, 78 MCM of treated water, 66 MCM from wadis, 4 MCM from cisterns

WATER COST MODULE: There will not be any increase in water cost, improving water tariff system leads to personal demand management practices which can reduce water demand to about 5% included into demand management program assumptions, willingness to pay will increase water project cost recovery which will affect project sustainability.

WATER QUALITY MODULE: It was assumed that all Municipalities will have wastewater collection, treatment and reuse systems and plants. It was also assumed that 78 MCM of collected and treated wastewater will be reused in agriculture.

KNOWLEDGE QUALITY MODULE: Consumer education and awareness level would affect his water use and practices, which could result in water demand reduction. In this case it was assumed that there is an increase in education and awareness to a level that will result in a succeeded efficient demand management program.

CHAPTER SIX

RESULTS AND DISCUSSIONS

6.1. RESULTS AND DISCUSSIONS

The results obtained from various WEAP Runs under various scenarios and management options (section 5.5 and Figure 25) were summarized, discussed, and presented in the following sections. The discussion was first given by particular management module then options were integrated into an overall water management representation for the West Bank Water Resources.

6.2. POLITICAL CONSTRAINTS MODULE

Under this module, the different water right options were assumed from Palestinians gaining full surface and groundwater rights to Palestinians gaining some surface and groundwater rights and to Palestinians continue living under current water allocations and constraints, and assuming that a national distribution grid is constructed and water is allocated equitably between Palestinians. Table 20 shows the unmet demand of the different modules for the three scenarios.

Table 20: Predicted unmet demand under the different scenarios and modules

scenario / module	Scenario 3: Independent State	Scenario 2: Compromise State	Scenario 1: existing
Political Constraints	0	239	153
Water Management	0	217	153
Water Availability	+	+	153
Future Expansion	+	+	153
Knowledge Quality	+	+	153
Water Quality	0	200	153
Data Quality	-	-	-
Water Cost	0	235	153
Overall	0	239	153

The Table demonstrated the significant effects for the assumed political situation on every other water management modules. The unmet water demand will vary significantly from to 0 in scenario3, to 239 MCM in scenario 2 to 153 MCM if the existing political situation continues. All modules rather than the political module will have no effect in the existing political situation scenario, since they are repressed by the political constraints module.

In scenario 2 and scenario 3; water availability and future expansion modules have significant effects on the unmet demand either as a reduction by increasing water availability or an increase as future needs will grow. WR management module has significant effects in reducing water gap either in the compromised state scenario or in the independent state scenario during water shortages.

6.3. FUTURE EXPANSION MODULE

Predicted water demand varies according to the three basic scenarios, see Figure 27; it is about three times its value compared with reference scenario.

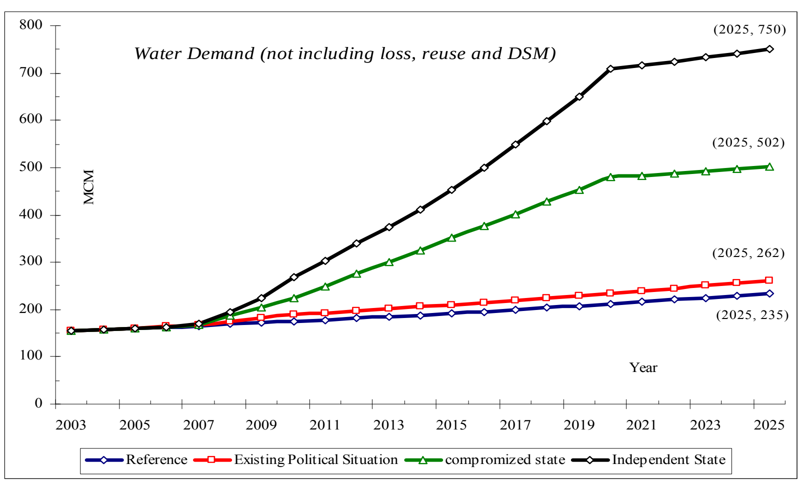

Figure 27: West Bank Predicted water demand

Table 21 shows the predicted water demand and water consumption for three scenarios by the year 2025. This proves the significant relation between water availability and/or accessibility module and future expansion module that are both affected significantly by the political situation module

Table 21: Predicted water demand and water consumption (MCM)

Action \ Scenario	Scenario 1: Independent State	Scenario 2: Compromise State	Scenario 3: existing
Water demand	750	502	262
Water consumption	900	321	156

6.4. WATER MANAGEMENT MODULE

When employed at appropriate levels, Water management can save significant amounts of water that can be developed for other purposes. **Conservation measures** can save water as much as 120 MCM at the end of 2025 for the Independent state scenario.

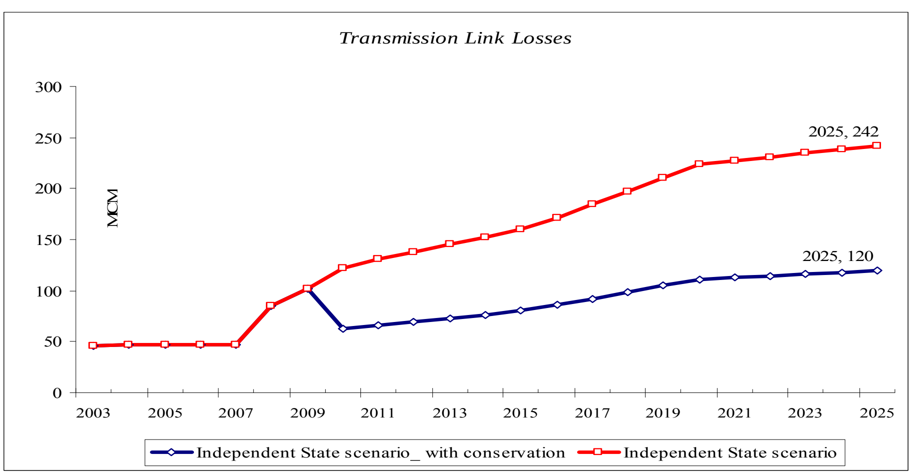

Figure 28: Effect of conservation measures on transmission link losses

Applying water resource management program, see Figure 29, model predicted that:

- 23% reduction in supply predictions using water management changes.
- About 1.5% reduction in supply predictions using water cost changes

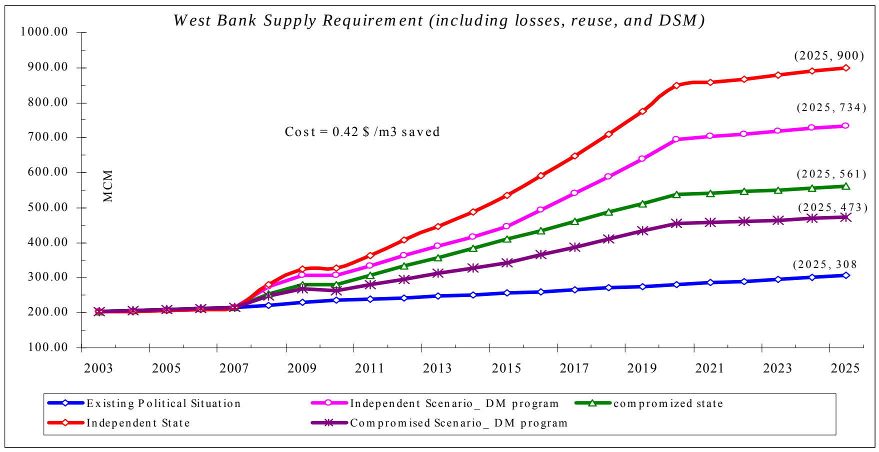

Figure 29: West Bank Predicted Supply Requirement

Water consumption that is the actual amount of water that is delivered to the demand sites after subtracting any transmission losses is shown in Figure 30. The Figure shows that applying conservation measures and DM program can save water as much as 205 MCM /yr by 2025 in scenario 3.

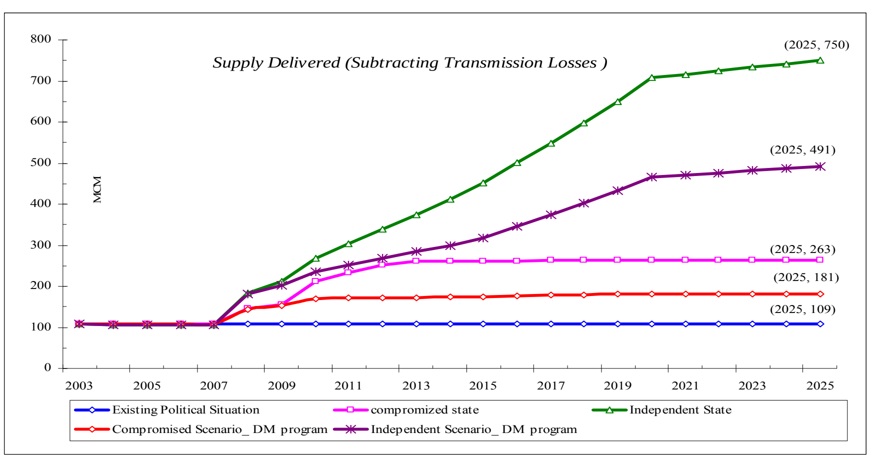

Figure 30: Supply Delivered

Table 22 shows predicted supply requirement for the three scenarios under the different modules

Table 22: Predicted Supply Requirements (MCM/yr)

module \ scenario	Scenario 3: Independent State	Scenario 2: Compromise State	Scenario 1: existing
Political Constraints	900	561	308
Water Management	734	473	308
Water Availability	+	+	+
Future Expansion	+	+	+
Knowledge Quality	+	+	308
Water Quality	822	522	308
Data Quality	-	-	-
Water Cost	891	556	308

The Table demonstrated the important role of water management in saving water and reducing predicted water demands.This varies significantly according to the variation in the poltical situation. Water availaibity and future expansion plays an important role. Knowledge quality contributes significantly to the success and efficient implementation of water management programs. The political module dominates other modules in the existing situation scenario, since other modules donnot have any effect on the situation. Risks associated with water data inaccuracy was not possible to consider due to model limitations and/or data availability.

6.5. WATER AVAILABILITY MODULE

Implementation of Internal resource scenario relying on the recognition of Palestinian water rights will add more than 700 MCM at the end of 2025 to fulfill all development needs.

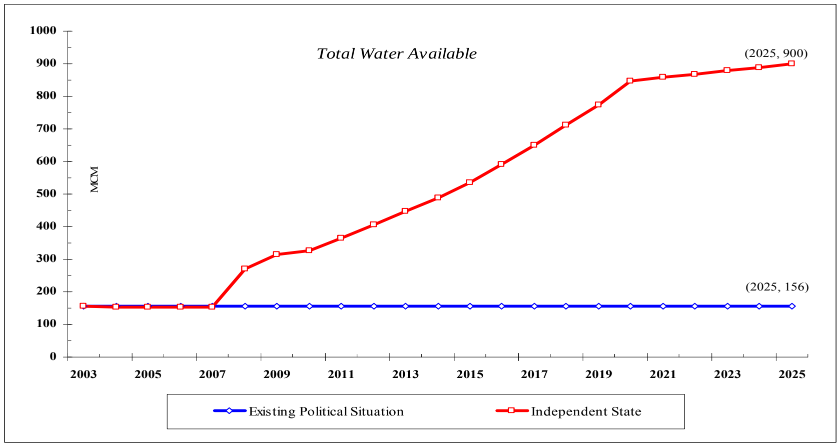

Figure 31: Total Water Available

The unmet demand is shown in Figure 32 .Having thier water rights, palestinian will definitely fill the gap of water demand; it turns out to be zero percent in the independent state scenario. Even that water demand is kept at the minimum WHO standards and no further development, the gap between demand and supply will be more than 150 MCM if the existing situation continues. There is a need to develop about 250 MCM of water to achieve some reasonable level of life and development.

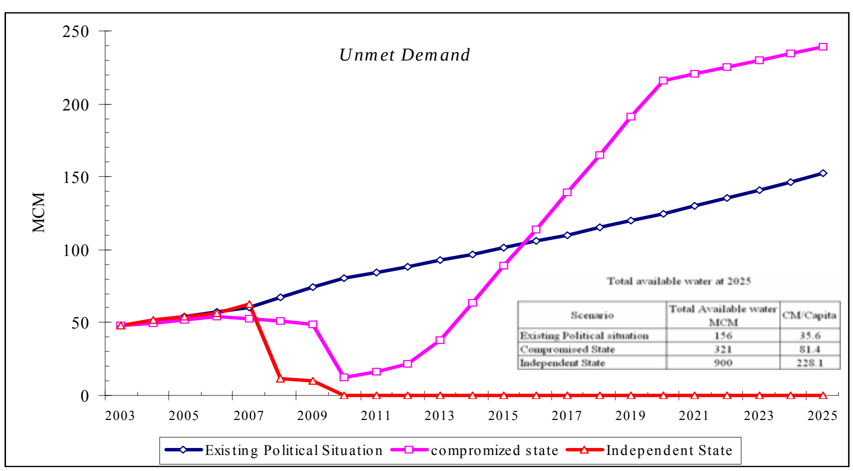

Figure 32: Unmet Demand

Figure 33 shows the predicted cumulative theoretical groundwater storage, neglecting Israeli abstractions from our groundwater resources; this indicates that Palestinian can develop their grounwater that fulfills their proposed needs while sustaining their water resources.

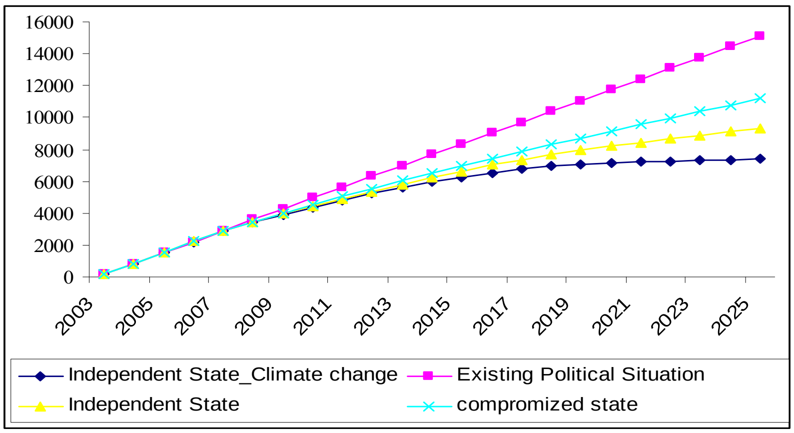

Figure 33: Estimation of cumulative theoretical groundwater storage

Hebron, Jenin, Nablus, and Ramallah will hardly suffer from water shortage if current situation continues. This requires more attention to those districts.

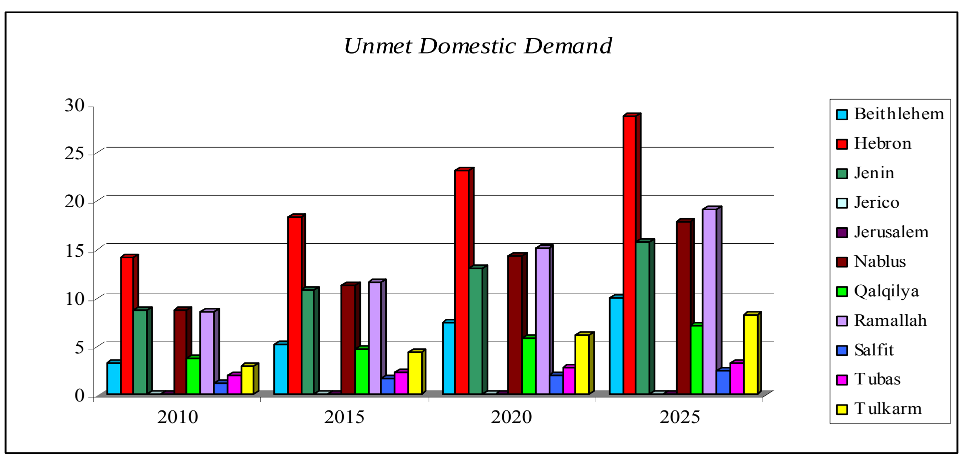

Figure 34: Reference unmet domestic demand for West Bank districts

Figure 35 shows water balance between demand and supply for the proposed Independent state scenario at the end of 2025. The results indicate that Palestinian can develop as much as water that fulfills all their proposed needs while sustaining their water resources.Also, despite that the study didn't mention Palestinian Returnees since there isn't a clear plan how they will be resettled, the study shows that there will be further amounts to be developed to satisfy their needs in addition to DM savings.

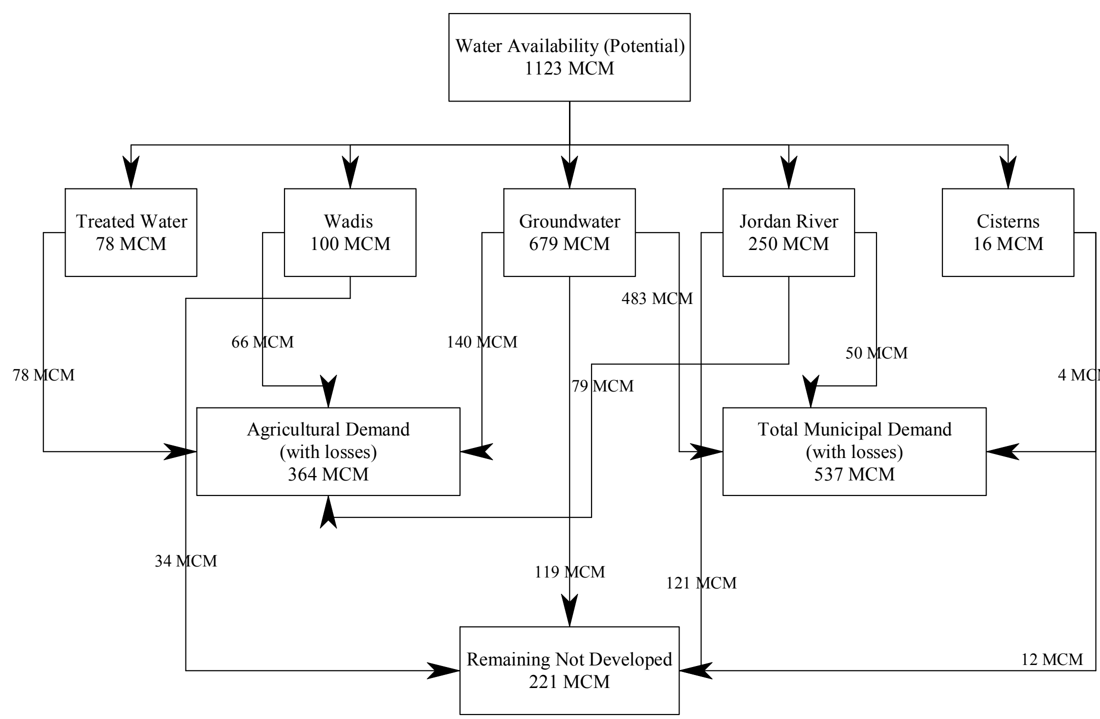

Figure 35: Water Balance (Independent State Scenario)

A climate change described as an increase in temperature of 2^{o}C in summer and 1.7^{o}C in winter and a decrease of rainfall of 50 mm at the end of 2040, the model predicted that in this situation the demand will increase by 14% and available water will decrease by 25%. During this extreme water shortage, water supply priority will be given to satisfy the domestic uses by 150 l/c/d, and the remainder of available water will be directed to the agricultural sector. This situation will result in a decrease of water demand by 16 %.

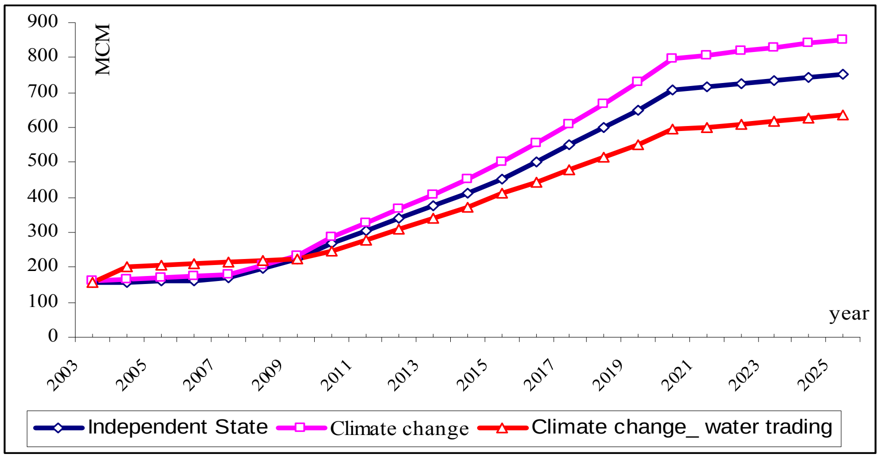

Figure 36: Predicted Water Demand under independent state climate change scenario

Applying the water trading between the sectors resulted in 42 % reduction of unmet demand in the year 2025. See the Figure below

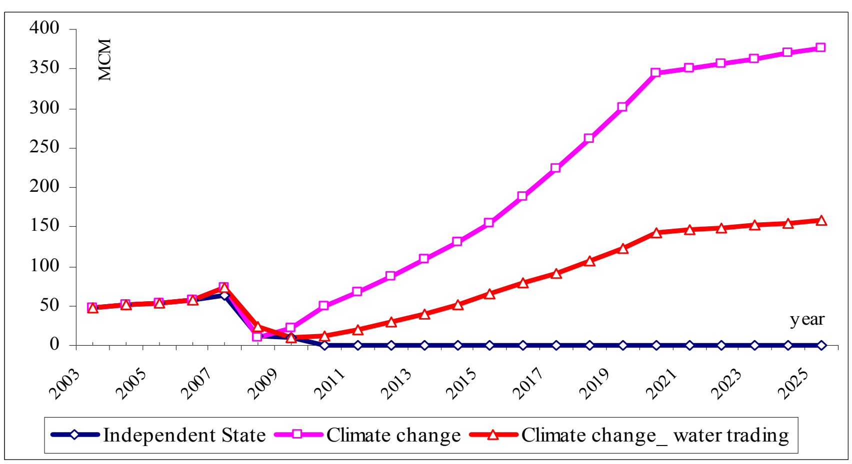

Figure 37: Predicted unmet demand under independent state climate change scenario

Predicted water demand for each district by 2025 for Scenario 3 is shown in Figure 38

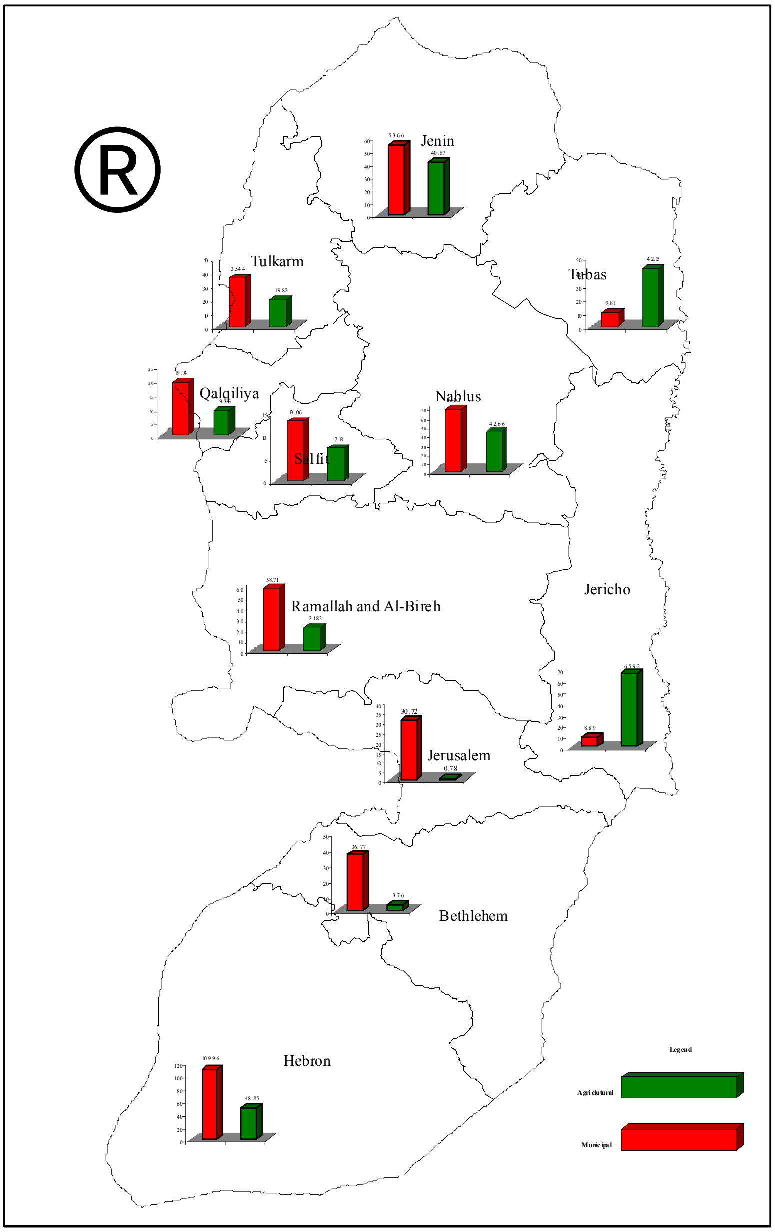

Figure 38: Projected Water Demand for Districts (Independent State Scenario

6.6. WATER COST MODULE

Model prediction for water cost module indicate that water cost will increase slightly during the design period up to 2015 in the independent state scenario and 0.250 US$ reduction in water cost by the year 2025. Also the model predicted a reduction 2% in unmet water demand by the year 2025 (Refer to Table 20).

6.7. WATER QUALITY MODULE

The model predicted a decrease in pollution generation to a convincing level and an increase of water availability for irrigation purposes to 39 MCM in the compromised state and 78 MCM in the Independent state. Accidental spills of hazardous wastes such as chemical or petrol spills could not be modeled in WEAP for GW.

6.8. DATA QUALITY MODULE

Risk of water data inaccuracy was not possible to consider due to model limitations and/or data availability

6.9. KNOWLEDGE QUALITY MODULE

The change in water demand for this module is included in the water demand predicted under water management module .This result emphasized the strong relation between management and awareness where the increase in consumer knowledge and awareness resulted in higher water conservation and demand reduction.

6.10. WEAP Representation of the Overall WR Management in the West Bank

As a result of WEAP output analysis, it can be shown that each module has an effect on each other, but this effect varies significantly according to the political situation which dominates all other modules (Refer to Table 20).

Water resource management cannot take place properly if the existing situation continues. Implementation of water resource management aspects can take place only when peace process moves on. The most important module that must be relied on in reducing water demand is the water management aspects. Changing water cost has an insignificant effect in reducing water demand compared to water resource management. Stakeholder involvement is important to be considered when implementing water resource management program.

A transition period s assumed that development of West Bank water resources will take place between the years "2007-2015". This assumption was to implement the management options, although it is totally affected by the development in the peace process.

Chapter Seven

Conclusions and Recommendations

7.1. CONCLUSIONS AND RECOMMENDATIONS

Based on the results obtained, the following points were concluded:

WEST BANK WR MODELING RESULTS

- Water demand varies significantly according to the assumed political situation. Water management aspects are significant
- Unmet water demand will grow dramatically if the existing situation continues
- Additional 700 MCM/yr should be developed to satisfy Palestinian needs and development, and a min. of 250 MCM/yr to achieve some reasonable level of living up to 2025
- Palestinians can successfully develop and manage their water resources
- Water cost module indicated a 0.250 US$ reduction in water cost and 9.2% in unmet water demand by the year 2025
- Applying water trading between sectors resulted in a decrease of water demand of 16 %. And 42 % reduction of unmet demand in the year 20

WEAP SHORTCOMINGS

- Water quality and data quality were not possible to implement by the model.
- Transmission losses are miscalculated while predicting supply requirement
- Optimization of groundwater abstractions is not possible

FUTURE RECOMMENDATIONS

- Decision makers should emphasize on water management aspects
- Stakeholder involvement importance to consider
- Creating a reliable water and wastewater system is important to implement water resource management
- Water supply options from groundwater aquifers are more reliable and secures Palestinian water rights
- Non conventional sources are distinguished by their high relative costs
- Possible water trading during the transmission period
- Using the new version of WEAP (WEAP-MODFLOW) to optimize the water abstractions/allocation
- The study attempts to develop a Water resources management WEAP model for the West Bank for the first time, so it will help other researchers, students, water management decision makers, and other stakeholders for understanding the situation and identifying the best management options for the West Bank. Also it can help the Palestinian negotiating team in their work.
- The study serves as the foundation of WRM model to be continued for additional research.

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Appendix A

Stakeholder Survey

Water Management Questionnaire

Stakeholder Code:

DSS water issue	Answer
1. Physical and Political Issues	
Israeli imposed and restricted water quotas has limited availability of water to Palestinian (including to farmers)	
Conflicts over water allocation between Palestinians and Israelis are limiting local economic development (including the expansion of agricultural land) and re-shaping political–economic landscapes of the district	
Palestinians will be able in the future of controlling and using their full water rights	
Palestinians will have to develop additional (conventional and non-conventional) water resources to meet their future water demands	
2. Environmental Issues	
There are environmental degradation processes in the district such as desertification and salinization of soils	
Negative impacts of uncontrolled disposal of agricultural waste as well as solid and liquid waste disposal are expected on groundwater quality	
I agree that PWA or the ministry of environment to set taxes to reduce pollution to groundwater.	
I know about the various environmental quality standards	
I feel sharing some responsibility towards environmental quality of the district	
I feel that environmental quality of the district is the full responsibility of the government	
I agree to install a dual water system (one line fresh and the other is treated wastewater) and use it where it is appropriate	
There is salinity and or industrial, and/or wastewater discharges into the water I use	
3. Water Management Issues	
I am comfortable and satisfied with the qualitative and quantitative water data available to farmers	
I feel that water rules and regulations set and adopted by PWA/PNA are in effect and implemented	
I believe that governmental rules and regulations are set for the benefit of farmers	
I think that the government (PWA, ministry of agriculture or else) should strengthen some of the farms or farming practices and inappropriate others	

My work or institution engage in significant communication with the public	
I think that the government (PWA, ministry of agriculture or else) should share with farmers on regular basis through brochures and reports the common conceptual framework and procedure and plans set including a discussion of the decision and communicate the proposed solution	
There are educational material being produced directly or indirectly by my work and/or institution	
I agree that groundwater withdrawal and/or recharge be used as a mean for smoothing climatic irregularities (droughts and/or floods) in the district	
I agree to reduce agricultural water demand to secure more fresh water for the domestic sector	
I think that much rain water can be conserved through local runoff control and harvesting projects	
Increasing the capacity of water users (farmers) would influence decision-making in district water management	
I believe that social mobilization and transformation is needed for farmers in the district in case of agricultural sector limitation and agricultural water being traded or transferred to other sectors	
Among obstacles to efficient water management is the overlap, conflict and fragmentation of competences between institutions	
Among obstacles to efficient water management is the lack of inexistent/ineffective participation of potential stakeholders in water management	
Among obstacles to efficient water management is the lack of problems with private sector participation in the provision of water and sanitation	
Among obstacles to efficient water management is the deficiencies in the implementation and enforcement of water quality standards	
Among obstacles to efficient water management is the lack of specific education programmes, awareness campaigns and training activities	
Among obstacles to efficient water management is the unclear allocation of water rights and deficiencies in conflict resolution	
Increasing pressure on groundwater resources is driven by the households demand for water	
Increasing stress on water resources is expected to be driven by population growth	
Ethical values/issues are relevant to my work	
Implementation of “low consumption technologies” (e.g., toilets, washing machines), water conservation technologies (e.g., roof tank) is inexistent and/or ineffective in the district	
Implementation of “supplementary water technologies” (e.g., wastewater reuse) is inexistent and/or ineffective in the district	

Increasing stress on water resources is expected to be driven by tourism growth	
Pressure on freshwater resources is driven by the agriculture demand for water	
4. Institutional Issues	
The minimal power and authority of PWA on water resources development and use has affected agricultural sector in the district	
My work/institution generate outputs which are or could be used by policy makers	
I think that the government (PWA, ministry of agriculture or else) should coordinate between itself, farmers –as one of the sector stakeholders – and the research/scientific, policy makers, and various decision makers	
The decision-making processes used by the government (PWA, ministry of agriculture or else) are transparent, responsive and flexible to public input (enabling public participation in decision making)	
The centralization of decision-making by the government (PWA, ministry of agriculture or else) has affected agricultural development within the district	
I believe that substantive stakeholder representation in PWA, the ministry of agriculture and others is necessary to improve and influence decision-making in district water management	
I believe that moving the decision making process from the government (PWA, ministry of agriculture and others) to farmers would result in better water management	
I believe that moving the decision making process from the government (PWA, ministry of agriculture and others) to private sector would result in better water management	
I recommend the implementation of a cooperative approach between the government, the stakeholders, and developers for better water management in the district.	
It is appropriate in Palestine to use a water management structure composed of bulk water utility (PWA) managing four sub-utilities (northern, central, southern, and coastal)	
I consider ethical values and issues in my work	
I believe that ethical values and issues should be considered in the institution where I work	
I undertake Gender Equality Actions in my work and/or institution	
If gender equality is undertaken in the work, does females undertake leading position in the work and or the institution	
Proper water management starts from the user and not from the government	

5. Socio-Economic Issues	
Are you happy with the marketing approach of agricultural products used in the district	
Farmers in the district have a hand on setting the price of agricultural products they produce	
I think that farmers should have a say in water pricing	
I agree to pay the real water price if the government or PWA set the price of water to its full cost including development and conveyance	
I will consider participating and working in full for or in an agro-market created by the government (ministry of agriculture, PWA, or else).	
I believe that economic growth in the district is directly connected to water availability constraints	
Urbanization in the district has placed a heavy burden on available human, financial and socioeconomic resources	
Among obstacles to efficient water management is the too low water price with respect to implementation of "full cost recovery" principles	
Among obstacles to efficient water management is the deficiencies in the tariff structure	
Among obstacles to efficient water management is the deficiencies in gender equity in (water-related) education and training, division of Roles and labour (e.g., salary discrimination) between men and women in all settings related to water	
Among obstacles to efficient water management is the lack of more equitable share of women in key stakeholder water-related institutions	
Among obstacles to efficient water management in the district is techno-economic barriers	
Among obstacles to efficient water management is the lack of investment in research and development activities	
6. Agricultural Issues	
I am comfortable and satisfied with the qualitative and quantitative of agricultural products needed for the next season	
I am happy with the agricultural extension services available	
I am well knowledgeable on agricultural matters of concern (production, cropping, watering, pesticides, insecticides, fertilizers, biotech of seeds and others)	
Farmers in the district know about modern agro technology	
I recommend increasing the size of agricultural land	
I will consider the application of soil protection methods such minimal tillage to prevent soil erosion/pollution/degradation	
I will consider the application of different distribution techniques to advance the efficiency of organic fertiliser	

I recommend limiting of live stocks fram sizes	
I believe that current Palestinian agricultural practice make farmers poorer	
Existing crop transpiration and irrigation models can be used to calculate the demand of water for any crops map of the district	
I think that existing land uses can be improved through better water and production (plant or animal) management practices	
I think that the government (PWA, ministry of agriculture or else) should appropriate some of the farms or farming practices and inappropriate others	
I think that the government (PWA, ministry of agriculture or else) should introduce to farmers new agro technologies and on farm water and production management approaches	
I recommend to farmers in the district to adopt a reallocation of crops according to crops capacity to protect the soil from erosion	
I adopt and use crop water allocation reduction techniques based on scientific merits (assuming it will not reduce crop production or yield)	
7. Wastewater Reuse	
In case of the availability of treated wastewater I will increase my farm land and use the treated water in addition to available fresh water	
In case of the government decided to establish a wastewater treatment and reuse committee/institution to be responsible for managing the treatment plant and reuse system, I will consider participating in such committee	
In case of the government decided to establish a wastewater treatment and reuse institution as private-stock type institution I will consider participating and/or buying the shares of such institution	
If the government of PWA set the price of treated wastewater to its treatment, storage, pumping, and conveyance cost I agree to pay such price	
Obsolete/poorly maintained technologies for wastewater collection, treatment, and reuse is not accepted	
I am willing to share and pay a portion of wastewater treatment costs	
I am willing to buy and eat agricultural product irrigated by treated water (well controlled and monitored up to standards)	
8. Data Management and Modelling	
I would like to have and use a computer model that guarantee simplicity of use in the input phase, in scenario setting and in processing output results	
I would like to have and use a computer model that guarantee predicting the evolution of the regional crops map, the crop yields and the associated Prices,.	
I would like to have and use a computer model that evaluate water use policies that combine the sustainability of natural resources (including	

hydrological processes) with regional economic development	
Existing rainfall, evapotranspiration rates can be used to estimate groundwater recharge rates for the district (or watershed)	
I trust the use of existing econometric models to dynamically determine crops maps from input variables including the israeli fixed water quota.	
I trust the use of existing econometric models to calculate crop yields from specific input variables including the israeli fixed water quota.	
I trust the use of existing econometric model to forecast shortterm crop prices from its historical values.	
I trust weather based forecasting models to estimate future precipitation, crops water needs and irrigation quota , groundwater levels, and other related variables	
As a local stakeholder in the district: I believe that the output a computer water management model would teach you about the basic landscape responses within the district	
As a local stakeholder in the district: I believe that the output a computer water management model would guide the decision makers in district development to the benefit of local communities	
Among obstacles to efficient water management is the lack of advanced information technology, and modelling	
Among obstacles to efficient water management is the deficiencies or denial of the rights to information access (to water, wastewater, agriculture and technological matters	
I think that current data available to you through PWA, ministry of agriculture or else can be used to provide a rational basis to identify priority areas for on farm water management actions	

9. Multiple Choice Issues

Prioritize the following marketing approaches:

- National marketing company
- Private –centralized marketing company
- Private marketing agents (prevailing)
- Other ……………………..

What do you suggest as to improve the implementation level of water rules and regulations

- Improve PWA to have special department on rules and regulations
- Set new water institutions for such purpose/ exterior to PWA
- Set new organization shared by farmers and PWA, and the Ministry of agriculture and environment.
- Other

In case of the government decided to establish a wastewater treatment and reuse committee/institution would you like it to be responsible for managing

- The treatment plant and reuse system
- The treatment plant
- The reuse system
- Pricing
- All of the above + future development
- Other………………………

Mark the most preferable water management institution for the district

- Directly through PWA
- Water department within municipality or village council
- A joint committee from PWA, farmers, and NGO's
- A joint committee from PWA and farmers
- Other……………………………………….

What is the most important factor(s) in encouraging farmers to support and use treated wastewater

- Adopt appropriate wastewater treatment technology
- Adopt appropriate monitoring and enforcement,
- Set abatement costs of pollutants to support the sustainability of the process
- Set flexible regulations and incentives for trading of treated wastewater with fresh
- Adopt broader environmental goals
- Support studies and research
- Encourage discussion and dialogue among stakeholders

In case of severe water shortages what option would you recommend most to overcome such shortage:

- Impose restrictions on water use in agriculture
- Impose restrictions on water use in cities
- Impose restrictions on water use in industry and tourism
- Other………………………

In case of severe water shortages what option would you recommend most to overcome such shortage:

- Increase pumping rates (although it is already at the safe yield)
- Impose ristrictions on water use
- Increase water prices
- Develop water through desalination
- Increase wastewater treatment and reuse
- Import water from outside
- Other..

Water scarcity in the district is due to:

- unfavourable hydrological and climatic conditions (e.g., precipitation/evapotranspiration balance, seasonal distribution)
- the change in district population (positive or negative)
- Israeli military control of Palestinian water resources
- Combination of ……….and ……….

Note (1) = Extremely unimportant or negative
(5) = Neutral, Don't know, or the issue is irrelevant
(10) = Extremely important or positive
Stakeholder Code:
1. Ministry1.1 PWA, 1.2 MO Agriculture, 1.3 MO Localities including municipalities, village council and etc
2. NGO's 2.1 UN 2.2 International 1.3 Local NGO
3. Private Sector 3.1 Private company, 3.2 individuals (rural, urban, refugee camps, etc)
4. Research/academic
5. Others ………

جامعة النـــجاح الوطنية
كلية الدراســات العليا

تطوير الخيـــارات الإداريـــة لمصـــادر الميـــاه في الضفة الغربيـــة باســـتخدام برنـــامج (WEAP)

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قدمت هذه الأطروحة اســـتكمالاً لمتطلبات درجة الماجســـتير في هندســـة الميـــاه والبيـــئة بكلية الدراسات العليا, جامعة النجاح الوطنية, نابلـــس, فلـــسطين

2007

تطوير الخيارات الإدارية لمصادر المياه في الضفة الغربية باستخدام برنامج (WEAP)

إعداد

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المـــلخـــص

يعاني الفلسطينيون من نقص حاد لمصادر المياه نتيجة للقيود التي فرضها الاحتلال الإسرائيلي على الفلسطينيين والتي تعوق دون تطويرِ مصادرِ جديدة وتحدٌ من توفر المياه للشعب الفلسطيني. وتفتقر الضفة الغربية لبنية تحتية جيدة لتوفير المياه مما تسبب في فقدان كميات كبيرة من المياه بالاضافة الى عدم توفر الدعم المالي لمشاريع جديدة. إضافة لكل ما تقدم فان النظام السائد لإدارةِ مصادرِ المياه في الضفة الغربية لا يستطيع مواكبة التزايد المستمر في الحاجة للمياه.

تكونت منهجية الدراسة مما يلي: (1)جمع البيانات اللازمة ومراجعتها (2) إجراء استطلاع رأي ميداني للجهات المساهمة في قطاع المياه للحصول على العوامل المهمة والمؤثرة في القرارات الإدارية لمصادر المياه (3) نمذجة نظام مصادر المياه في الضفة الغربية باستخدام برنامج (WEAP) يهدف لمحاكاة الواقع لدراسة وتقييم الخيارات المختلفة يعمل كنظام مساعد وداعم لإتخاذ القرارات.

تشير النتائج التي حصلنا عليه الى أن الطلب على المياه يختلف باختلاف السناريو للوضع السياسي المحتمل, كما تؤكد على أهمية تطبيق نظم إدارية تهدف إلى توفير استهلاك المياه. أيضاً تشير الدراسة الى حاجة الفلسطينيين لتطوير مصادر اضافية تقارب 700 مليون متر مكعب من المياه لسد الاحتياجات المائية للأعوام العشرين القادمة, وعلى خلاف ذلك فإن الفجوة بين مقدار التزود والطلب على المياه سوف تزداد اتساعاً إذا استمر الوضع الحالي. خلصت الدراسة الى إمكانية تطوير نظام خاص باستخدام برنامج (WEAP) مساعد وداعم لإتخاذ القرارت المتعلقة بمصادر المياه في الضفة الغربية وتحقيق الفائدة المرجوة من هكذا نظام.