An-Najah National University
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A BENEFIT-COST ANALYSIS OF TREATED WASTEWATER REUSE FOR IRRIGATION IN TUBAS

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Dedication

To the soul of my mother who encouraged me to continue my study and taught me how to challenge the difficulties. To my father, my brothers and my sisters, and to my husband Monther for his support and encouragement and to my children Mustafa and Jawan, and to the mother of my husband for her support, and to every one helped me.

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LIST OF TABLES

LIST OF FIGURES

LIST OF Appendix figures

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Abstract

The West Bank, Palestine suffers from water scarcity due to the high population growth rate, the political situation that dictates the utilization and development of the water resources and the arid and semiarid climate conditions. Reuse of treated wastewater can be a source of water for the irrigation of agricultural crops and thus this will lessen the stress on the water resources, increase the agricultural productivity and prevent the pollution of the soil and groundwater.

In Tubas City, there is a shortage of water due to the increase in water demand (domestic and agricultural). Raw wastewater is discharged into wadies and which has a negative impact on groundwater resources. Treated wastewater reuse is expected to become a potential solution for this shortage in water availability and environmental problems.

This work investigated the feasibility of reusing treated wastewater for irrigation in the Tubas area. A questionnaire was distributed to analyze the public opinion toward the construction of a wastewater treatment plant and the corresponding reuse of the treated wastewater in agricultural irrigation. Thereafter, a benefit-cost analysis was carried out to estimate the cost of the reuse of the treated wastewater in Tubas area. The study considered five options for wastewater treatment in Tubas area: construction of a treatment plant for the wastewater originating from the north of Tubas, south of Tubas, north of Tubas and Tayaser village, all of Tubas, and all of Tubas and Tayaser village, respectively. The study analyzed three systems for secondary wastewater treatment: activated sludge (AS), trickling filter (TF) and aerated lagoons (AL).

The results of the questionnaire showed that the majority of responders support the idea of having a wastewater treatment plant in Tubas. The results of the benefit- cost analysis showed that the total costs (US$/$m^3$) for the AS treatment for the five options are: 1.73, 1.93, 1.65, 1.57 and 1.52, respectively in 2010. The total costs (US$/$m^3$) for the TF treatment for the five options are: 1.55, 1.72, 1.47, 1.41 and 1.36, respectively in 2010. The total costs (US$/$m^3$) for the AL treatment for the five options are: 1.39, 1.54, 1.32, 1.27 and 1.24, respectively in 2010.

Chapter One
Introduction

1.1. Background

Palestine and the majority of the Middle East countries suffer from water scarcity. The problem of water shortage has governed life in Palestine for a long time and it will be more serious in the coming years (Al-Zeer, 2000). Population growth, the change of lifestyle, and accelerated urbanization threaten the water supply sector in general and agriculture in particular. This leads to both a sharp increase in water consumption and water pollution (Al-Zeer, 2000). Water scarcity in Palestine can be related to the political situation where Israel imposes unfair and discriminative control over the Palestinian water resources (Zimmo and Imseih, 2006). In addition, the arid and semi arid climate conditions of the region and the rainfall variability worsen this situation (Zimmo and Imseih, 2006). Therefore water shortage in Palestine represents a critical limitation to potential development and even to irrigation in the present time (Zimmo and Imseih, 2006).

Historically, agriculture played an important role in the Palestinian economy and life where the availability of water is the most important factor affecting this sector (Zimmo and Imeseih, 2006). Agricultural irrigation is the largest sector for water consumption in Palestine, utilizing up to 65% of the available water, although irrigated areas constitute less than 11% of the total Palestinian cultivated areas in the West Bank ((Zimmo and Imeseih, 2006).

Reclaime wastewater is becoming a new water resource for agricultural irrigation since the good-quality water resources available for irrigation are decreasing (Haruvy, 1997). Many benefits can result from using treated wastewater in irrigation. This will preserve the scare water sources and increase the agriculture productivity. At the same time when using the nutrients available in wastewater this decreases the fertilizers costs (Haruvy, 1998). Another advantage of reusing treated wastewater is the reduction of environmental pollution by the prevention of groundwater pollution from the infiltration of wastewater effluent to the aquifer (Al- Zeer , 2000).

There is an increase in water demand (domestic and agricultural) in Tubas district, West Bank, due to the continuous increase in population. At the same time, there is a shortage in water supply. Wastewater treatment and reuse for irrigation could become one of the main alternatives to lessen the problem in the shortage of water.

The aim of this study is to investigate and assess the potentiality of the reuse of treated wastewater for irrigation in Tubas area. In addition, the study will examine the feasibility of wastewater reuse using a benefit- cost analysis.

1.2. The Study Area

Tubas City (see Figure 1.1) is located in the northern area of the West Bank. It is 27 km northeast of Nablus and a few kilometers west of the Jordan River. It is currently under the administration of the Palestinian Authority and is the center of Tubas Governorate (Wikpedia, 2008). The average elevation of the city is 375 meters above mean sea level. The City of Tubas covers an area of $58km^2$ and had a population of approximately 22,000 in the year 2008 (Hosam Abo Alian, Tubas Municipality, Personal communication, December, 2008).

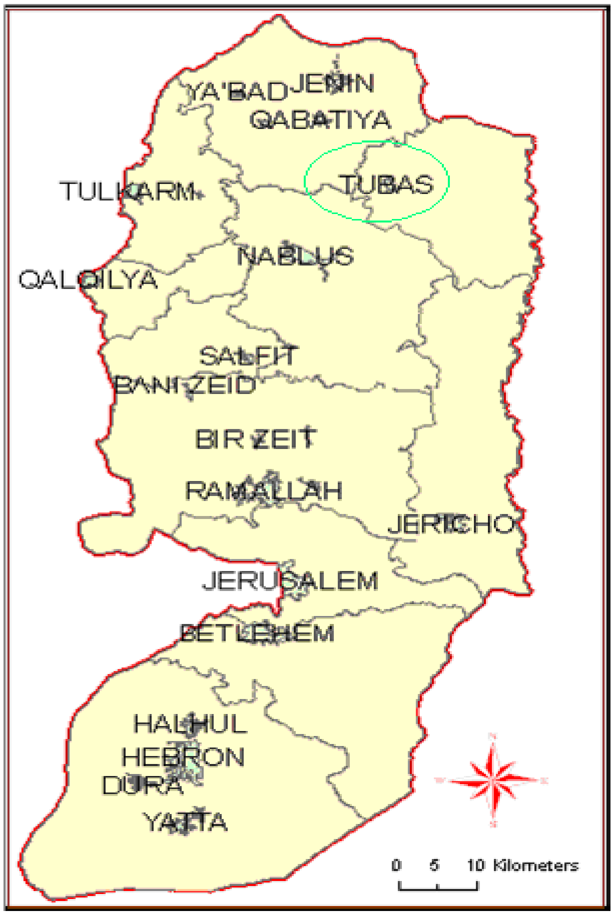


Figure (1.1): Location of Tubas Governorate in the West Bank

The climate is dominantly Mediterranean and semi-arid with mild rainy winters and dry, moderately hot summers. The range of temperature is from 18 to 24 °C. The average annual rainfall in the area for the last six years is 480 mm where most of the rainfall falls between October and April. The maximum annual rainfall for the same years was recorded in 2003 and was 639 mm while the minimum was 326 mm in the year 2008.

The main sources of water in Tubas are rainfall, springs, and groundwater. Groundwater is obtained from Tammun and Faria wells. The amount of bought water in 2008 was 556580 m³, the amount of sold water was 405837

m^3, and the water leakage was 150743 m^3. Agriculture depends exclusively on rainfall for irrigation water (Hosam Abo Alian, Tubas Municipality, Personal communication, December, 2008). The per capita water consumption in Tubas is 51 L/d, and the estimated water loss in the water distribution system is 27%.

Table (1.1) summarizes the agricultural areas in Tubas City where the total agricultural area occupies 14,782 dunums (Hosam Abo Alian, Tubas Municipality, Personal communication, December, 2008).

Table (1.1): Description of agricultural areas in Tubas

Crop Type	Area (dunum)	Amount of water (m^3/dunum)
Wheat	5,100	250
Olive	4,000	350
Hoummus	1,950	300
Clover	800	250
Baiqa	700	250
Onions	610	350
Basila	600	300
Sesame	200	350
Almond	172	400
Beans	200	300
Kamoun	150	250
Barley	120	200
Aniseed	100	250
Cantaloupe	50	350
Figs	20	300
Tomatoes	10	400
Total	14,782	

1 dunum = 1000 m^2

Sample from the domestic raw wastewater of Tubas city were collected for analysis from one of wastewater collection cesspit to give use information bout the characteristics of raw wastewater in Tubas. Testes were conducted at the laboratories of An-Najah National University. The laboratory analysis included the following tests:

* Chemical Oxygen Demand (COD)
* Biochemical Oxygen Demand (BOD)
* Total Suspended Solids (TSS)
* Total Dissolved Solids (TDS)

In Tubas raw wastewater originates from domestic sources. The characteristics of wastewater are impacted by water consumption, population density, and the habits of the population. The analytical results of the analysis are presented in Table (1.2). The typical values of each parameter for Jordan are given in the table beside the value of our sample (pescod, 1992).

Table (1.2): Characteristics of raw wastewater in Tubas

Parameter	Unit	Value	Typical Value
COD	mg/l	800	300-1400
BOD	mg/l	464	100-300
TSS	mg/l	532	300-600
TDS	mg/l	1332	350-1200

As shown in Table 1.2, wastewater composition concentrations in Tubas is higher than the typical values of domestic wastewater in BOD and TDS and this can be attributed to the low water consumption is approximately 51 l/d per person.

1.3. Problem Definition

Wastewater treatment has received little attention in Palestine due to the lack of wastewater collection and disposal systems and treatment. In the West Bank, only 45% of the houses are connected to a sewerage system (Palestinian Central Bureau of Statistics, 2009). The existing treatment plants are heavily overloaded, have poor maintenance and operation, and suffer from the lack of experienced operators (Al-Zeer, 2000).

In Tubas City there is no wastewater collection system and all the wastewater is discharged into collection pits (cesspits) constructed beside the houses. This wastewater is either left to infiltrate into the deeper soil or the cesspits are evacuated where this collected wastewater is discharged into the nearby Wadis causing serious environmental pollution.

The construction of a wastewater collection network is essential for Tubas City along with the construction of a wastewater treatment plant. The treated wastewater can be used to increase the agricultural area in Tubas to help in alleviating the impact of water scarcity on rain-fed agriculture food shortages and reduce the gap between water supply and demand.

1.4. Objectives of the study

The overall objective of this study is to investigate the reuse of the treated wastewater for irrigation purposes in Tubas area using benefit cost analysis that takes the following factors into consideration:

* Future population and water consumption
* Potential locations of wastewater treatment plants

* Areas to be irrigated with treated wastewater
* Crops to be irrigated with the treated wastewater
* Wastewater treatment technologies
* The needed infrastructure for an efficient reuse scheme

1.5. Motivations

The following are the key motivations to carry out the work:

1. The lack of a wastewater collection and disposal system causes potential pollution to the groundwater.
2. There is a shortage in water for agriculture in Tubas area and thus by utilizing the treated wastewater in agriculture this will increase the production and reduce the gap between supply and demand.
3. The nutrients in the treated wastewater can be beneficial for agriculture and consequently reduce the use of chemical fertilizers.
4. I have an interest to study wastewater treatment in Tubas because it is my home town and I want to help in solving the problems of water shortage in Tubas.
5. This is an important topic at the national level and the outcome of this work can be further considered for implementation in other areas in the West Bank.

1.6. Research Questions

The following are the research main questions:

1. What is the public opinion in Tubas area regarding the use of treated wastewater in irrigation?

2. What are the factors that should be considered before implementing a wastewater reuse scheme in Tubas Governorate?

3. What is the cost associated with the reuse of wastewater in Tubas area?

1.7. Research methodology

Figure 1.2 presents the research methodology. I started by the collection of needed data from all available sources. Since the public opinion regarding the wastewater reuse in Tubas area is quite important to be known, a questionnaire was developed and distributed. Characteristics of wastewater of Tubas would be determined by selecting samples and making lab tests. A frame work for benefit-cost analysis was adapted and customized for Tubas area taking the following into consideration: The population forecasts will be determined to estimate the volume of treated wastewater that may be used for agricultural purposes and the size of areas that may be irrigated with treated wastewater, the treatment technology will be selected by taking into account some factors such as the reuse type and water quality requirements, the characteristics of wastewater, the location of the treatment plant which depends on the available area, remoteness from groundwater wells, and the topography to minimize conveyance costs. The economic analysis will compare the cost and the benefits and consider the financial costs and the cost associated with any positive or negative impact of water reuse.

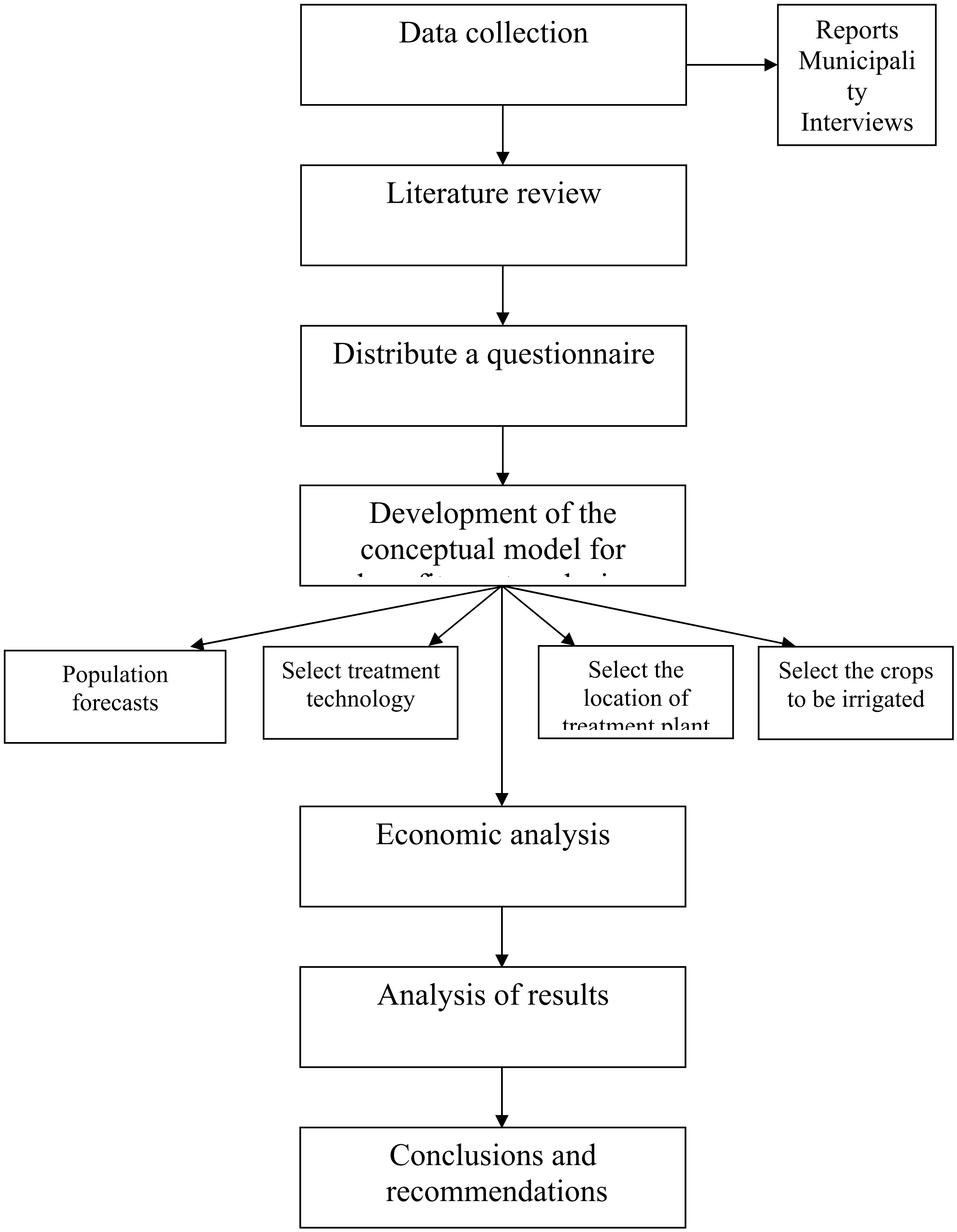


Figure (1.2): The Flow chart of the research methodology

1.8. Thesis Outline

The subject matter of the thesis is presented in six chapters. This first chapter outlines the background, project area, problem definition, objectives, motivations, the research questions and the methodology of the research. The second chapter outlines the importance of wastewater treatment, the Palestinian experiences of reusing treated wastewater, benefits of wastewater treatment, sectors for reuse wastewater, economics of reclaimed wastewater irrigation and obstacles related to the reuse of wastewater. The third chapter describes the questionnaire and the corresponding outcome. The fourth chapter develops a conceptual model for benefit-cost analysis for Tubas area to calculate the costs and benefits resulting from the potential implementation of wastewater reuse. The fifth chapter discusses the analysis and the results of wastewater reuse in irrigation in Tubas area. The overall conclusions and recommendations are provided in Chapter Six.

Chapter Two
Literature review

2.1. Importance of wastewater reuse

The reuse of treated wastewater is becoming a common practice world wide. Reclaimed wastewater is a valuable non-conventional water resource, especially in the Middle East and North Africa. This area has experienced rapid population growth, urbanization, and development of industrial and agricultural activity, which has increased scarcity of water supplies (Kaayyal and Jamrah, 1999). This region also has experienced a drought throughout the last decades that made the water supply insufficiently balanced to the demand (Hochstrat et al, 2008). The availability of wastewater treatment technology makes it possible to obtain a source of water for agriculture, which consumes about 87% of total water in the Middle East and North Africa (Abu Madi et al, 2003). Reuse of treated wastewater can also decrease vulnerability to extreme climatic events and seasonal demand peaks due to the ongoing drought.

Palestine in particular suffers from a serious water shortage. This is due to many reasons, including Palestine's location in a transitional zone between arid and semi arid desert climates, the growing population of growth rate of 3 – 3.5% (Palestinian Central Bureau of Statistics, 2009), and the political situation which causes the lack of control over Palestinian water sources (Fatta et al, 2004). The average per capita water consumption is approximately 55 l/c/d, or 55% of the World Health Organization (WHO) minimum standard, and it is the lowest average per capita in the world (Abu Zahra, 2001).

2.2. The Palestinian experience of reusing treated wastewater

The experience of Palestinians in the reuse of wastewater is young. There are eight wastewater treatment plants in Palestine: five in the West Bank and three in Gaza Strip. The quality of the treated effluent of these plants is generally low; except for the Al-Bireh plant which achieves good efficiency (see Table 2.1 for summary of relevant data).

Table (2.1) Basic data of the existing wastewater treatment plants in Palestine. (Zimmo and Imseih, 2006)

Plant location	Year of construction	Type of treatment	Number	Efficiency [%]	Incoming flow [m^3/d]
West Bank					
Jenin	1970's	aerated lagoon, stabilization pond	2 1	not working	1,200
Tulkarem	1970's	stabilization pond	3	20	1,200
Ramallah	1970's	aerated lagoon, stabilization pond	2 2	30	2,900
Al-Bireh	2000	extended aeration system	2	95	4,000
Hebron	1970's	stabilization pond	3	not working	2,100
Gaza Strip					
Beit Lahia	1997	aerated lagoon facultative, polishing	4 1 1	70	9,400
Gaza	1977 1986, 1999 expanded	anaerobic pond, aerated lagoon	2 2	60	42,000
Rafah	1980	aerated lagoon	1	45	3,816

There were many attempts to reuse wastewater in the West Bank and Gaza Strip. The first project was done in Gaza in 1986 and the second was in

Jabalia; both projects were funded by the UNDP and both of them failed. The UNDP related failure due to the lack of funds in the municipality and lack of trained staff, also the farmers did not accept the idea of the reuse when they could take the fresh water from private wells with lower cost than treated wastewater (Abdo, 2008).

Other projects carried out in Gaza Strip include a Swedish project in Beit Hanoun, the European hospital in Khan Younis, and a French project for the reuse of reclaimed wastewater in Gaza Strip in 2003. This French project is considered the most important experiment in reusing wastewater in Palestine. The objectives of the project were to demonstrate the reusing of wastewater in a local context and to produce references for future projects. Due to the increasing water scarcity in Gaza, these pilot projects showed that treated wastewater can improve the water scarcity and the acceptance of local community for reusing wastewater and the technical and economic feasibility with safe and good quality effluent (Abdo, 2008).

In Al-Bireh wastewater treatment plant (WWTP) there are two types of effluent: high effluent quality and very high quality. For high quality effluent, subsurface drip was used and applied to orchards, olives, ornamentals, grape stocks, processed vegetables and restricted area landscaping. For very high quality effluent, drip irrigation was used and applied on cooked vegetables. A Birzeit University and an Abu-dees University project used treated effluent for flushing toilets and for landscape purposes (Zimmo and Imseih, 2006).

A Palestinian Agricultural Relief Committee project collected gray wastewater from 20 houses with about 180 inhabitants and treated it with a treatment plant consisting of an anaerobic pond, gravel filter, sand filter and polishing pond and used treated effluent to irrigate home gardens and trees. A Palestinian Hydrology Group project started in 1997 at Bani Zaid North of Ramallah to improve the collection and treatment for 25 households and reuse effluent in agriculture. There are also universities and research studies such as the experiment in Birzeit University in the Master of Science program which studied the interaction of reclaimed wastewater from Al-Bireh treatment plant and the quality and quantity of bean plants. The results show that the production increased without use of chemical fertilizers and no detections of pathogens were recorded. Another study is being implemented in Tulkarem in cooperation with the Ministry of Agriculture (MOA) and An-Najah University to study the impact of irrigation with reclaimed gray wastewater on the production of fodder plant crops (Abdo, 2008).

2.3. Benefits and disadvantages of wastewater reuse

Due to the growing shortage of water resources, unconventional water sources such as treated wastewater must be sought. There are many benefits that can result from using treated wastewater. The most important benefit is the preservation of the environment by reducing pollution caused by discharge of untreated wastewater. The use of treated wastewater reduces the constant and continuing depletion of groundwater. At the same time it offers an alternative water resource in an economical and efficient way (Papaiacovou, 2001). This source of water is reliable and constant because it does not depend on rain but depends on the production of sewage that is relatively constant during the year and from year to another. It also enhances the quality of conventional water resources by reducing the demand on fresh water resources (Friedler, 2001). The supply of treated wastewater increases with the population growth, and it can be adapted to agricultural use so it serves as a source of both water and nutrients to reduce fertilization cost and increase the agricultural production while water sources and environmental quality are preserved (Haruvy, 1998).

There are some economic benefits of wastewater reuse. For instance, the total cost of wastewater treatment can be shared by urban and rural sectors. The urban sector will benefit from the reduction of the cost of sewage treatment while the rural sector will benefit from getting a constant source of water at lower cost than importing conventional water from a distance. It can also boost the agricultural development and enhance the public health and environment. Another economic benefit is that the cost benefit analysis usually is performed for 25 years while the lifetime of wastewater treatment infrastructure is at least 40 years, so the annual repayment for recovery is lower than the value calculated for a 25 year period (Friedler, 2001).

There are many risks from reusing wastewater. The effluent of treated wastewater may harm the environment, health, soil, aquifers and crops if it contains pollutants such as BOD, COD, TSS, micro-organic pollutants, trace elements, pathogenic micro- organisms, macro-nutrients (nitrogen, phosphorus) and salinity (Haruvy et al, 1999).

Some risks are short term such as exposure to microbial pathogens; others are long term such as increase in salinity with continued use of treated wastewater. The microbial pathogens enter the environment through many ways such as directly through defecation in water, contamination with sewage effluent or runoff from soil or land surfaces (Toze, 2006). Transmission of pathogens to humans can occur through consumption of irrigated produce or meat of cattle that have grazed on irrigated land. (Abu-Madi, 2006).

Microbial pathogens include bacteria, protozoa, viruses and helminthes; the risk from microbial pathogens depends on their count and the dispersion of them in water. The concentration of various constituents of recycled water can increase with each reuse and can have an important impact on the environment especially when using treated wastewater for irrigation purposes. Sodium is the most persistent and the most difficult element to remove from water, and it impacts the soil and the growth of crops (Toze, 2006). Extra nitrogen may increase groundwater pollution by leaching below the root zone and affecting the health of people that consume groundwater.

For example, Israel has a high level of wastewater reuse for agricultural irrigation, and nitrate concentration was higher than European drinking water standard of 45 mg/l in more than half of the wells in Israel and higher than Israeli standard of 90 mg/l in 20% of the Israeli wells (Haruvy, 1997). Also the nutrients that contribute to plant growth can cause eutrophication when they run off into surface water. Therefore, qualitative ranking have to be used because even when physicochemical composition of wastewater is known the long term impact that reuse will have on the environment is still uncertain (Abu-Madi, 2006).

2.4. Sectors for using treated wastewater

Treated wastewater can be used in landscape irrigation (public and private), cleaning (vehicles/street/building), commercial air conditioning, construction (concrete/dust control) and industry (cooling/processing) (Okun, 2000; Ammary, 2007).

Other activities for wastewater reuse are recreational/environmental uses (lakes and ponds/stream flow/fisheries/snowmaking), potable reuse (blending in water supply reservoirs/blending in ground water), industrial recycling (cooling water/ boiler feed/ process water/heavy construction), non potable urban uses (fire protection/toilet flushing) and ground water recharge (Asano, 2006).

Groundwater recharge is an important category for reclaimed water because it can increase the reliability of water supply. Groundwater recharge can reduce and even reverse declines of groundwater levels, protect underground fresh water from salt water intrusion, avoid water loss from evaporation, and prevent taste and odor problems due to algae and pollution. Underground storage also reduces costs because fewer surface reservoirs are needed (Asano, 2006).

The most common use of treated wastewater is in the agricultural sector. For example, most wastewater treatment plants in Jordan use their effluent in the agricultural process to irrigate crops in the Jordan Valley (Ammary, 2007). Many benefits can result from using treated wastewater in irrigation. For example, water shortages can be resolved, a high quality resource can be used, and crop production can be increased (Lubello et al, 2004). The nutrients in reclaimed wastewater can be used to grow crops, so the nitrogen and phosphorus of sewage might reduce use of commercial fertilizers (Fatta et al, 2004). The cost of treatment can be reduced by using soil treatment so there is no need for tertiary treatment. Environmental degradation can also be reduced because sewage is no longer being discharged with no or inadequate treatment. There are also disadvantages and possible risks that have to be considered. These include the substances in the effluent such as heavy metals, nitrate, and organic matter that may cause damage to the environment, toxicity to plants, harm to groundwater and soil and the spreading of pathogenic germs that harm human health (Abdo, 2008).

The crops to be irrigated depend on the treatment processes and water quality. According to the World Health Organization guidelines (WHO, 2006), irrigated crops may be grouped as restricted and unrestricted agricultural irrigation. Restricted irrigation refers to the irrigation of fodder, fiber, seed crops, pasture, and land areas with restricted public access. Unrestricted irrigation refers to the irrigation of food crops that can be eaten raw or uncooked (Abu-Madi, 2006). In Israel, they use reclaimed wastewater to irrigate industrial crops, cotton and fodder, citrus trees and unrestricted irrigation crops (Bixio et al, 2006).

2.5. Processes of wastewater treatment

The quality of wastewater is defined by many constituents. Macro-organic matter includes biochemical oxygen demand (BOD), chemical oxygen demand (COD) and total suspended solids (TSS). Other constituents include micro-organic pollutants, trace elements which result from industrial water use, pathogenic microorganisms, and salinity from inorganic soluble salts. Wastewater also contains nutrients such as nitrogen and phosphorous which can be both a pollution hazard and fertilizer (Haruvy, 1997).

The processes of wastewater treatment are generally classified into preliminary, primary, secondary and tertiary (advanced) processes. The quality of treated wastewater depends on the processes of treatment. Primary treatment removes settleable solids with adsorbed materials while secondary treatment removes biologically degradable organic materials, including up to 80 – 90% of BOD (Lawrence et al, 2002). Using tertiary processes improves the quality of effluent as it reduces the TSS, VSS, COD, BOD and nutrients such as nitrogen and phosphorus (Hamoda et al, 2004).

Primary treatment processes include screening of coarse solids and sedimentation and grit removal while secondary treatment includes low rate processes such as stabilization ponds and high rate processes such as activated sludge or oxidation ditches. Tertiary treatment includes nitrification-denitrification and soil and aquifer treatment (Haruvy, 1997).

2.6. Economics of reclaimed wastewater irrigation

With the increasing use of treated wastewater in irrigation, economic analyses must be done from different points such as treatment costs, maximizing farmers' income and evaluating environmental impacts. To examine the economic viability we need a cost- benefit analysis for many aspects such as treatment cost, level of population and income of the country, land requirements, power price, climate conditions, distance between wastewater production place and water reuse site, size of plant, flow design and flow seasonality (Urkiaga et al, 2008).

2.6.1. Financial costs of wastewater reclamation

The most important aspect to take when studying the feasibility of reusing wastewater is the economic and financial viability. The cost effectiveness of a reuse project depends on the volume of reclaimed water used; where the more water utilized, the more the cost-effective the project (Urkiaga et al, 2008).

The cost of reclaimed water reuse includes both internal cost of treating wastewater and distributing reclaimed water and external costs of environmental or social nature. Internal costs include the investment cost (land, civil works, machinery and equipment and connection works), financial costs and operating and maintenance costs (Hernandez et al, 2006).

The conveyance and distribution of treated wastewater can be a large portion of reuse project costs. This is because it includes pipelines, pump station and storage facility. The conveyance and distribution cost in Jordan and Tunisia in

(Table 2.2) represent, respectively about 18-67% and 21-76% of total cost of wastewater reuse projects (Abu-Madi, 2006).

Table (2.2): Costs of wastewater treatment and conveyance and distribution against tariff of wastewater sale, in Jordan and Tunisia (Abu-Madi, 2006)

Tariff / cost	Jordan		Tunisia	
	JD/m³	US$/m³	TD/ m³	US$/m³
Tariff *	0.0-0.049	0.0-0.08	0.02-0.10	0.014-0.08
Conveyance and distribution costs Operational costs Total costs incl. depreciation	 0.028-0.084 0.070-0.147	 0.04-.012 0.10-0.21	 0.125-0.21 0.175-0.35	 0.09-0.15 0.13-0.25
Treatment costs Operation costs Total costs incl. depreciation	 0.014-0.238 0.035-0.665	 0.02-0.34 0.05-0.95	 0.042-0.24 0.056-1.30	 0.03-0.17 0.04-0.93
Total costs of treatment and conveyance incl. depreciation	0.105-0.812	0.15-1.16	0.231-1.65	0.17-1.18
Conveyance and distribution costs as percentage of the total costs incl. deprecation	18.1-66.7%		21.2-75.8%	

One US$= 0.70 JD = 1.4 TD (exchange rates of 2009)

2.6.2.Economic impacts of wastewater reclamation

Before making any decision related to wastewater reuse we should take into account the aspects related to both costs and benefits. The benefits include the agricultural output produced by the recycled water, aquifer recharge, saving wastewater disposal cost and avoided costs by prevention of health risks. The costs include wastewater treatment, storage and conveyance costs and agricultural production costs (fertilization and irrigation) and costs associated with environmental degradation, aquifer pollution, salinity, health risk and soil structure deterioration (Haruvy et al, 1999).

A reuse project should maximize the net national benefits, i.e., benefits minus costs and minus environmental damage. Hazards decrease as effluent quality is improved and as the conveyance distance of the effluent to the reuse location increases; at the same time this will increase the costs (Haruvy, 1998). The result of the difference between income and costs helps to determine whether or not the project is feasible. Lack of planning is one of the problems sometimes associated with water reuse projects, which makes the real price of a reuse project higher than the estimated one, so the total benefit and cost of the project must be accurately analyzed to get the true feasibility of the study (Hernandez et al, 2006).

2.6.3. Prices of reclaimed water

The price of treated wastewater must be based on the costs, and a regeneration project should aspire to recover its overall costs, including distribution systems (Hernandez et al, 2006). At the same time, to encourage the usage of treated wastewater the cost to users of the effluent (e.g. farmers) must be affordable. The success of reuse projects in Palestine depends on their ability to cover the cost of service. The operation and maintenance cost should be reduced to the lowest amount possible by using highly efficient procedures, and the government should cover the gap between full cost and affordability.

The farmers using the treated effluent must contribute to the cost of using treated wastewater for irrigation (Adelphi, 2004). However, to avoid the rejection of farmers to use and pay for treated wastewater, the price of treated wastewater for the farmer should be not higher than fresh water; farmers should have to pay operation and maintenances costs only. The wastewater producers (i.e. residents of the municipality) should pay the full costs of treatment (Abu-Madi, 2006).

2.7. Obstacles for reusing wastewater

There are obstacles for reusing wastewater in any place. The principal constraint for reusing wastewater is the technical aspects affecting the quality of treated wastewater.

In Islamic countries, there is an additional obstacle of public attitudes related to religious beliefs about water reuse (Almas and Scholz, 2006).

A fatwa decree made by the Islamic Council of Research and Consultation in 1979 said that treated wastewater could be used for all purposes as long as it meets standards of health (Almas and Scholz, 2006). This idea should be included when introducing the idea of wastewater reuse to the public, as well as emphasizing the costs and benefits.

There are many obstacles for reusing wastewater in Palestine including political, financial, social, and technical issues as well as the lack of experience (Zimmo and Imseih, 2006). The acceptance of public opinion for water reuse is considered an important factor; many water reuse projects have not succeeded because they did not consider the social opinion (Urkiaga et al, 2008).

Palestinian local society still has many concerns about using the treated wastewater in agriculture, although most people claim to be aware of health effects and restrictions on the choice of crops, so the main challenge is establishment of public awareness programs to change people's negative perception of water reclamation and reuse.

The unstable political situation makes it very difficult to move forward on reuse projects due to the lack of communication with Israeli authorities and lack of Palestinian control over resources. The lack of wastewater collection and disposal systems and the poor condition of existing wastewater treatment plants (limited capacity, poor maintenance and lack of experienced operators) make it difficult to get high quality treated wastewater.

Another obstacle is the limited coordination with other institutional stakeholders responsible for water reuse such as the Ministry of Agriculture, the Environmental Quality Authority, the Ministry of Health and the Palestinian Water Authority (Zimmo and Imseih, 2006).

Chapter Three

Public perspective on wastewater reuse in Tubas Area

3.1. Introduction

Public acceptance for wastewater reuse is considered the main factor for a successful wastewater treatment and reuse project (Zimmo and Imseih, 2006). The local society in Palestine has concerns toward the initiative of using treated wastewater in agriculture (Zimmo and Imseih, 2006). Many wastewater reuse projects were planned yet only a few projects were implemented. While the reasons behind these failures may be attributed to both technical and socio-cultural aspects, it is very difficult for any municipality to set up, finance, construct and operate a wastewater treatment plant without public acceptance (Adelphi, 2004).

In order to make a preliminary study to assess the main issues related to the construction of the proposed wastewater treatment plant in the Tubas area for the sake of reusing wastewater in agriculture, a questionnaire was prepared and carried out in the summer of 2008. The questionnaire did aid in collecting relative information regarding the public perspective towards using treated wastewater in agriculture in the study area. The following sections summarize the outcome of the questionnaire.

3.2. The study responders

Tubas City has a population of 22,000 and thus the number of responders for the questionnaire was 384 and were rounded up to 400. This number was computed using the following equation (see equation 1) (Israel, 1992):

$n = Z^2Pq/e^2$ (Eq.1)

where:

n: sample size,

Z: z-score corresponding to our confidence level (for 95% confidence, we use Z=1.96),

e: desired level of precision = ±5%,

P: estimated proportion of an attribute,

q: 1-P

It should be mentioned that we took P = 0.5 (maximum variability) to produce a more conservative sample size (i.e. larger sample size).

The total number of farmers in Tubas area is 3,000 (Hosam Abo Alian, Tubas Municipality, Personal communication, February, 2008). As such, 54 farmers received the questionnaire.

3.3. The methodology of the questionnaire

The questionnaire is composed of two sections where the first section consists of 11 questions of yes-or-no type (Appendix A). The questions in the first section addressed the following issues:

- Acceptance level for having a wastewater collection network and a near-by wastewater treatment plant,
- The residents' trust in the capability of the municipality for operating the wastewater treatment plant efficiently,
- The possibility of using treated wastewater in cleaning and their willingness to consume vegetables or fruits irrigated with treated wastewater,
- The type of plants that they support to irrigate with treated wastewater,
- The acceptance of financial contribution to the wastewater treatment and reuse

In the second section, there are also 11 questions. Nine out of these questions are of multiple choices while the remainder requires a short answer. In the multiple choices for the questions 6, 7, 8, 9, and 11 the responders can choose multiple answers from the list available by giving weight for the answer from 0 to 100%. This means that if you choose one answer the weight of it will be 100% and if you chose more than one answer you must assign the weight for all the answers. For question six; it was answered only by people who opposed re-using treated wastewater. Questions 7, 8, 9, and 10 were answered by people who agreed with the re-using of treated wastewater and by the people who was natural.

The questions in the second section addressed the following issues:

- Water needs to be met in Tubas, type of wastewater collection and disposal, and the frequency of emptying the wastewater collection cesspit,
- The overall attitude toward the reuse of treated wastewater, the reasons for opposing the reuse, major concerns regarding the reuse, type of plants that can be considered in the reuse, the reasons for wastewater reuse in agriculture and the potential difficulties and challenges that may face the wastewater treatment plant,
- Total monetary amount of the water consumed along with the willingness to financially contribute of the wastewater treatment expenses per one cubic meter.

The responders were chosen randomly yet in a stratified manner. This selection approach insured a balanced distribution of gender, age and education degree. The questionnaire was distributed by hand and filled in at the same time. In order to guarantee that the questionnaire will be easily understood by responders, it was translated into Arabic. After the completion of all questionnaires by the responders, all results were filled into a spreadsheet. Finally, a software program called Statistical Package for Social Sciences (SPSS) was utilized to carry out the statistical analysis of questionnaire results.

3.4. Analysis of the results

The full survey results are given in Appendix B.

The characteristic of the study responders were as follows:

1. Gender: 54.3% of responders are males while the remainder are females.
2. Age: 47% of responders are less than 30 years, 24.5% are between 31 and 40 years old, 17.3% are between 41 and 50 years old and 11.2% are above 51 years old. Overall, the age range of the responders is between 17 and 68 years.
3. Education level: 25.8% were less than tawjihi level (high school), 25% were at tawjihi level and 49.3% were beyond the tawjihi level.
4. Job: 14% of responders are farmers and 86% had other professions.

The key results of the questionnaire are summarized as follows:

- Almost 50% of the responders collect the used tap water for the irrigation of their planted home gardens. About 85% of the responders had an absorbency executing pit for wastewater disposal, while the rest used impermeable pits. The majority of responders empty their wastewater collection pits once every three months at most, and 35% report they have never had their pit emptied. Raw wastewater is discharged into Wadi Al Faria which causes pollution of groundwater; thus it is necessary to treat wastewater in Tubas to prevent the pollution of groundwater.

- Only 13% of the responders believe that water in Tubas is sufficient for domestic and agricultural use see (Table 3.1). This small percentage clearly shows that Tubas needs to find out additional sources of water.

Table (3.1): Sufficiency of water for the different use types

Water is sufficient for	Frequency	Percentage
Domestic use only	178	44.5
Agricultural use only	4	1.00
Domestic and agricultural	52	13.0
insufficient for any of the above	166	41.5
Total	400	100%

- 97% of the responders support the idea of having wastewater collection system in Tubas while 92% of the responders support the idea of having a wastewater treatment plant in Tubas.

- The majority of the responders (68%) oppose the idea of having a wastewater treatment plant near their homes.

- 65.5% of the sampled population agrees in general to reuse the treated wastewater.

- The concerns about the reuse of wastewater are almost equal for the four categories: agricultural, industry, household or domestic and irrigate planted home garden (Table 3.2).

Table (3.2): Preference regarding wastewater reuse

Preference regarding wastewater reuse	Frequency	Percentage of concern
Agricultural	123	27.5
Industry	130	24.8
Household or domestic	38	22.5
Irrigate planted home garden	121	25.1

- 60% of the responders support the idea of using the treated wastewater in cleaning.

- 54% of the responders support the idea of irrigating vegetables with treated wastewater; however, only 45% of the responders were willing to consume fruits or vegetables irrigated by treated wastewater. This indicates that people in theory support the using of treated wastewater but they become less supportive when actually faced with the consequence.

- 77% of the responders support the idea of irrigating trees with treated wastewater while 75% of the responders support the idea of irrigating fodder crops with treated wastewater.

- The responders, who agreed to use the treated wastewater in irrigation, support the reuse in the irrigation of crops and plants that are not consumed by human beings such as flowers or fodder crops (Table 3.3). However, the majority of the responders agree to use the treated wastewater in agriculture, since this saves water (Table 3.4)

Table (3.3): Crops type irrigated with treated wastewater

Irrigation Use	Frequency	Percentage of Supporting use
Vegetables eaten after cooked	22	22.3
Planted not eaten (flowers)	251	30.3
Vegetables eaten after being cooked or not cooked	27	21.7
Any type of fodder crops	145	25.7

Table (3.4): Reuse for using wastewater in agriculture

Reasons for using treated wastewater in agriculture	Frequency	Percentage of reason
This will save water	146	33.5
This will increase the product due to the nutrients in the treated wastewater	77	35.8
Wastewater available all the time	42	30.7

- The reasons behind the opposing the reuse of treated wastewater emerge from the religious beliefs and the health concerns (Table 3.5)

Table (3.5): The reasons for opposing the reuse of treated wastewater

The reasons of opposing the reuse of treated wastewater	**Frequency**	**Percentage of reason**
Religions	15	25.9
Cultural	7	4.60
Health risk	87	28.9
Breaths (disgust)	51	40.6

-There are some potential problems for having a treatment plant in Tubas, the responders expressed their diffidence that the municipality will treat wastewater effectively; they were nearly equally split between trusting (38%) and not trusting (37%) the municipality, while 25% did not know and there will be some obstacles that may hinder the construction of the wastewater treatment plant. The major obstacle is the cost of the treatment (Table 3.6)

Table (3.6): The different difficulty types for construction WWTP

Most difficulty for construction WWTP	**Frequency**	**Percentage of difficulty**
Cost	115	35.6
Public opinion	60	23.5
Effect on the environment	26	20.1
Operation	48	20.8

- Almost 67% of the responders currently pay 100 NIS or less per month for water consumption (Table 3.7).

Table (3.7): Total amounts of water bills

The value of water bill (NIS per month)	Frequency	Percentage
50 and less	98	24.5
51-100	169	42.3
101-150	81	20.3
151 and more	52	12.9
Total	400	100%

One US$= 3.8 NIS (exchange rates of 2008)

- 88% of the responders support the idea of financially contributing to the treatment of wastewater.

- About 60% of responders agree to financially contribute an amount of one NIS/m^3 to help in treating wastewater (Table 3.8)

Table (3.8): The amount of contribution per cubic meter of treated wastewater

The amount of contribution (NIS/m^3)	Frequency	Percentage
Nothing	55	13.8
1	234	58.5
2	72	18.0
3	39	9.70
Total	400	100%

One US$= 3.8 NIS (exchange rates of 2008)

Chapter Four
Development of the Conceptual Model for the Benefit - Cost analysis

4.1. Introduction

Economic considerations become more important as the potential use of treated wastewater increases. For any wastewater decision-making issue related to wastewater reuse, one should analyze the cost of the reuse project by conducting a comprehensive cost-benefit analysis (CBA) (Haruvy, 1997). This chapter explains the methodologies that are applied to estimate the cost and benefit of wastewater treatment and reuse in irrigation in Tubas area. The CBA covers the following options as depicted in Figure (4.1):

Option 1: Reuse of wastewater generated from the north of Tubas

Option 2: Reuse of wastewater generated from the south of Tubas.

Option 3: Reuse of wastewater generated from the north of Tubas and Tayaser village.

Option 4: Reuse of wastewater generated from the entire area of Tubas.

Option 5: Reuse of wastewater generated from the entire area of Tubas and Tayaser village

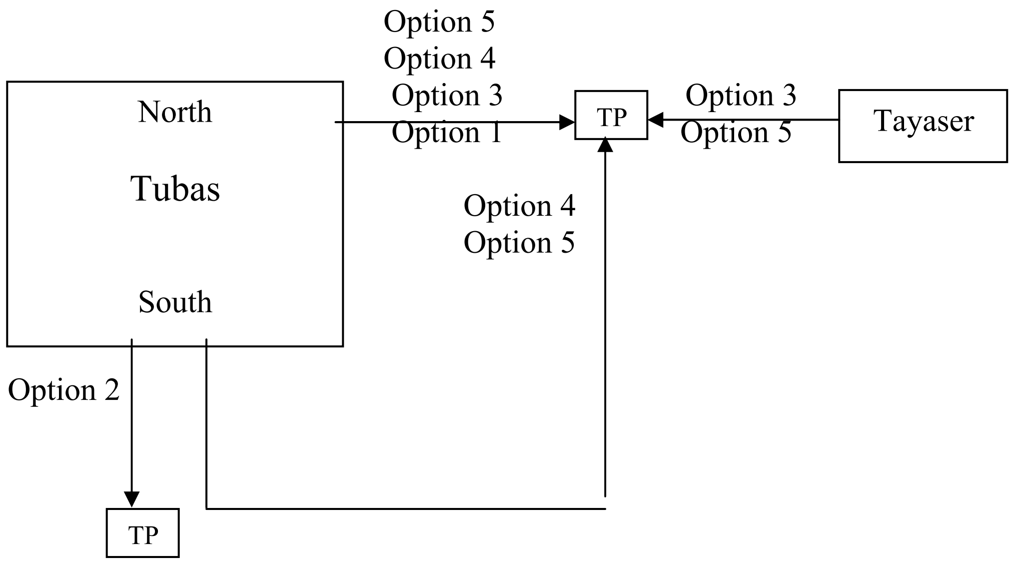


Figure (4.1): options for wastewater treatment and reuse in Tubas

4.2. Wastewater treatment technologies

A centralized wastewater system will be considered to collect wastewater to the treatment plant(s). This system depends on gravity to deliver wastewater from the generation areas to the wastewater treatment plant. In any decision-making process for wastewater treatment and reuse we should take into account water quality requirements, the types of planted crops and the cost (Haruvy, 1997). Restricted agricultural irrigation will be considered for the Tubas area, especially to irrigate olives, fodders and barley. Restricted irrigation requires effluent standards for the Biological Oxygen Demand (BOD), Total Suspended Solids (TSS) reach 20 mg/l and 30 mg/l respectively, which can be achieved by secondary treatment processes. The plant will also need to use disinfection (Haruvy, 1997).

The processes of secondary treatment that are selected in our study are activated sludge, trickling filter and aerated lagoons. To prevent the spread of waterborne disease we need the disinfection of wastewater (Abu-Madi, 2006). There are various disinfection processes such as chlorination, ultraviolet radiation, and ozone. In this study, the chlorine disinfection process will be considered.

4.3. Methodology

To estimate the cost and benefit of wastewater treatment and reuse first we need to estimate the population of Tubas for the year 2035 by taking a growth rate of 3% (Palestinian Central Bureau of Statistics, 2009). Then we determined the amount of wastewater generated each year by multiplying the per capita water consumption which equals 100 l/d per capita by the projected number of people to be served, and assuming that 80% of the water consumed will become wastewater. We assumed that there will be an increase in the water consumption from 51 l/d per capita to 100 l/d per capita. This is due to the new source of water that was developed in south of Tubas where it is expected that this source will start to function in 2010). Then we calculated the amount of treated wastewater available for reuse each year by assuming 75% of wastewater will be available for reuse at irrigation sites due to evaporation and leakage in the conveyance system (Abu-Madi, 2006).

The analysis covers the costs and benefits of wastewater treatment technology, conveyance, storage and irrigation systems. The methods of calculation are described in the following sections based chiefly on the work of Abu-Madi (2006). The analysis covers the period of 25 years from 2010 to 2035.

4.4. Investment costs

The total investment costs include: conventional biological secondary wastewater treatment plants, chlorination disinfection system, seasonal reservoirs, conveyance lines to transport the treated wastewater to the irrigation sites and surface irrigation system. The procedure for the calculations of the investment costs are explained in the following sections:

4.4.1. The investment costs for biological secondary wastewater treatment plants

Various secondary treatment processes can be selected such as conventional activated sludge, trickling filter and aerated lagoons. The investment costs for each type of the wastewater treatment process are calculated as follows:

The cost of wastewater treatment plant was obtained by taking the cost of similar plants with different capacities and locations given in Table 4.1 (which gives the investment costs and the annual operation costs for different plants for secondary treatment proces) and multiplying the known cost by the ratio of the two capacities raised to the power 0.79 as given by the following equation (1) (Abu-Madi, 2006).

$CC2 = CC1 * (C2/ C1)^{0.79}$ (Eq.1)

Where:

CC2: the cost of wastewater treatment plant for year 2035

CC1: The costs for a secondary wastewater treatment plant serving different inhabitants taken from Table 4.1 (Abu-Madi, 2006).

C1: the population of plants outlined in Table 1 (Abu-Madi, 2006)

C2: The projected population to be served by the plant for year 2035.

The wastewater treatment plant is expected to be constructed in 2010.

A growth rate of 3% was used to calculate the project number of population for year 2035 (C2). It should be noted that the investment costs for the plant given in Table 4.1 are for years prior to 2010 so to calculate the investment costs using equation (1) we determine the specified implementation year (2010) using an inflation rate of 3% (Abu-Madi, 2006).

Table (4.1): Costs for a secondary WWTP (Abu-Madi, 2006).

Secondary treatment process	Investment costs	Annual operation costs
Conventional Activated Sludge (Al-Bireh: 50,000 inhabitants capacity)	7,000,000 (2000 US$)	232,805 (2005 US$)
Aerated Lagoons (WadiAlsir: 75,000 inhabitants capacity)	7,142,857 (1997 US$)	103,324 (2000 US$)
Trickling filters (Al-Baqa: 103,000 inhabitants capacity)	10,391,829 (1999 US$)	238,571 (2000 US$)

4.4.2. The investment costs for wastewater disinfection systems

The costs for the chlorination system and that of operation and maintenance costs are calculated by the following equation (2) (Abu- Madi, 2006):

$Z1 = 0.2\times(141966.0Q - 502.4Q^2 + 250042.7)$ (Eq.2) where:

Z1: investment costs for the chlorine system in dollars

Q: average dry weather flow (MCM/yr). It is assumed that average dry weather flow entering the disinfection system equals the flow of the raw wastewater entering the secondary wastewater treatment plant.

0.2: Correction factor for regional differences.

It should be noted that the investment costs for chlorine per system calculated using equation (2) are for the year 1995 so we determine for the year 2010 using an inflation rate of 3% (Abu-Madi, 2006).

4.4.3. The investment costs for seasonal reservoirs

To improve the flexibility of treated wastewater we need storage reservoirs, which help stabilize the flow from one day to another and improve the quality of treated wastewater by increasing the retention time (Almasrie et al, 2007). The investment costs for the seasonal reservoirs is 0.47 US$/$m^3$ of wastewater entering the wastewater treatment system yearly (Abu-Madi, 2006).

4.4.4. The investment costs for conveyance lines

It is planned to transfer the treated wastewater from the WWTP to be reused for agricultural irrigation. These transfers were evaluated by calculating the investment costs for transmission lines. In our study we chose steel pipe with diameter of 12 inches. The investment cost per meter of conveyance line is 130 US$ which includes excavation, bedding, backfilling, fitting, pipe installation, reinstatement, cleaning and testing (Adly, Universal Group, Personal communication, February, 2009).

The length of the conveyance line required to transport the treated wastewater from the treatment in the north to the irrigated area was estimated to be about 1.8 km.

4.4.5. The investment costs for surface irrigation schemes

The investment costs for surface irrigation is 400 US$/dunum of irrigated land (Hasan Al-Ashqar, Ministry of Agriculture, Personal communication, February, 2009). The total area of irrigated land was determined by dividing the volume of wastewater reuse for irrigation by the volume of water required to irrigate one dunum of land for a specific crop. The water required for the crop varies with the change of crop, climate, soil, topography and others (Abu-Madi, 2006). The total water requirement for the crops (olives, barley, and fodder crops) suggested for irrigation with treated wastewater is 1,100-1,400 m^3/dunum/year (Abu-Madi, 2006). Based on the rainfall data, the irrigation of 200-500 (avg. 350) m^3/dunum will be required during the rainy season between October-March and full irrigation of 600-800 (avg. 700) m^3 /dunum is required during the dry season between April- September (Abu-Madi, 2006).

The total investment costs for surface irrigation were calculated by multiplying the investment costs per one dunum of irrigated land for specified implementation year by the total dunums of irrigated land for barley, fodder and olives trees (Abu-Madi, 2006).

4.4.6. The investment costs for pumping

For option 4 and 5 we need to pump wastewater from the south of Tubas to the treatment plant in the north. This is due to the difference in elevation of about 100 m from the south to the north. So there is a need for two 20 horsepower pumps with a pump speed of 2930 revolution per minute (r.p.m) and with a head of 67 m. The two pumps will be in series. The cost of the two pumps is 15600 US$ (Riyad Mubslat, Tubas Municipality, Personal communication, March, 2009)

4.5. Running costs

The running costs of the project include the operation and maintenance costs for the centralized wastewater treatment systems comprising secondary wastewater treatment plants, chlorine disinfection systems, seasonal storage facilities and conveyance system (Abu-Madi, 2006). The procedures of calculations are explained in the following sections:

4.5.1. The running costs for secondary wastewater treatment plants

The annual operation and maintenance (O&M) cost of a biological wastewater treatment plant was obtained by taking the cost of similar plants with different capacities (Table 4.1) as given by the following equation (3) (Abu-Madi, 2006).

$O\&M\ 2 = O\&M\ 1 * (C\ 2/ C\ 1)^{0.6}$ (Eq.3)

Where:

O&M 2: the O&M costs of the wastewater treatment plant for each year

O&M 1: The O&M costs for the similar secondary wastewater treatment plant serving different inhabitants as outlined in Table 4.1.

C1: the population of plants outlined in Table 1 (Abu-Madi, 2006)

C2: The projected population to be served by the plant for each year of operation.

It should be noted that the O&M costs for the plant given in Table 4.1 are for years prior to 2010 so to calculate the O&M costs using equation (3) we determine the specified implementation cost for the year 2010 using an inflation rate of 3% (Abu-Madi, 2006).

4.5.2. The running costs for chlorine disinfection system

The annual O&M costs for chlorine disinfection system are calculated using equation (4) (Abu-Madi, 2006):

$$Z = (0.2)\times (26228.6Q-123.4Q^2 +40639.4) \qquad \text{(Eq.4)}$$

where:

Z: O&M costs for chlorine disinfection systems in dollar

Q: wastewater flow (MCM/yr)

0.2: a correction factor in order to account for regional differences.

It should be noted that the running costs for chlorine disinfection system calculated using equation (4) are for the year 1995 so we determine for the year 2010 using an inflation rate of 3% (Abu-Madi, 2006).

4.5.3. The running costs for seasonal storage and conveyance systems

The annual O&M costs for seasonal storage facilities are assumed to be 5% of the investment costs. The O&M costs of conveyance are assumed to be 10% of the investment costs. In both cases, an annual increase of 1% of these costs was assumed (Abu-Madi, 2006).

4.5.4. The running costs for the pumps

The required power for operating the two pumps is calculated using Equation5

Power required:

$N = PgHQ/\ell$ (Eq.5)

where

Q= the discharge in m^3/sec

H= the manometric head in meters

P= the density of water to be pumped in kg/m^3

g= acceleration of gravity in meter per squared second

ℓ= efficiency of the pump

4.6. Economic benefit

The economic benefit for the wastewater treatment plant is related to the use of treated wastewater for irrigation. It includes the value of treated wastewater reused for irrigation and the production value of irrigated crops (Abu-Madi, 2006). The economic benefits are estimated in the following sections:

4.6.1. The economic value of treated wastewater reused for agricultural irrigation

The economic value of treated wastewater reuse for irrigation was estimated at 0.50 US$/$m^3$ of reuse wastewater (Mostaf Swafta, Local Farmer, personal communication, February, 2009) The annual economic value was estimated by multiplying the economic value per cubic meter of reused wastewater by the total volume of wastewater reused for irrigation (Abu-Madi, 2006).

4.6.2. The production value of irrigated crops

The treated wastewater will be reused for restricted agricultural irrigation of olives, barley and fodder and this will improve the agricultural sector by increasing the area of irrigated agricultural land and the amount of production (Abu-Madi, 2006). The production values of irrigated crops were estimated by multiplying the total dunums of irrigated land by the production value of one dunum cultivated. The production value of land cultivated with barley and fodder is 215 US$/dunum and 300 US$/dunum for olives trees (Mostaf Swafta, Local Farmer, personal communication, February, 2009).

Chapter Five
Result and Analysis

5.1. Introduction

The previous chapters presented the methodology that was implemented to quantify the costs and benefits associated with implementation of a wastewater management system. This chapter will analyze the results of costs and benefits of wastewater treatment and reuse for agricultural irrigation for the five options.

5.2. Options for wastewater treatment and reuse in Tubas

The topography of Tubas is divided into two watersheds, where the first drains to the north and is called Malih (approximately 60% of Tubas) while the other drains to the south and is called Faria. As such part of the generated wastewater that results from Tubas will be drained to the Malih while the reminder drains to Faria watershed (Figure 5.1) (Hosam Abu Alian, Tubas Municipality, Personal communication January, 2009). Due to this topographic nature there are five options for the reuse of wastewater in Tubas. The reuse of treated wastewater will be for agricultural irrigation.

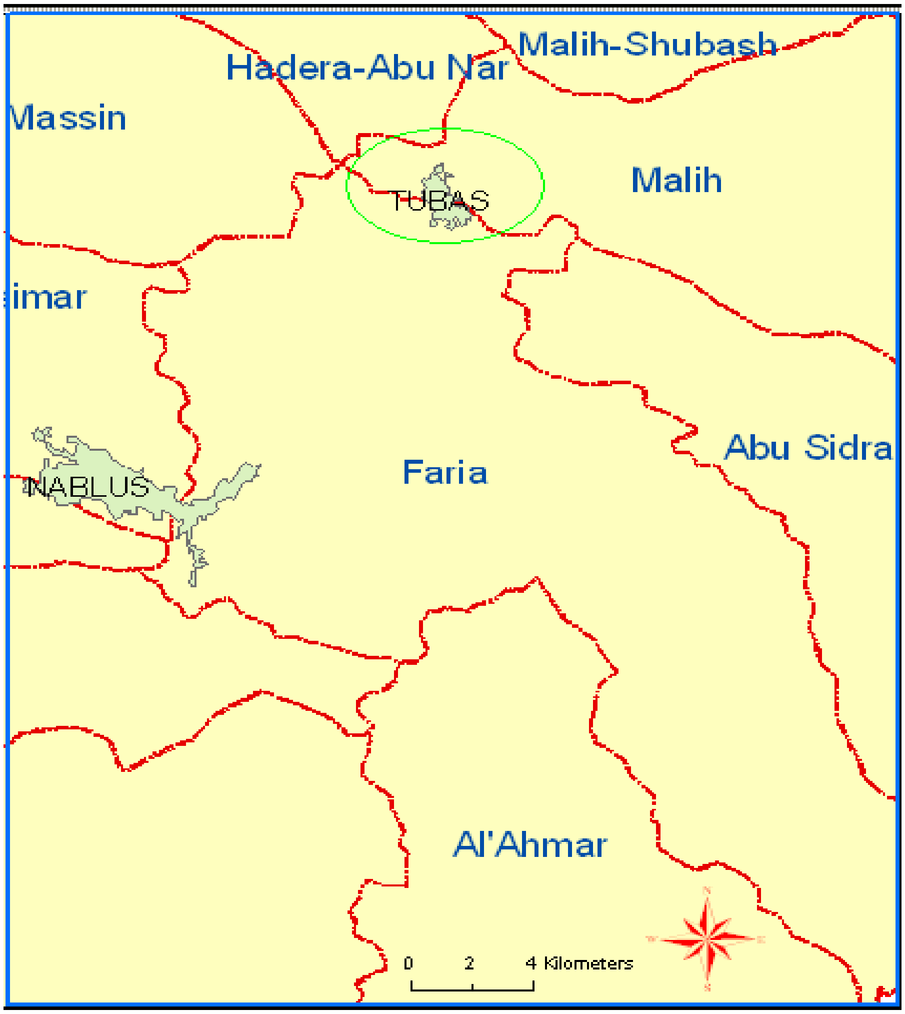


Figure (5.1): Watershed of Tubas

In the following sections, all options are illustrated and discussed.

5.2.1 Option 1: Reuse of wastewater from the north of Tubas:

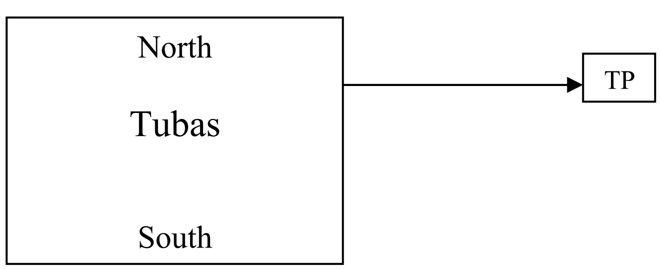


Figure (5.2) : Option 1(reuse of wastewater from the north of Tubas)

The population size for north part of Tubas is estimated to be 14,400 inhabitants in 2010; the specific water consumption is expected to be 100 l/c/d, and the constant population growth rate for Tubas is 3% per year. As such the total amount of treated wastewater that will be available from the town is 420,480 m^3 in 2010 and 880,380 m^3 in year 2035 and only about 75% of these amounts (315,360 m^3 in 2010 and 660,285 m^3 in 2035) will be available for reuse at irrigation sites due to evaporation and leakage during conveyance and distribution. The amounts produced during rainy and dry season are the same at 157,680 m^3 in 2010.

The land area that will be irrigated with treated wastewater during dry months of 2010 and 2035 are 225 dunums and 472 dunums, respectively. The total water requirement for the crops (olives, barley and fodders) suggested for irrigation with treated wastewater is 700 m^3/dunum during the dry season. In the rainy season there will be supplementary irrigation of 350 m^3/dunum, so we need to store about 78,840 m^3 and 165,071 m^3 in 2010 and 2035, respectively. These amounts that are treated in the rainy season will be used to irrigate in the dry season so we increase the land area under treated wastewater irrigation by another 113 dunums and 236 dunums in 2010 and 2035, respectively.

This study will be based on using the treated wastewater for irrigation of 60 dunums of olives trees according to the available area of olives in irrigation site and 278 dunums of barley and fodder crops in 2010. These areas will have to increase gradually every year to reach about 100 dunums of olives and 607 dunums of barley and fodders by year 2035.

Table (5.1): Calculation of land area that can be irrigated with treated wastewater (option 1)

		2010	2015	2020	2025	2035
1	Total amount of treated wastewater (m^3)	420,480	487,465	565,078	655,102	880,380
2	Total amount of treated wastewater available for irrigation (m^3)	315,360	365,599	423,809	491,327	660,285
3	Availability during rainy season (m^3)	157,680	182,799	211,904	245,663	330,143
4	Availability during dry season (m^3)	157,680	182,799	211,904	245,663	330,143
5	Excess amount of treated wastewater in rainy season (m^3)	78,840	91,400	105,952	122,832	165,071
6	Excess amount of treated wastewater in dry season (m^3)	0	0	0	0	0
7	land area that can be irrigated (full) in dry seas. (du)	225	261	303	351	472
8	Additional land area that can be irrigated with treated wastewater stored from rainy season (dunums)	113	131	151	175	236
9	Total land area irrigated (du)	338	392	454	526	707

1= daily per capita water consumption*projected population*80%*365

2 = 75%*line 1 (due to evaporation and leakage in conveyance systems)

3= 0.5* line 2 (assuming the rainy season and dry season are each 6 months)

4=0.5* line 2 (assuming the rainy season and dry season are each 6 months)

5= 0.5*line 4

7= line 4/water required to irrigate one dunum of crops during dry season

8=line 5/water required to irrigate one dunum of crops during dry season

9= line 7 + line 8

5.2.2. Option 2: Reuse of wastewater from the south of Tubas:

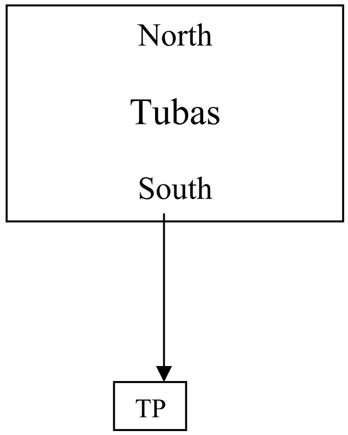


Figure (5.3): Option 2 (reuse of wastewater from the south of Tubas)

The population size for the south part of Tubas is estimated to be 9,600 inhabitants in 2010; the specific water consumption is expected to be 100 l/c/d, and the constant population growth rate for Tubas is 3% per year. As such the total amount of treated wastewater that will be available from the town is 280,320 m^3 in 2010 and 586,920 m^3 in the year 2035 and only about 75% of these amounts (210,240 m^3 in 2010 and 440,190 m^3 in 2035) will be available for reuse at irrigation sites due to evaporation and leakage during conveyance and distribution. The amounts produced during rainy and dry season are the same at 105,120 m^3 in 2010.

The land area that will be irrigated with treated wastewater during dry months of 2010 and 2035 are 150 dunums and 314 dunums, respectively. The total water requirement for the crops (olives, barley and fodders) suggested for irrigation with treated wastewater is 700 m^3/dunum during the dry season. In the rainy season, there will be supplementary irrigation of 350 m^3/dunum, so we need to store about 52,560 m^3 and 110,048 m^3 in 2010 and 2035, respectively. These amounts that are treated in the rainy season will be used to irrigate in the dry season so we increase the land area under treated wastewater irrigation by another 75 dunums and 157 dunums in 2010 and 2035, respectively.

This study will be based on using the treated wastewater for irrigation of 60 dunums of olives trees according to the available area of olives in irrigation site and 165 dunums of barley and fodder crops in 2010. These areas will have to be increased gradually every year to reach about 100 dunums of olives and 372 dunums of barley and fodders by year 2035.

Table (5.2): Calculation of land area that can be irrigated with treated wastewater (option 2)

		2010	2015	2020	2025	2035
1	Total amount of treated wastewater (m^3)	280,320	324,967	376,738	436,715	586,920
2	Total amount of treated wastewater available for irrigation (m^3)	210,240	243,725	282,554	327,536	440,190
3	Availability during rainy season (m^3)	105,120	121,863	141,277	163,768	220,095
4	Availability during dry season (m^3)	105,120	121,863	141,277	163,768	220,095
5	Excess amount of treated wastewater in rainy season (m^3)	52,560	60,931	70,638	81,884	110,048
6	Excess amount of treated wastewater in dry season (m^3)	0	0	0	0	0
7	land area that can be irrigated (full) in dry seas. (du)	150	174	202	234	314
8	Additional land area that can be irrigated with treated wastewater stored from rainy season (dunums)	75	87	101	117	157
9	Total land area irrigated (du)	225	261	303	351	472

1= daily per capita water consumption*projected population*80%*365

2 = 75%*line 1 (due to evaporation and leakage in conveyance systems)

3= 0.5* line 2 (assuming the rainy season and dry season are each 6 months)

4=0.5* line 2 (assuming the rainy season and dry season are each 6 months)

5= 0.5*line 4

7= line 4/water required to irrigate one dunum of crops during dry season

8=line 5/water required to irrigate one dunum of crops during dry season

9= line 7 + line 8

5.2.3 . Option 3: Reuse of wastewater from the north of Tubas and Tayaser village:

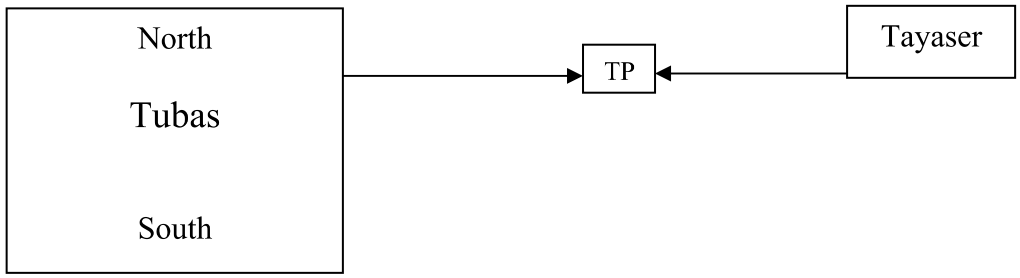


Figure (5.4): Option 3 (reuse of wastewater from the north of Tubas and Tayaser)

The population size for the north part of Tubas and Tayaser village is estimated to be 17,900 inhabitants in 2010, the specific water consumption is expected to be 100 l/c/d, and the constant population growth rate for Tubas and Tayaser is 3% per year. As such the total amount of treated wastewater that will be available from the two areas is 522,680 m^3 in 2010 and 1,094,387 m^3 in year 2035 and only about 75% of these amounts (392,010 m^3 in 2010 and 820,790 m^3 in 2035) will be available for reuse at irrigation sites due to evaporation and leakage during conveyance and distribution. The amounts produced during rainy and dry season are the same at 196,005 m^3 in 2010.

The land area that will be irrigated with treated wastewater during dry months of 2010 and 2035 are 280 dunums and 586 dunums, respectively. The total water requirement for the crops (olives, barley and fodders) suggested for irrigation with treated wastewater is 700 m^3/dunum during the dry season. In the rainy season there will be supplementary irrigation of 350 m^3/dunum, so we need to store about 98,003 m^3 and 205,198 m^3 in 2010 and 2035, respectively. These amounts that are treated in the rainy season will be used to irrigate in the dry season so we increase the land area under treated wastewater irrigation by another 140 dunums and 293 dunums in 2010 and 2035, respectively.

This study will be based on the suggestion to use the treated wastewater for irrigation of 60 dunums of olive trees according to the available area of olives in the irrigation site and 360 dunums of barley and fodders in 2010. These areas will have to be increased gradually every year to reach about 100 dunums of olives and 779 dunums of barley and fodders by year 2035.

Table (5.3): Calculation of land area that can be irrigated with treated wastewater (option 3)

		2010	2015	2020	2025	2035
1	Total amount of treated wastewater (m^3)	522,680	605,929	702,435	814,330	1,094,387
2	Total amount of treated wastewater available for irrigation (m^3)	392,010	454,447	526,826	610,747	820,790
3	Availability during rainy season (m^3)	196,005	227,223	263,413	305,374	410,395
4	Availability during dry season (m^3)	196,005	227,223	263,413	305,374	410,395
5	Excess amount of treated wastewater in rainy season (m^3)	98,003	113,612	131,707	152,687	205,198
6	Excess amount of treated wastewater in dry season (m^3)	0	0	0	0	0
7	land area that can be irrigated (full) in dry seas. (du)	280	325	376	436	586
8	Additional land area that can be irrigated with treated wastewater stored from rainy season (dunums)	140	162	188	218	293
9	Total land area irrigated (du)	420	487	564	654	779

1= daily per capita water consumption*projected population*80%*365

2 = 75%*line 1 (due to evaporation and leakage in conveyance systems)

3= 0.5* line 2 (assuming the rainy season and dry season are each 6 months)

4=0.5* line 2 (assuming the rainy season and dry season are each 6 months)

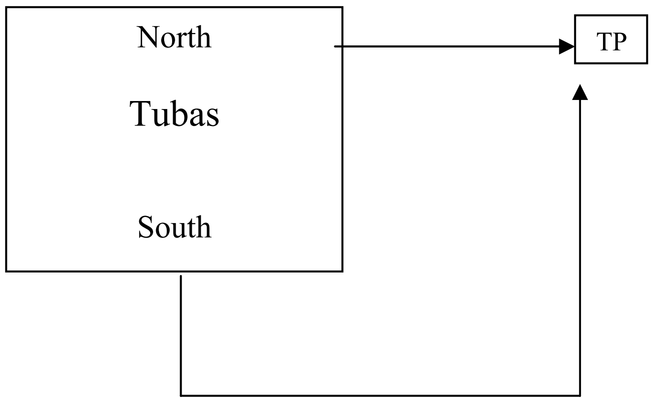
5= 0.5*line 4

7= line 4/water required to irrigate one dunum of crops during dry season

8=line 5/water required to irrigate one dunum of crops during dry season

9= line 7 + line 8

5.2.4. Option 4: Reuse of wastewater from the entire area of Tubas



Figure(5.5): Option 4 (reuse of wastewater from the entire area of Tubas)

The population size for all Tubas is estimated to be 24,000 inhabitants in 2010, the specific water consumption is expected to be 100 l/c/d, and the constant population growth rate for Tubas is 3% per year. As such the total amount of treated wastewater that will be available from the town is 700,800 m^3 in 2010 and 1,467,329 m^3 in year 2035 and only about 75% of these amounts (525,600 m^3 in 2010 and 1,100,497 m^3 in 2035) will be available for reuse at irrigation sites due to evaporation and leakage during conveyance and distribution. The amounts produced during rainy and dry season are the same at 262,800 m^3 in 2010.

The land area that will be irrigated with treated wastewater during dry months of 2010 and 2035 are 375 dunums and 786 dunums, respectively. The total water requirement for the crops (olives, barley and fodders) suggested for irrigation with treated wastewater is 700 m^3/dunum during the dry season. In the rainy season there will be supplementary irrigation of 350 m^3/dunum, so we need to store about 131,400 m^3 and 275,124 m^3 in 2010 and 2035, respectively. These amounts that are treated in the rainy season will be used to irrigate in the dry season so we increase the land area under treated wastewater irrigation by another 188 dunums and 393 dunums in 2010 and 2035, respectively.

This study will be based on the suggestion to use the treated wastewater for irrigation of 60 dunums of olive trees according to the available area of olives in the irrigation site and 503 dunums of barley and fodders in 2010. These areas will have to be increased gradually every year to reach about 100 dunums of olives and 1,079 dunums of barley and fodders by year 2035.

Table (5.4): Calculation of land area that can be irrigated with treated wastewater (option 4)

		2010	2015	2020	2025	2035
1	Total amount of treated wastewater (m^3)	700,800	812,432	941,817	1,091,817	1,467,329
2	Total amount of treated wastewater available for irrigation (m^3)	525,600	609,324	706,363	818,863	1,100,497
3	Availability during rainy season (m^3)	262,800	304,662	353,181	409,431	550,248
4	Availability during dry season (m^3)	262,800	304,662	353,181	409,431	550,248
5	Excess amount of treated wastewater in rainy season (m^3)	131,400	152,331	176,591	204,716	275,124
6	Excess amount of treated wastewater in dry season (m^3)	0	0	0	0	0
7	land area that can be irrigated (full) in dry seas. (du)	375	435	505	585	786
8	Additional land area that can be irrigated with treated wastewater stored from rainy season (dunums)	188	218	252	292	393
9	Total land area irrigated (du)	563	653	757	877	1,179

1= daily per capita water consumption*projected population*80%*365

2 = 75%*line 1 (due to evaporation and leakage in conveyance systems)

3= 0.5* line 2 (assuming the rainy season and dry season are each 6 months)

4=0.5* line 2 (assuming the rainy season and dry season are each 6 months)

5= 0.5*line 4

7= line 4/water required to irrigate one dunum of crops during dry season

8=line 5/water required to irrigate one dunum of crops during dry season

5.2.5. Option 5: Reuse of wastewater from the entire area of Tubas and Tayaser village.

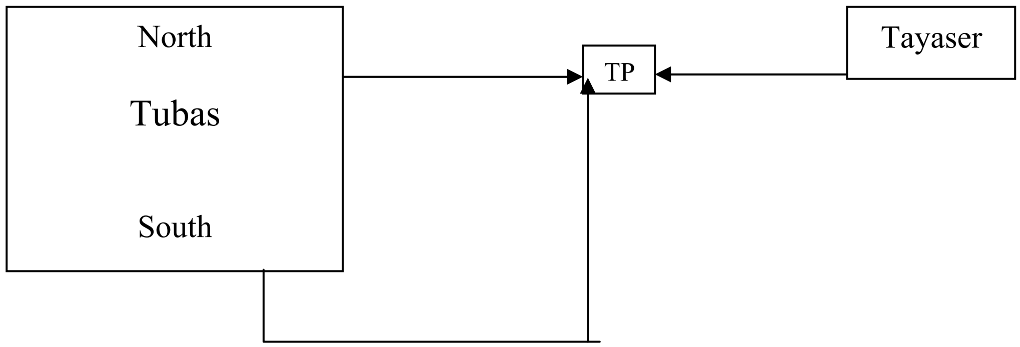


Figure (5.6): Option 5 (reuse of wastewater from the entire area of Tubas and Tayaser village)

The population size for all Tubas and Tayaser village is estimated to be 27500 inhabitants in 2010, the specific water consumption is expected to be 100 l/c/d, and the constant population growth rate for Tubas and Tyaser is 3% per year. As such the total amount of treated wastewater that will be available from the town is 803,000 m^3 in 2010 and 1,681,307 m^3 in year 2035 and only about 75% of these amounts (602,250 m^3 in 2010 and 1,260,980 m^3 in 2035) will be available for reuse at irrigation sites due to evaporation and leakage during conveyance and distribution. The amounts produced during rainy and dry season are the same at 301,125 m^3 in 2010.

The land area that will be irrigated with treated wastewater during dry months of 2010 and 2035 are 430 dunums and 901 dunums, respectively. The total water requirement for the crops (olives, barley and fodders) suggested for irrigation with treated wastewater is 700 m^3/dunum during the dry season. In the rainy season there will be supplementary irrigation of 350 m^3/dunum, so we need to store about 150,563 m^3 and 315,245 m^3 in 2010 and 2035, respectively. These amounts that are treated in the rainy season will be used to irrigate in the dry season so we increase the land area under treated wastewater irrigation by another 215 dunums and 450 dunums in 2010 and 2035, respectively.

This study will be based on the suggestion to use the treated wastewater for irrigation of 60 dunums of olive trees according to the available area of olives in irrigation site and 585 dunums of barley and fodders in 2010. These areas will have to be increased gradually every year to reach about 100 dunums of olives and 1,251 dunums of barley and fodders by year 2035.

Table (5.5): Calculation of land area that can be irrigated with treated wastewater (option 5)

		2010	2015	2020	2025	2035
1	Total amount of treated wastewater (m^3)	803,000	930,896	1,079,147	1,251,045	1,681,307
2	Total amount of treated wastewater available for irrigation (m^3)	602,250	698,172	809,380	938,284	1,260,980
3	Availability during rainy season (m^3)	301,125	349,086	404,690	469,142	630,490
5	Availability during dry season (m^3)	302,125	349,086	404,690	469,142	630,490
6	Excess amount of treated wastewater in rainy season (m^3)	150,563	174,543	202,345	234,571	315,245
7	Excess amount of treated wastewater in dry season (m^3)	0	0	0	0	0
	land area that can be irrigated (full) in dry seas. (du)	430	499	578	670	901
8	Additional land area that can be irrigated with treated wastewater stored from rainy season (dunums)	215	249	289	335	450
9	Total land area that can be irrigated (du)	645	748	867	1,005	1,351

1= daily per capita water consumption*projected population*80%*365

2 = 75%*line 1 (due to evaporation and leakage in conveyance systems)

3= 0.5* line 2 (assuming the rainy season and dry season are each 6 months)

4=0.5* line 2 (assuming the rainy season and dry season are each 6 months)

5= 0.5*line 4

7= line 4/water required to irrigate one dunum of crops during dry season

8=line 5/water required to irrigate one dunum of crops during dry season

9= line 7 + line 8

5.3. Location of suggested WWTPs

Before suggesting locations for the wastewater treatment plants many factors must be taken into account such as area availability. The land area needed for a WWTP is nearly 20 to 30 dunums (Almasri, et al, 2007). The area must be far away from the residential areas (as we found from the questionnaire in Chapter 3 that the people did not prefer that the wastewater treatment plant to be near their homes). Any suggested location for a WWTP must be far away from the Faria wells to prevent the pollution of ground water. The location must minimizes the conveyance costs by making the best use of topography, and not to be too far away from the served communities.

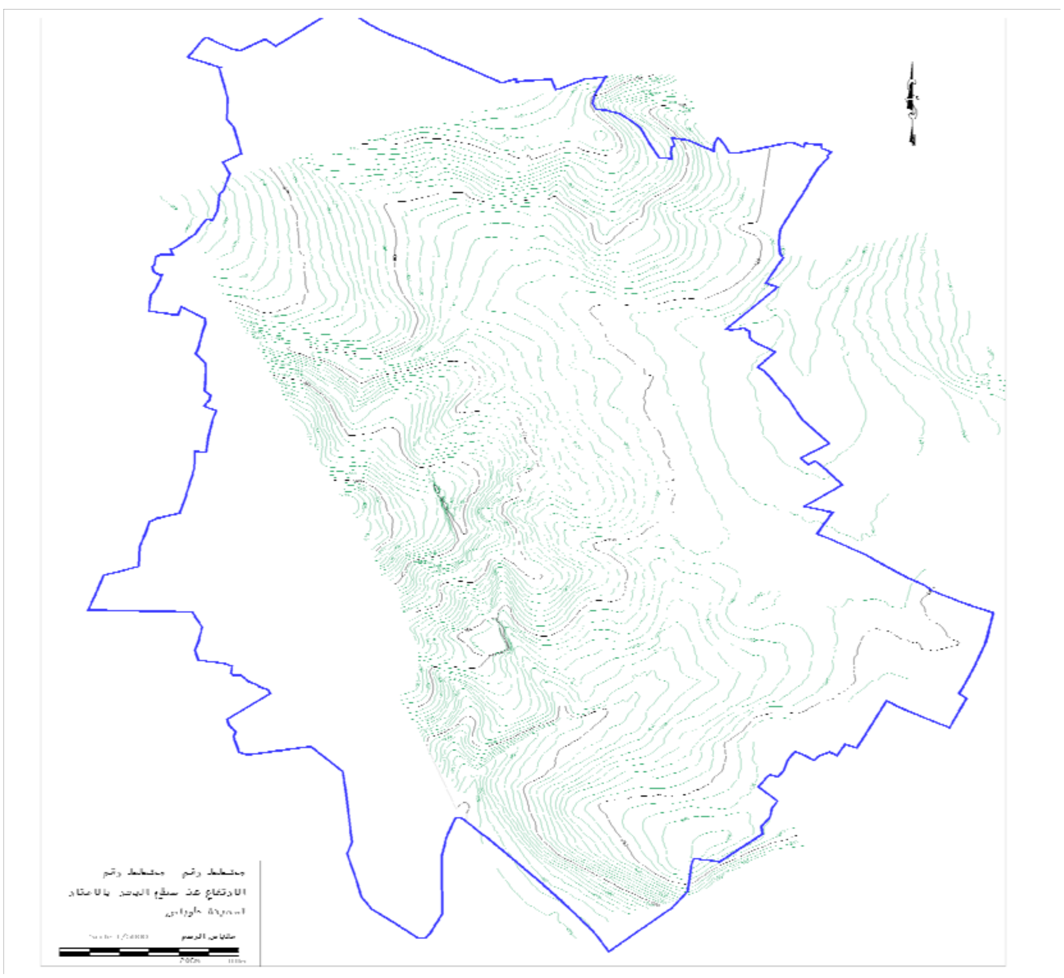


Figure (5.7): Topographic map for Tubas

Different locations were suggested that tackle the five options and these are given as follows:

Location 1: the suggested location for the WWTP will be in the north of Tubas. The locations of suggested irrigation sites are in the northeast of Tubas where there are olive trees with an area of about 1,000 dunums and barley and fodder crops with an area of about 5,500 dunums (Amen Abed Alrazq, Tubas Agricultural Department, personal communication, February, 2009).

Location 2: the suggested location for the WWTP will be in the south of Tubas. This option is not feasible for many reasons since there are no available areas of open land in the south for the treatment plant, it will be far away from the irrigation sites, we will not use the topography in best way (we will need to pump water to irrigation the sites) and it will be near the wadi Faria so it may cause pollution of ground water.

Location 3: the suggested location for the WWTP will be in the north of Tubas. It will be for the northern part of Tubas and Tayaser village. The locations of suggested irrigation sites are in the northeast of Tubas where there are olives trees with an area of about 1,000 dunums and barley and fodder crops with an area of about 5,500 dunums (Amen Abed Alrazq, Tubas Agricultural Department, personal communication, February, 2009).

Location 4: the suggested location for the WWTP will be in the north of Tubas. It will serve the north part and the south. For the north part of the town we depend on gravity to deliver wastewater to the treatment plant while we need to pump the wastewater from the south of Tubas to the treatment plant. The locations of suggested irrigation sites are in the northeast of Tubas where there are olives trees with an area of about 1,000 dunums and barley and fodder crops with an area of about 5,500 dunums (Amen Abed Alrazq, Tubas Agricultural Department, personal communication, February, 2009).

Location 5: the suggested location for the WWTP will be in the north of Tubas. It will be for the all Tubas and Tayaser village. For the north part and Tayaser village we depend on gravity to deliver wastewater to the treatment while for the south part we need to pump the wastewater from the south of Tubas to the treatment plant. The locations of suggested irrigation sites are in the northeast of Tubas where there are olives trees with an area of about 1,000 dunums and barley and fodder crops with an area of about 5,500 dunums (Amen Abed Alrazq, Tubas Agricultural Department, personal communication, February, 2009).

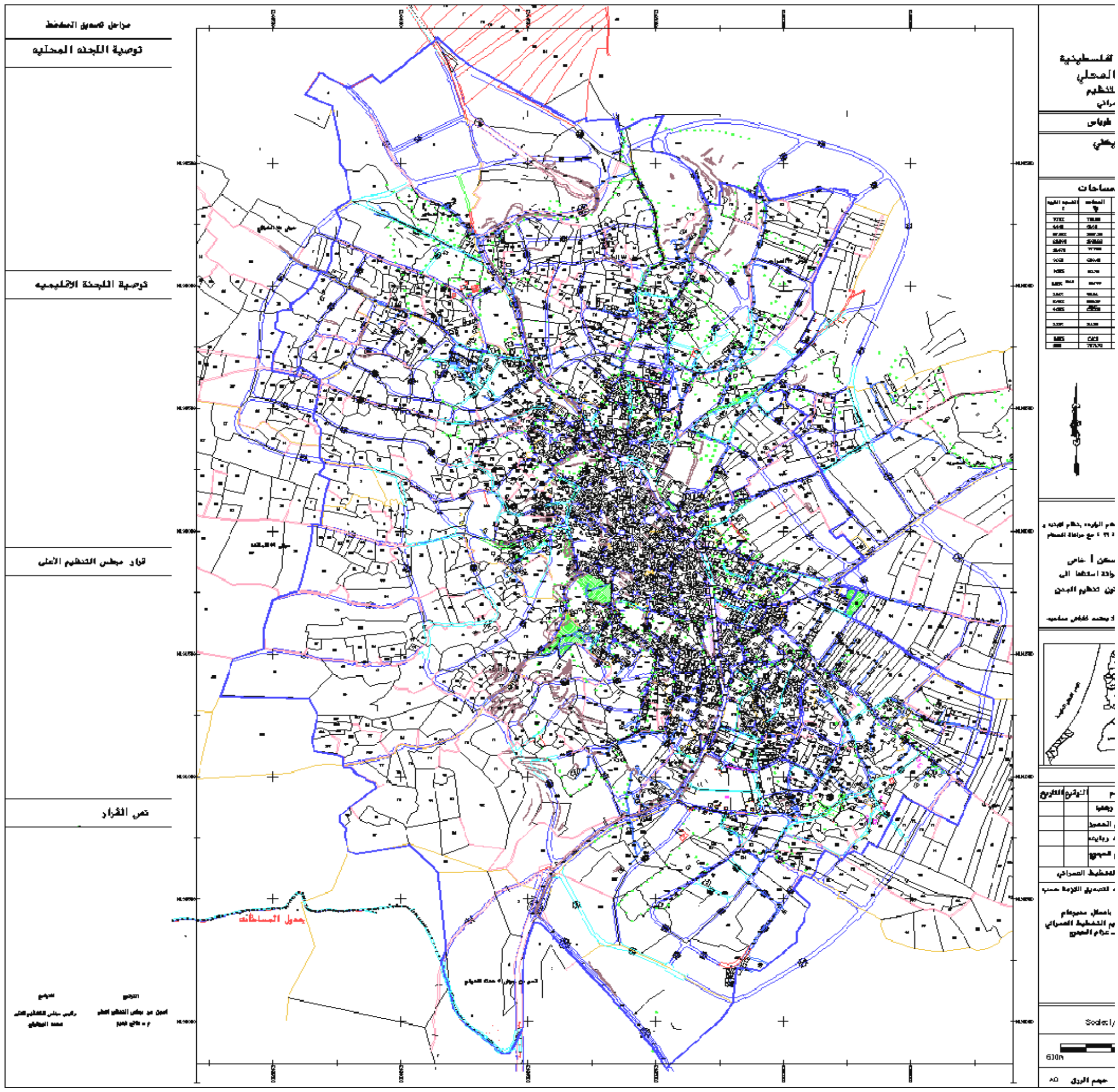


Figure 5.3 Tubas plan

5.4. Investment costs

The investment costs will be made for year 2010. The calculations are made for three major treatment systems: Activated Sludge (AS), Trickling Filters (TF) and Aerated Lagoons (AL) for each of the five treatment options (Appendix C). We also estimate the investment costs of chlorine disinfection, seasonal storage and conveyance of treated wastewater to the irrigation site. As such we present the equations that are applied to quantify the investment costs in Chapter Four.

The results of the investment costs (Table 5.6) show that the investment costs of Activated sludge (AS) are higher than that of using Trickling filter (TF) and Aerated Lagoons (AL). The investment costs per cubic meter of treated wastewater through Conventional Activated Sludge system are 0.97, 1.06, 0.92, 0.86 and 0.84 US$ for the five options, respectively (Table 5.6 and Appendix C). The investment costs per cubic meter of treated wastewater through Trickling Filter systems are 0.85, 0.94, 0.81, 0.76 and 0.73 US$ for the five options, respectively, while the investment costs per cubic meter of treated wastewater through Aerated Lagoon system are 0.8, 0.89, 0.76, 0.72 and 0.69 US$ for the five options, respectively.

Table(5.6): Investment costs comparison for different and reuse options.

Investment costs	Option 1	Option 2	Option 3	Option 4	Option 5
Investment costs for the Activated Sludge (AS) (US$)	6,308,492	4,579,451	7,491,574	9,444,654	10,517,003
Investment costs for the Trickling Filter (TF) (US$)	5,450,064	3,956,303	6,472,158	8,159,473	9,085,902
Investment costs for the Aerated Lagoons (AL) (US$)	5,106,214	3,706,696	6,063,824	7,644,684	8,512,664
Investment costs for the Chlorine Disinfection (US$)	116,735	103,821	126,135	142,483	151,843
Storage investment costs (US$)	413,779	275,852	514,362	689,645	790,214
Conveyance investment costs (US$)	234,000	234,000	234,000	234,000	234,000
Total investment costs for AS option (US$)	7,073,005	5,193,124	8,366,071	10,526,382	11,695,130
Total investment costs for TF option (US$)	6,214,577	4,569,976	7,346,655	9,241,201	10,264,030
Total investment costs for AL option (US$)	5,870,727	4,320,369	6,938,321	8,726,412	9,690,791
Annual investment costs of AS option depreciated over 25 years (US$/year 2010)	406,188	298,230	480,446	604,508	671,626
Annual investment costs of TF option depreciated over 25 years (US$/year 2010)	356,890	262,444	421,903	530,702	589,441
Annual investment costs of AL option depreciated over 25 years (US$/year 2010)	337,143	248,110	398,453	501,139	556,522
Investment costs for AS option (US$/m³)	0.97	1.06	0.92	0.86	0.84
Investment costs for TF option (US$/m³)	0.85	0.94	0.81	0.76	0.73
Investment costs for AL option (US$/m³)	0.80	0.89	0.76	0.72	0.69

5.5. Running costs

The running costs of wastewater treatment for the five reuse options are calculated for each year between 2010 and 2035 (Appendix C). The running costs (Table 5.7) show that the O&M costs of using Activated Sludge (AS) are higher than that of Trickling Filters (TF) and Aerated Lagoons (AL). The O&M costs decrease with time as we can see in Appendix C. For example, the O&M costs of TF for option 1 decrease from 0.70 US$/$m^3$ in 2010 to 0.58 US$/$m^3$ in 2035. This is due to the increase of the population served and the increase in wastewater quantities.

Table (5.7): Running cost comparison for different treatment and reuse options in 2010

O&M costs	Option 1	Option 2	Option 3	Option 4	Option 5
O&M costs for AS option (US$/year 2010)	127,883	100,267	145,716	173,749	188,537
O&M costs for TF option (US$/year 2010)	98,470	77,206	112,202	133,787	145,173
O&M costs for AL option (US$/year 2010)	51,589	40,448	58,783	70,091	76,056
O&M costs for Chlorine Disinfection (US$/year 2010)	16,093	14,951	16,924	18,371	19,201
Storage O&M costs (5% of investment) (US$/year 2010)	20,689	13,793	25,718	34,482	39,511
Conveyance O&M costs (10% of investment) (US$/year 2010)	23,400	23,400	23,400	23,400	23,400
Surface irrigation costs (400 US$/dunum)	135,154	90,103	168,004	225,257	258,107
Total annual O&M costs for AS option (US$/year 2010)	323,219	242,514	379,763	494,287	547,851
Total annual O&M costs for TF option (US$/year 2010)	293,806	219,452	346,248	454,324	504,488
Total annual O&M costs for AL option (US$/year 2010)	246,924	182,695	292,829	390,629	435,371
O&M for AS option (US$/m^3)	0.77	0.87	0.73	0.71	0.68
O&M for TF option (US$/m^3)	0.70	0.78	0.66	0.65	0.63
O&M for AL option (US$/m^3)	0.59	0.65	0.56	0.56	0.54

5.6. Total unit costs

The total annual unit costs are calculated by taking the sum of the total investment costs per m^3 and the total O& M per m^3 of treatment options for the five options. The calculation results for each year are shown in Appendix C. As we can see from Table 5.8 the total unit costs for the treatment option with Activate sludge is higher than with Trickling Filter and Aerated Lagoon. We can see from the Appendix C that the total unit costs of treatment decrease every year due to increase of population. The total unit costs of treatment with Trickling Filter for option 1 decrease from 1.55US$/ m^3 in 2010 to 0.98US$/ m^3 in 2035

Table (5.8): Total unit costs for different treatment and reuse options in 2010

Costs	Option 1	Option 2	Option 3	Option 4	Option 5
Total costs for AS option (US$/m³)	1.73	1.93	1.65	1.57	1.52
Total costs for TF option (US$/m³)	1.55	1.72	1.47	1.41	1.36
Total costs for AL option (US$/m³)	1.39	1.54	1.32	1.27	1.24

5.7. Suggested wastewater tariffs

Wastewater treatment projects are very expensive and require a huge investment so we need to design a proper tariff system. In most developing countries the municipalities pay the operation costs only, while the investment costs are funded by external aid agencies (Abu-Madi, 2006). External funding is the major factor for making wastewater treatment projects in Palestine, while local funding options are rarely used (Abu-Madi, 2006).

If the treated wastewater is too expensive, farmers may reject paying for and they will not utilize it. To avoid this rejection and to make the treated wastewater attractive, the farmers should pay the storage O&M costs, conveyance O&M costs and surface irrigation costs only and the other treatment costs have to be paid by the households (Abu-Madi, 2006).

The calculation shows that the farmers will have to pay for irrigation with treated wastewater for the five options 0.57, 0.61, 0.55, 0.54 and 0.53 US$ /m³, respectively in 2010. These tariffs will be reduced to 0.35, 0.37, 0.34, 0.33 and 0.33 US$/ m³ for the five option, respectively in 2035.

Table (5.9): Suggested tariffs for the treatment and reuse options in 2010

Suggested tariffs	Option 1	Option 2	Option 3	Option 4	Option 5
Tariffs to be paid by farmers (only O&M costs) (US$/m³)	0.57	0.61	0.55	0.54	0.53
Tariffs to paid by households and industries (might need subsidy by municipalities or utilities)					
With AS option (US$/m³)	1.17	1.32	1.09	1.03	0.99
With TF option (US$/m³)	0.98	1.11	0.92	0.87	0.83
With AL option (US$/m³)	0.82	0.93	0.77	0.73	0.70

5.8. Benefits from using treated wastewater for irrigation crops

There are benefits that will result from using treated wastewater in agriculture. These benefits are the increase in the production of agriculture due to the increase irrigation and the economic value that the farmers will get from using the treated wastewater to irrigate their crops. The farmers will gain 0.75, 0.75, 0.74, 0.74 and 0.74 US$ for each cubic meter of treated wastewater they use for irrigation in 2010 for the five reuse options respectively (Table 5.10 and Appendix C).

Table (5.10) : Benefit from the different reuse options in 2010

Benefits	Option 1	Option 2	Option 3	Option 4	Option 5
Economic benefit (US$/m³)	157,680	105,120	196,005	262,800	301,125
Crop production (US$/m³)	77,745	53,530	95,402	126,176	143,833
Total benefit to farmers (US$/m³)	0.75	0.75	0.74	0.74	0.74

Chapter Six
Conclusions and Recommendations

In this thesis, wastewater treatment and reuse for irrigation purposes in Tubas, West Bank – Palestine, was studied and evaluated. The study concentrated on knowing the public opinion towards using treated wastewater in agriculture in the study area through distribution of a questionnaire; we also determined the cost and benefit of wastewater treatment and reuse through development of a benefit- cost analysis. The results show a number of important conclusions.

6.1. The main conclusions drawn from the present study are summarized below:

1- Only 13% of the responders believe that water in Tubas is sufficient for domestic and agricultural use.

2- The majority of the responders (92%) support the idea of having a wastewater treatment plant in Tubas.

3- 77% of the responders support the idea of irrigating trees with treated wastewater while 75% of the responders support the idea of irrigating fodder crops with treated wastewater.

4- The majority of responders support the reuse in the irrigation of crops and plants that are not consumed by human beings such as flowers or fodder crops.

5- 38% of responders trust that the municipality will treat wastewater effectively, while 25% didn't know.

6- 88% of the responders support the idea of financially contributing to the treatment of wastewater.

7- The study considered five options for collective wastewater treatment from Tubas. The first option studied the construction of a treatment plant for the wastewater from north of Tubas (approximately 60% of Tubas). The second option studied the construction of a treatment plant for the wastewater from south of Tubas. The third option studied the construction of a treatment plant for the wastewater from north of Tubas and Tayaser village. The fourth option studied the construction of a treatment plant for the wastewater from all of Tubas. The fifth option studied the construction of a treatment plant for the wastewater from all of Tubas and Tayaser village.

8-The best location to be considered for the construction of WWTPs in options 1,3,4,5 is in the north of Tubas for many reasons, such as that it will be far away from Faria well so there will be low risk for pollution of ground water, there is available land, and the topography slope can be utilized so that the system is under gravity flow which minimizes pumping requirements. For option 2, there is no feasible location for a WWTP in the south because there is no land available, the area is too close to the Faria well, and it is too far from the irrigated areas.

9- The first and the third options are the most feasible for treating wastewater. The third option is more likely due to the location of treatment plant (down hill of Tayaser village); it will easy to collect water from Tayaser village and north of Tubas using gravity flow. Also the number of people served in the third option is larger than option 1. Option 2 is not feasible, as discussed above, due to the lack of a suitable site to construct a WWTP. For the fourth and fifth option, it will be difficult to pump water from south to the treatment plant located in the north.

10- The total amounts of wastewater generated and available for irrigation are shown in (Table 6.1).

Table (6.1): The total amount generated and available for irrigations for the five options

	Option 1	**Option 2**	**Option 3**	**Option 4**	**Option 5**
Total amount of treated wastewater (m^3) in 2010	420,480	280,320	522,680	700,800	803,000
Total amount of treated wastewater available for irrigation (m^3) in 2010	315,360	210,240	392,010	700,800	602,250
Total amount of treated wastewater (m^3) in 2035	880,380	586,920	1,094,389	1,467,329	1,681,307
Total amount of treated wastewater available for irrigation (m^3) in 2035	660,280	440,190	820,790	1,100,497	1,260,980

11- The public opinion, economics, land use, soil and topography of the study area limit the crop to be irrigated with treated wastewater to barley, fodder crops and olives trees

12-The location of the agricultural area suggested to be irrigated with treated wastewater is located in the north east of Tubas about 1800 m from the proposed wastewater treatment plant.

13-The area land that can be irrigated with treated wastewater for the five options are shown in (table 6.2)

Table (6.2): The land area that can be irrigated with treated wastewater for five options

	Option 1	Option 2	Option 3	Option 4	Option 5
Total land area that can be irrigated (dunums) in 2010	338	225	420	536	645
The suggested land area of olives trees in 2010 (dunums)	60	60	60	60	60
The land area of barley and fodder in 2010 (dunums)	278	165	360	503	585
Total land area that can be irrigated (dunums) in 2035	707	472	879	1,179	1,351
The suggested land area of olives trees in 2035 (dunums)	100	100	100	100	100
The land area of barley and fodder in 2035 (dunums)	607	372	779	1,079	1,215

14-The study analyzed three systems for secondary treatment: activated sludge (AS), trickling filter (TF) and aerated lagoons (AL) in addition to seasonal storage and conveyance of treated wastewater to the irrigation site and disinfection by chlorine.

15-The cost calculation results show that the total costs of AS system is higher than that with TF and AL. The total costs of AS, TF and Al for the five options shown in (table 6.3)

Table (6.3): The total costs for the five options

Costs	Option 1	Option 2	Option 3	Option 4	Option 5
Total costs for AS option (US$/m³)	1.73	1.93	1.65	1.57	1.52
Total costs for TF option (US$/m³)	1.55	1.72	1.47	1.41	1.36
Total costs for AL option (US$/m³)	1.39	1.54	1.32	1.27	1.24

16- To encourage farmers to use and pay for treated wastewater, the farmers will have to pay O&M costs related to storage, conveyance and distribution of treated wastewater; the treatment costs will be paid by households.

17- Suggested tariffs of the farmer and the total benefit for the farmer are shown in (table 6.4)

Table (6.4): the suggested tariffs of the farmer and the total benefit for the farmer for the five options

	Option1	Option2	Option3	Option4	Option5
Tariffs to be paid by farmers (only O&M costs) (US$/m³) in 2010	0.57	0.61	0.55	0.54	0.53
Tariffs to be paid by farmers (only O&M costs) (US$/m³) in 2035	0.35	0.37	0.34	0.33	0.33
Total benefit to farmers (US$/m³)	0.75	0.75	0.74	0.74	0.74

6.2. Recommendations

The following are the recommendations:

1- It is necessary to construct a wastewater collection network in Tubas.

2- It is necessary to construct a wastewater treatment plant in Tubas to solve the shortage of water and the environmental problems resulting from improper disposal of wastewater.

3-There is an urgent need for public awareness and training programs to inform and educate people about the benefits of a wastewater reuse project to gain positive public attitudes towards wastewater treatment.

4-Conduct workshops in coordination with other municipalities about the methods of wastewater treatment to enhance the public trust in the ability of the municipalities in treating wastewater sustainability.

5-Conduct training programs to educate the public about the possible health hazards associated with using treated wastewater and how they could protect themselves from these hazards.

6-Conduct training programs to educate the farmers about the types of crops that can be irrigated with the treated wastewater.

7-Trickling filters (TF) are likely the best method of secondary treatment. Aerated lagoons (AL) are not feasible because they need a large area, and activated sludge (AS) has the largest cost.

8-The environmental impact of the wastewater treatment plant should be studied by implementing an environmental impact assessment study for the proposed project.

9-It is of great importance to implement similar studies in other areas of the West Bank.

APPENDIX

Appendix A: Public Opinion Questionnaire

Date: Place:
Gender: male, female
Age:
Education degree: less than tawjihi, tawjihi, more than tawjihi.
Job: farmer, other than.

Part one

Questions	Yes	No	I don't know
1-Do you collect the used tap water to irrigate your planted home garden			
2-Do you support the idea of having a wastewater collection system in Tubas?			
3- Do you support the idea of having a wastewater treatment plant in Tubas?			
4- Do you oppose having a wastewater treatment plant near your home?			
5-Do you trust that the municipality will treat wastewater in a good way?			
6-Do you support the idea of using treated wastewater in cleaning?			
7-Would you be willing to eat fruits or vegetables irrigated with treated wastewater?			
8-Do you support the idea of irrigating vegetables with treated wastewater?			
9-Do you support the idea of irrigating trees with treated wastewater?			
10- Do you support the idea of irrigating fodder crops with treated wastewater?			
11- Do you support the idea of contributing the people contributing small amounts of money for treating wastewater			

Part two

Place a circle around the correct answer in your opinion for the question 2 to10
Note: for the question 6,7,8,9 and 11 please give weight for the answer from 0 to 100%

1-The total amounts of your water bill in month (in NIS) is:…………….

2- From your point, is the water in Tubas sufficient to meet the needs for
1-Domestic use only
2- Agricultural use only
3- Domestic and agricultural
4- insufficient for any of the above

3- The type of wastewater collection cesspit in your home is:
1- Absorbency
2- Impermeable pit

4- The frequency of emptying the wastewater collection cesspit :
1- We do not empty
2- Every month
3- Every quarter a year
4- Semi annual
5- Once a year

5- Your overall attitude about re-using treated wastewater is:
1-Agree
2- Opposing
3- Neutral

6-If you are opposing the reuse of treated wastewater, the reason that prompted you is:
1- Religions
2- Cultural
3- Health risk
4- Breaths (disgust)

7- Your preference for the reuse of wastewater is in:
1- Agricultural
2- Industry
3- Household or domestic
4- Irrigate the planted home garden
5- All of above

8- If you agree to use treated wastewater in irrigation you support the use of it in:
1- Vegetables eaten after being cooked
2- Planted but not eaten (flowers)
3-Vegetables eaten after being cooked or not cooked
4- Any type of fodder crop
2- Any type of plants

9- I agree for using treated wastewater in agriculture because I think that:
1- This will save water
2- This will increase the product due to the nutrients in the treated wastewater
3- Wastewater available all the time
4- All of the above

10- From your point the most difficulty that can discourage the idea of having wastewater treatment plant is :

1-Cost
2- Public opinion
3-Effect on the environment
4- operation efficiency
5- All of the above

11- I agree to financially an amount of………….. NIS for the Treating of wastewater per m3

Appendix B: Questionnaire Results

The sample consists of 400 responders from the city of Tubas. The sample was selected as a stratified random sample. The following figures show the sample distribution due to its independent variables.

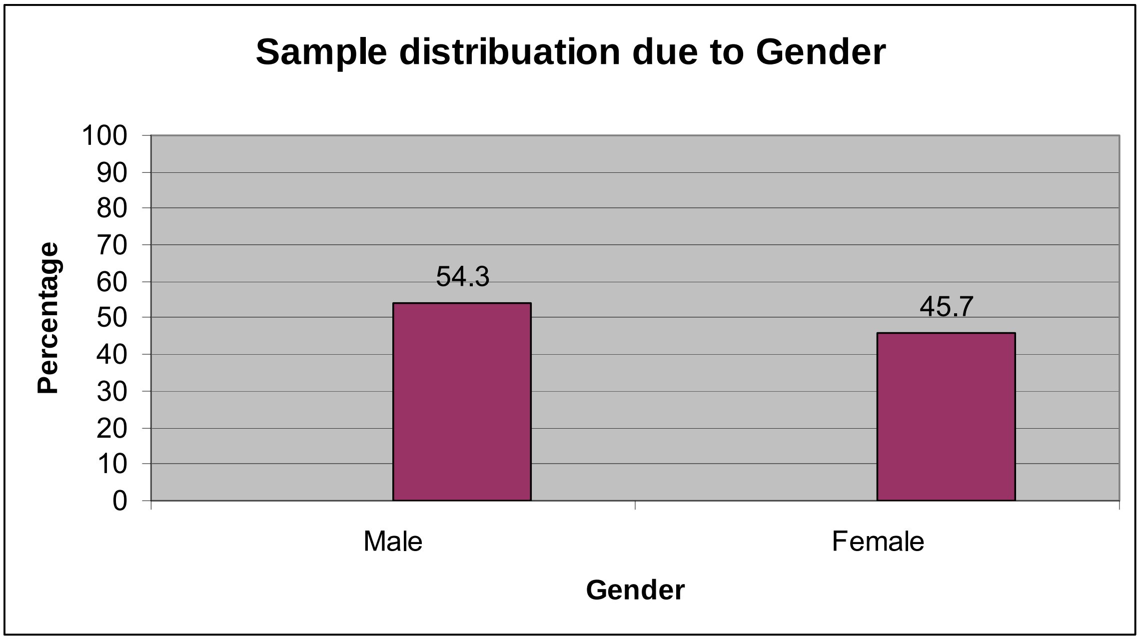


Figure (B1): Sample distribution due to Gender variable

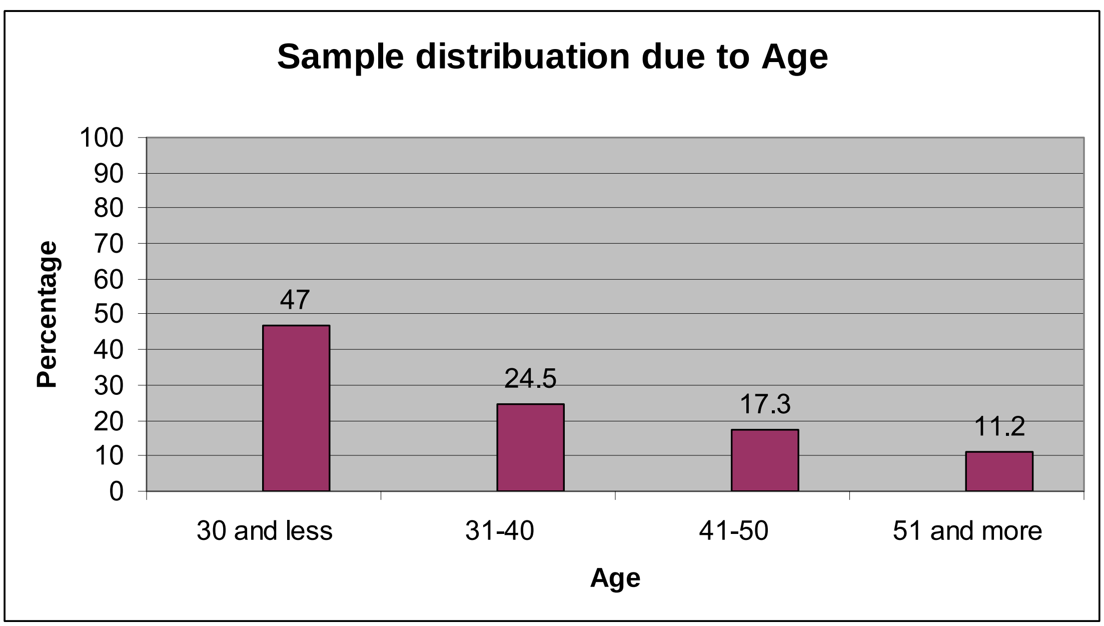


Figure (B2): sample distribution due to age

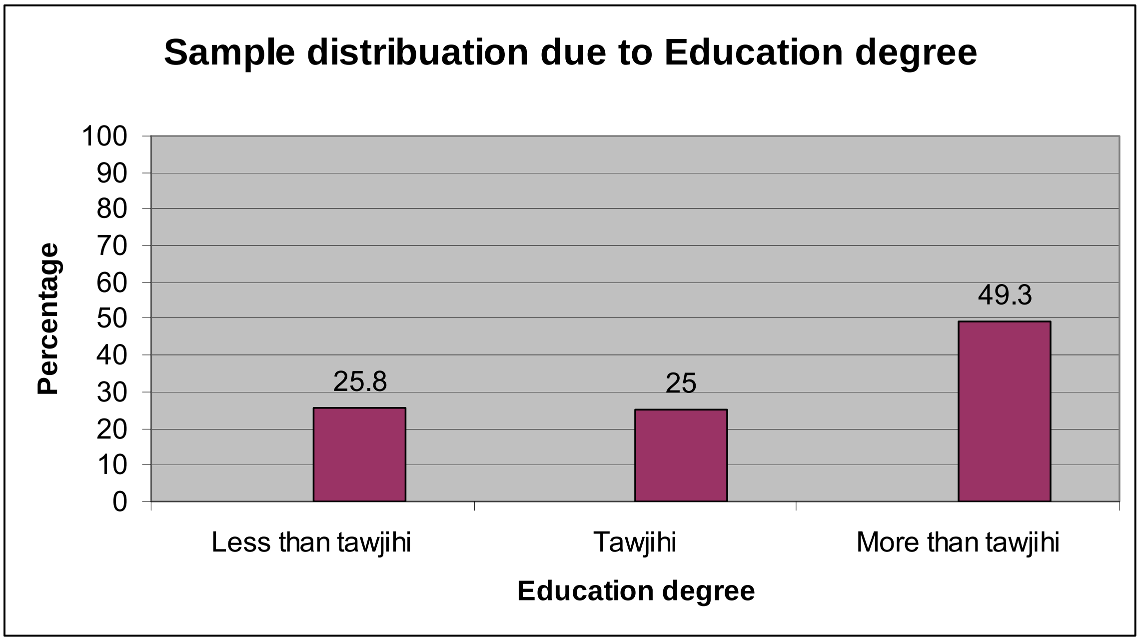


Figure (B3) :Sample distribution due to education degree

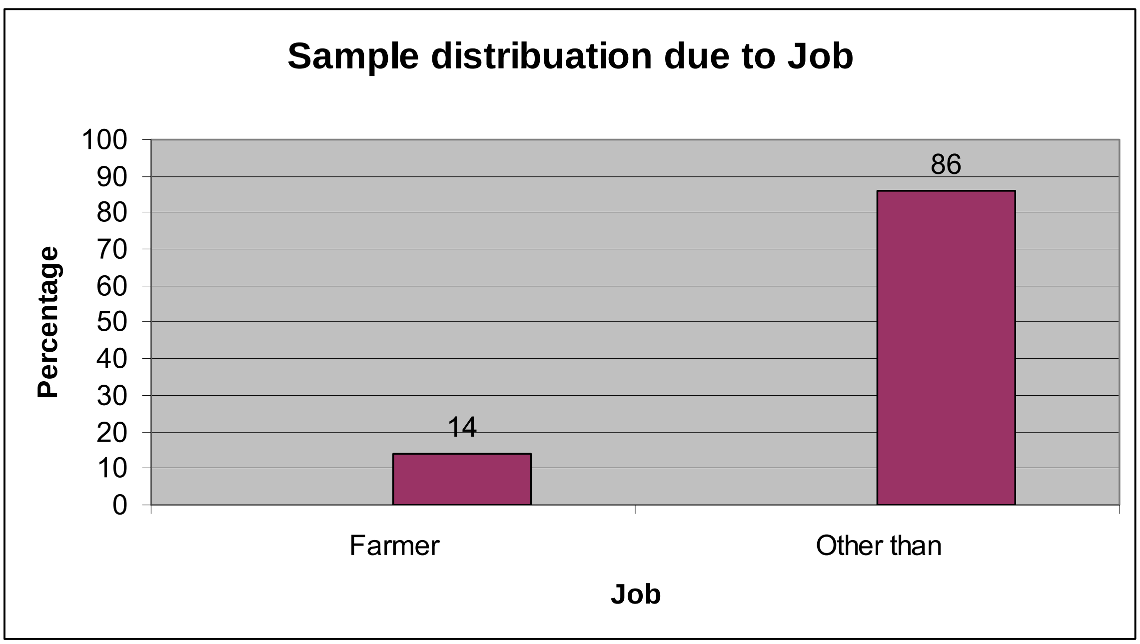


Figure (B4): Sample distribution due to job

Study results

Part One :
Question1:
Do you collect the used tap water to irrigate your planted home garden?

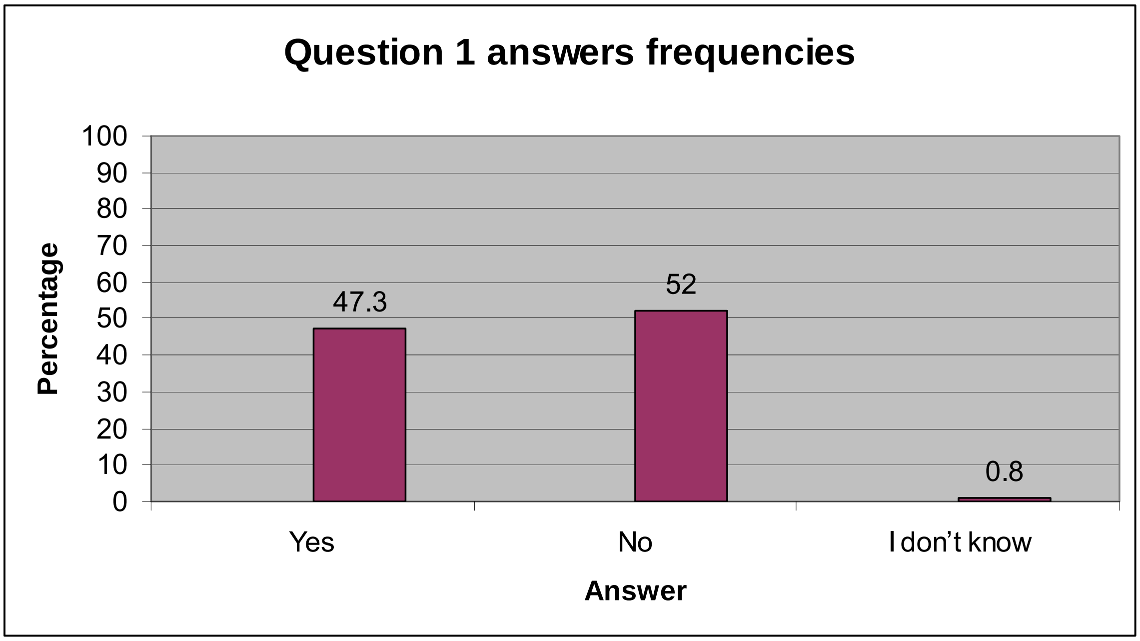


Figure (B5): Sample distribution due to question 1 answer frequencies

Question 2:
Do you support the idea of having a wastewater collection system in Tubas?

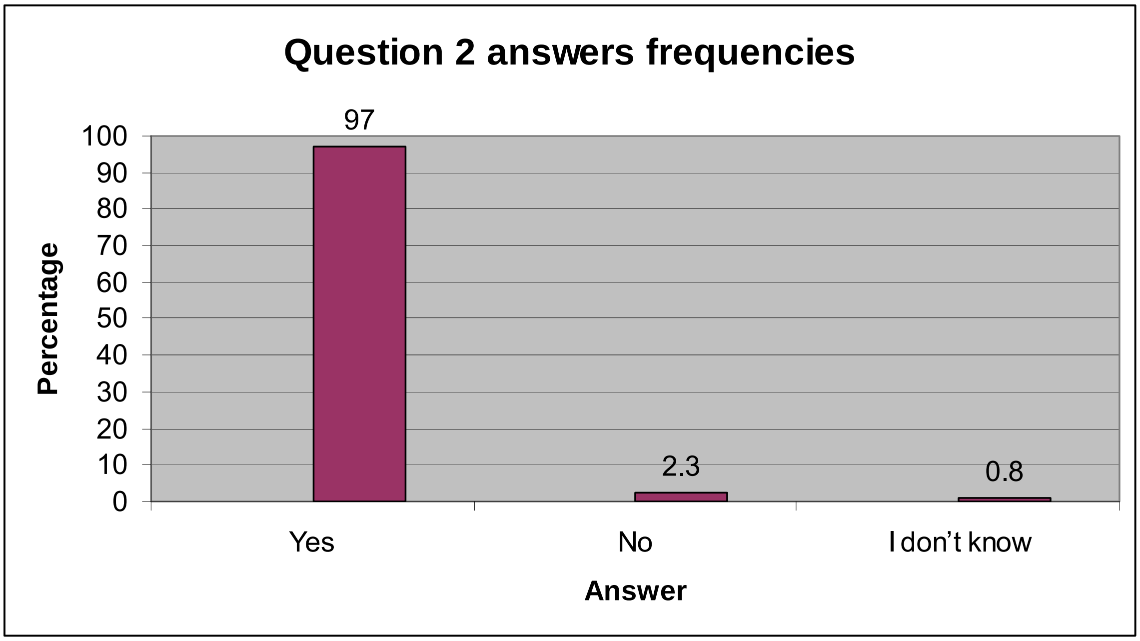


Figure (B 6): Sample distribution due to question 2 answer frequencies

Question 3:
Do you support the idea of having a wastewater treatment plant in Tubas?

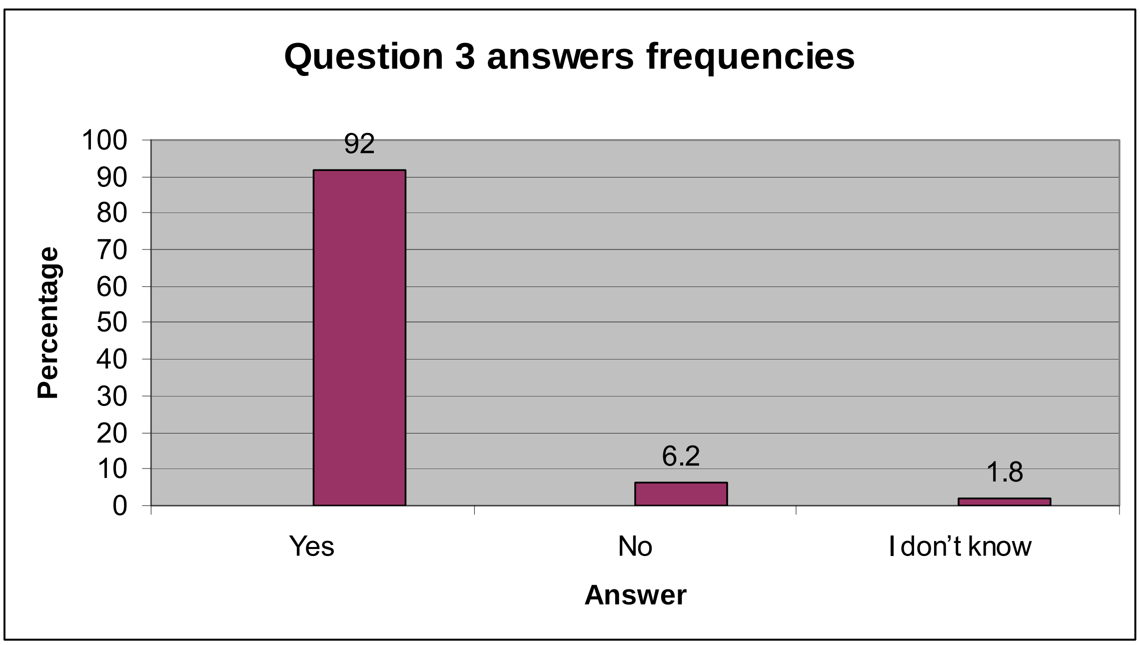


Figure (B7): Sample distribution due to question 3 answer frequencies

Question 4:
Do you oppose to having a wastewater treatment plant near your home?

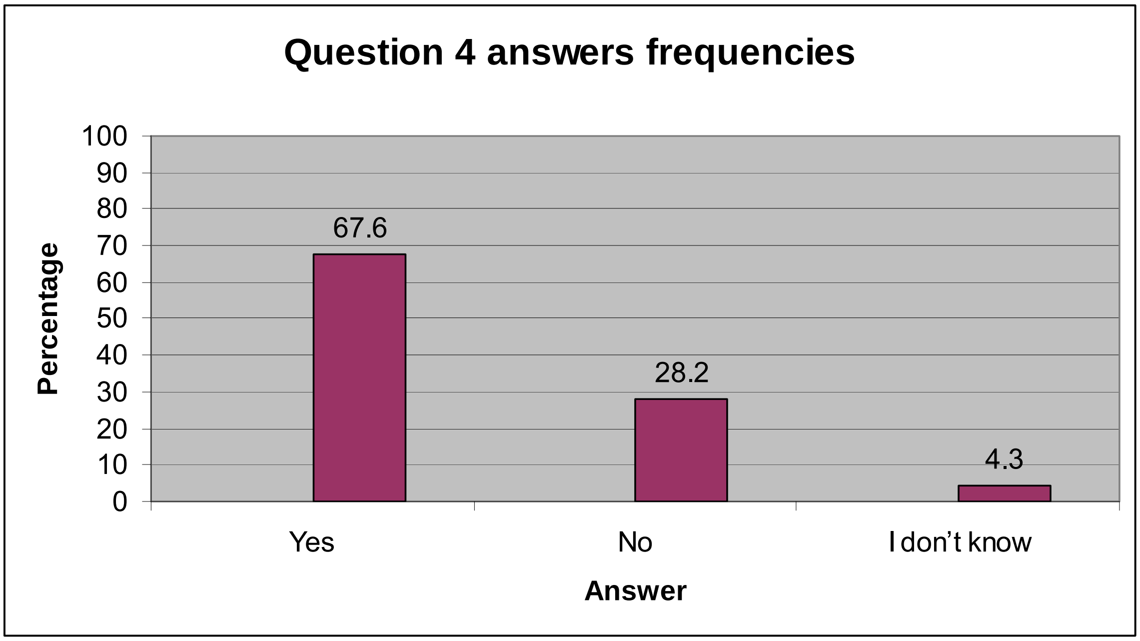


Figure (B8): Sample distribution due to question 4 answer frequencies

Question 5:
Do you trust the municipality will treat wastewater in a good way?

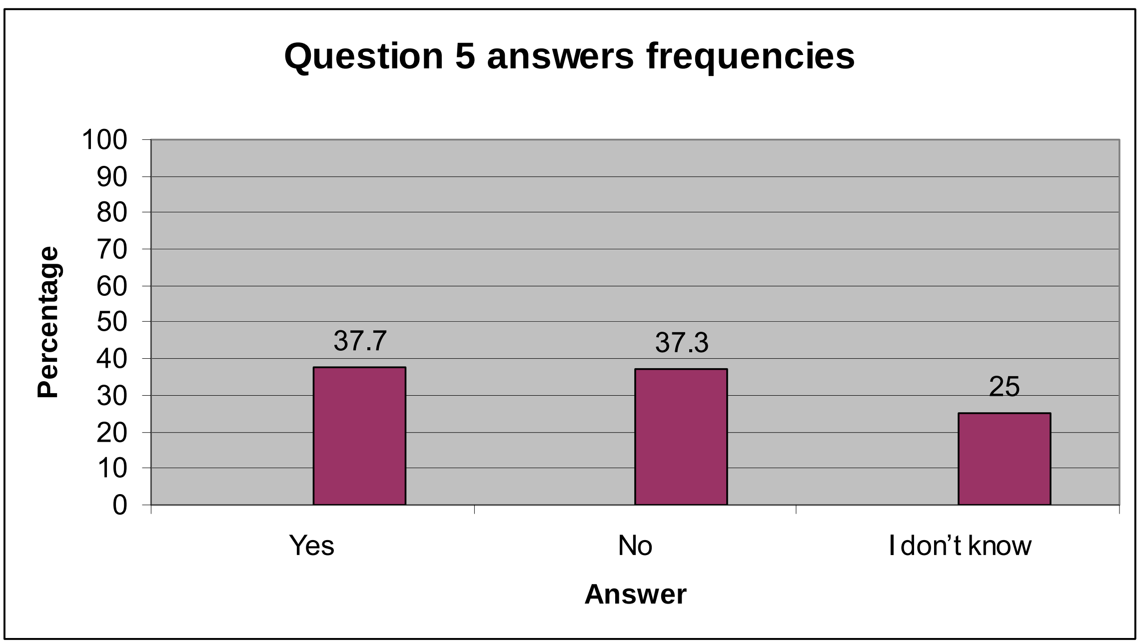


Figure (B9): Sample distribution due to question 5 answer frequencies

Question 6:
Do you support the idea of using treated wastewater in cleaning?

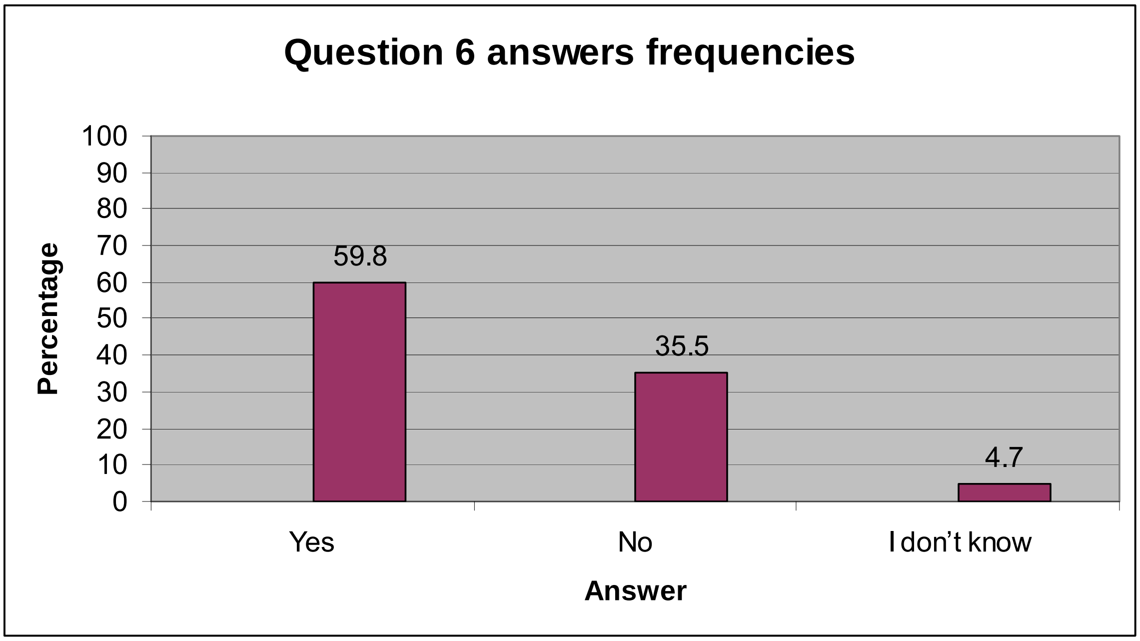


Figure (B10): Sample distribution due to question 6 answer frequencies

Question 7:
Would you be willing to eat fruits or vegetables irrigate with treated wastewater?

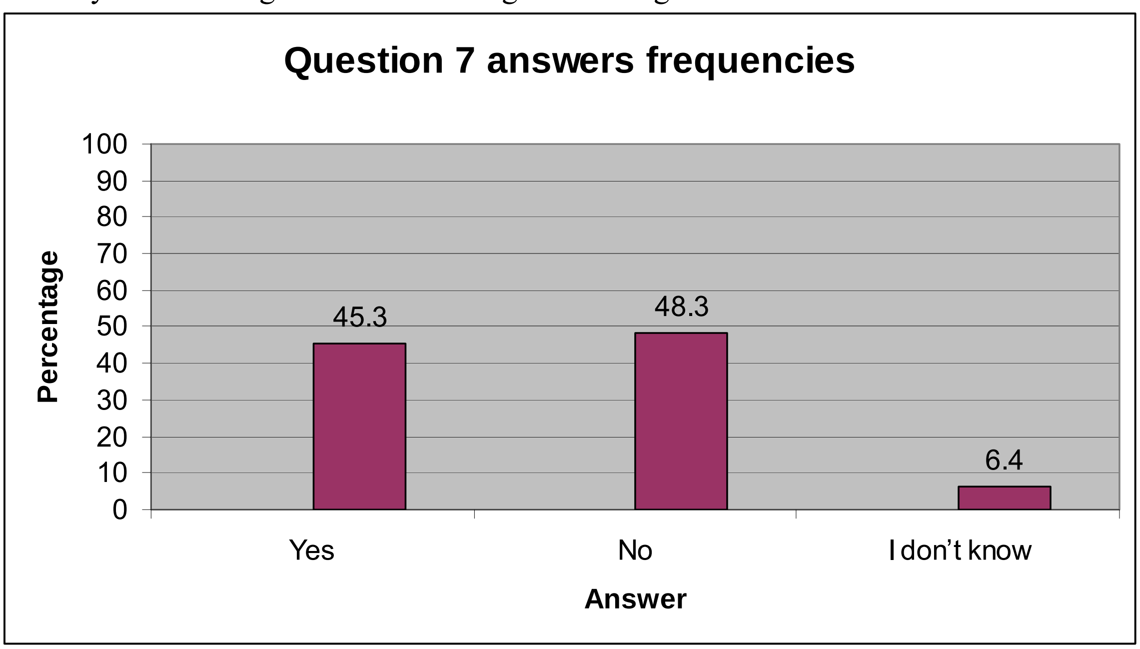


Figure (B11): Sample distribution due to question 7answer frequencies
Question 8:
Do you support the idea of irrigating vegetables with treated wastewater?

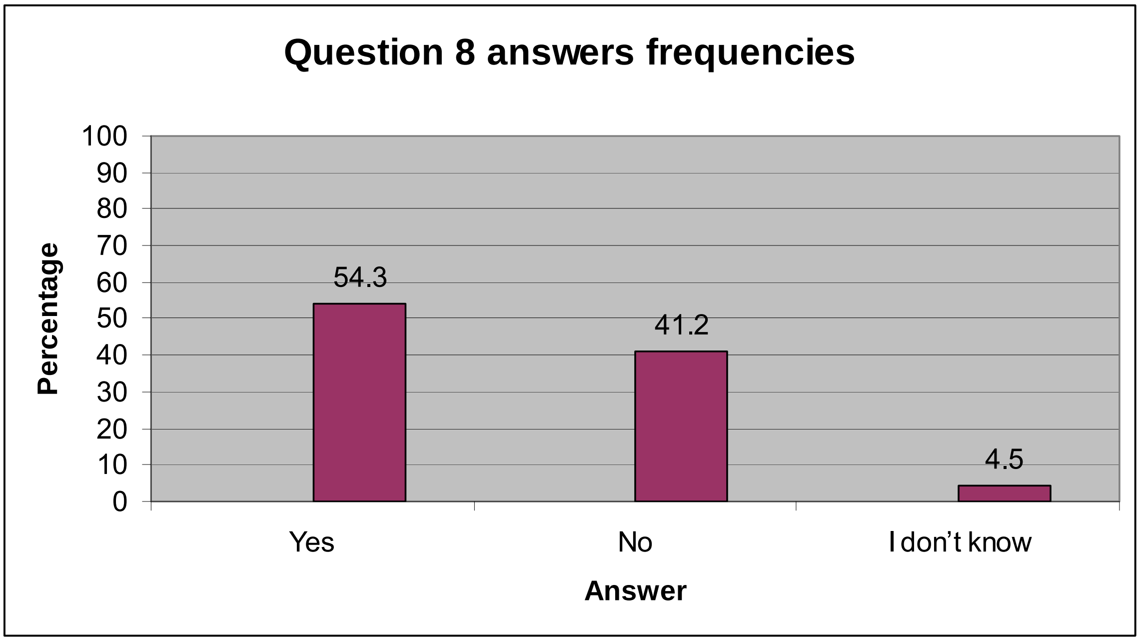


Figure (B12): Sample distribution due to question 8 answer frequencies

Question 9:
Do you support the idea of irrigating trees with treated wastewater?

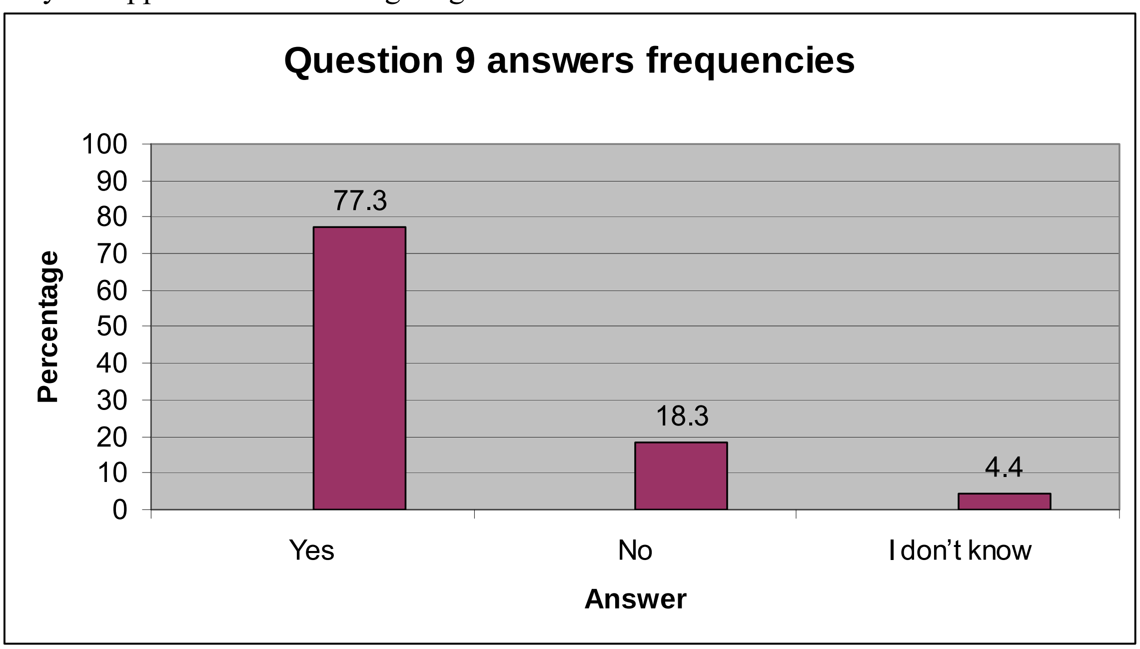


Figure (B13): Sample distribution due to question 9 answer frequencies

Question 10:
Do you support the idea of irrigating fodder crops with treated wastewater?

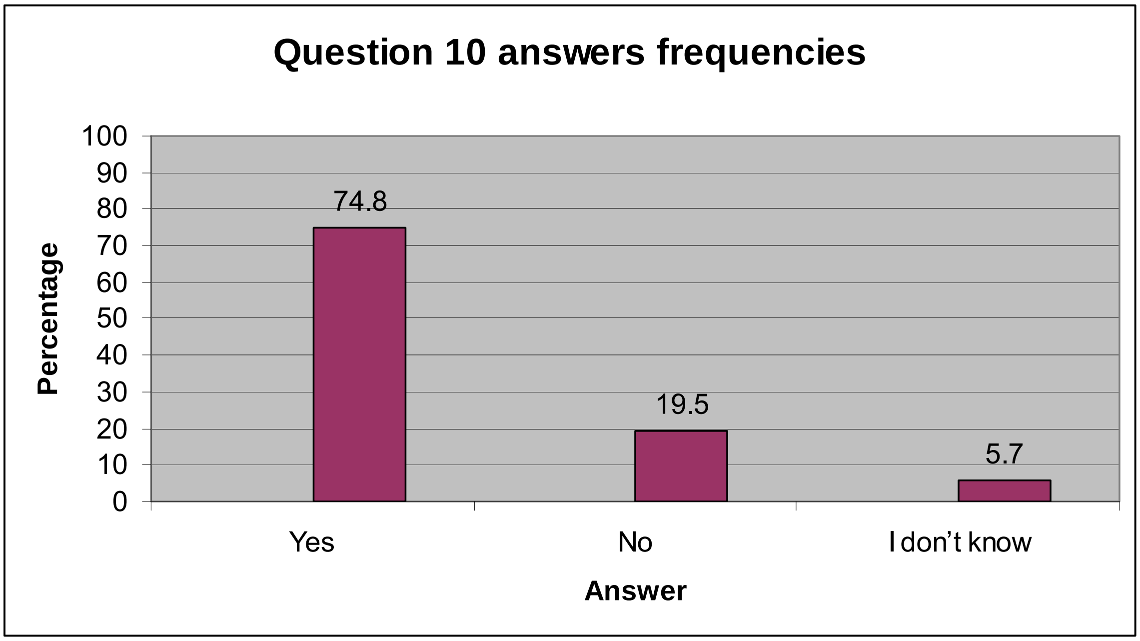
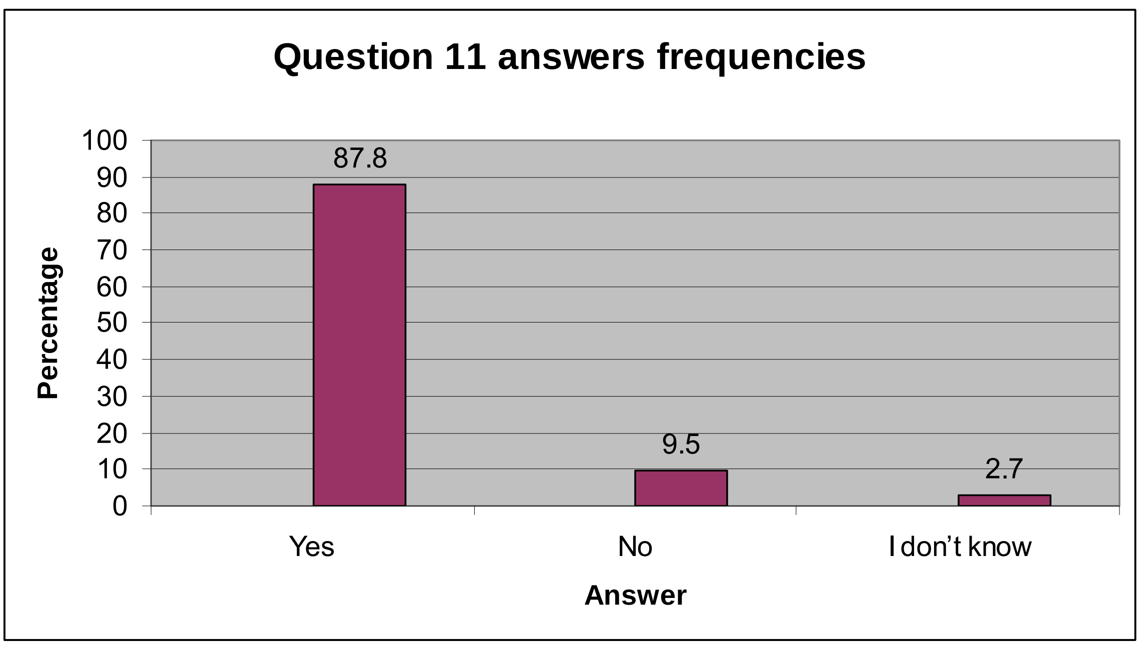


Figure (B14): Sample distribution due to question 10 answer frequencies

Question 11:
Do you support the idea of the people contributing small amounts of money for treating wastewater?



Figure(B15): Sample distribution due to question 11answer frequencies

Part Two :

1. The total amounts of your water bill in month (in NIS)

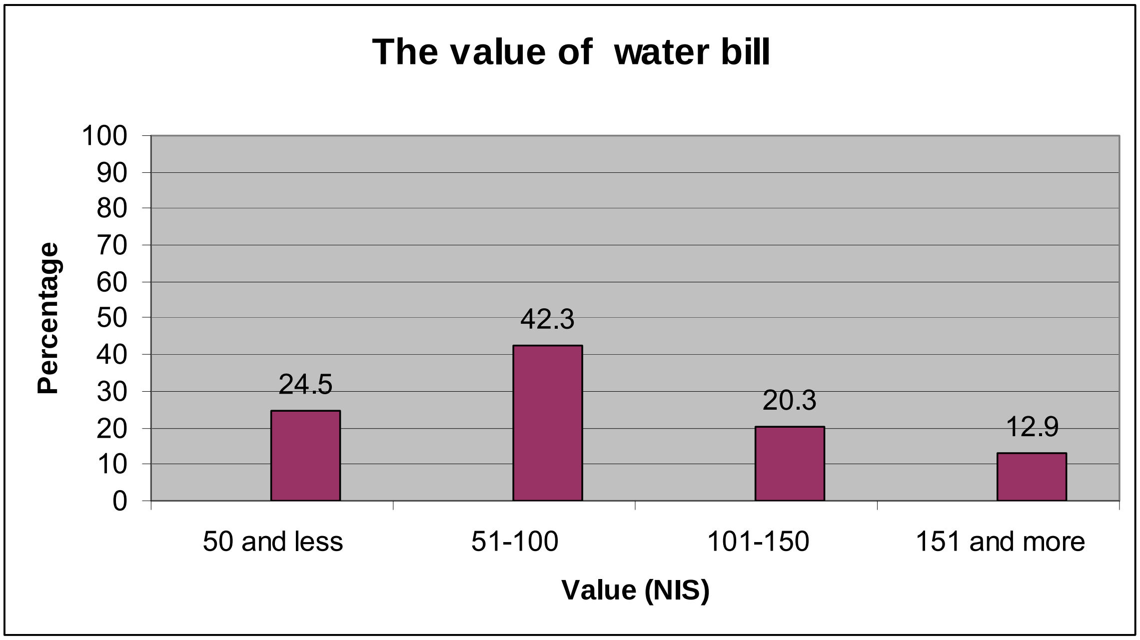


Figure (B16): Sample distribution due to the total amounts of water bill

2- From your point the water in Tubas is enough to meet the needs for

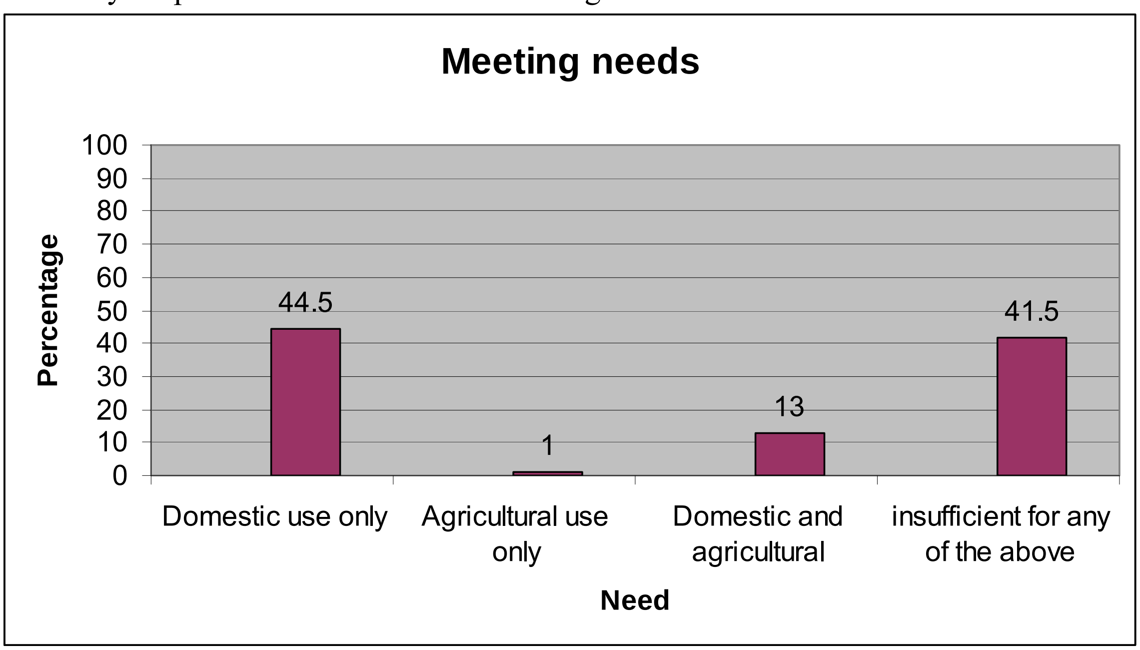


Figure (B17): Sample distribution due to meeting needs of water

3- The type of wastewater collection cesspit in your home is:

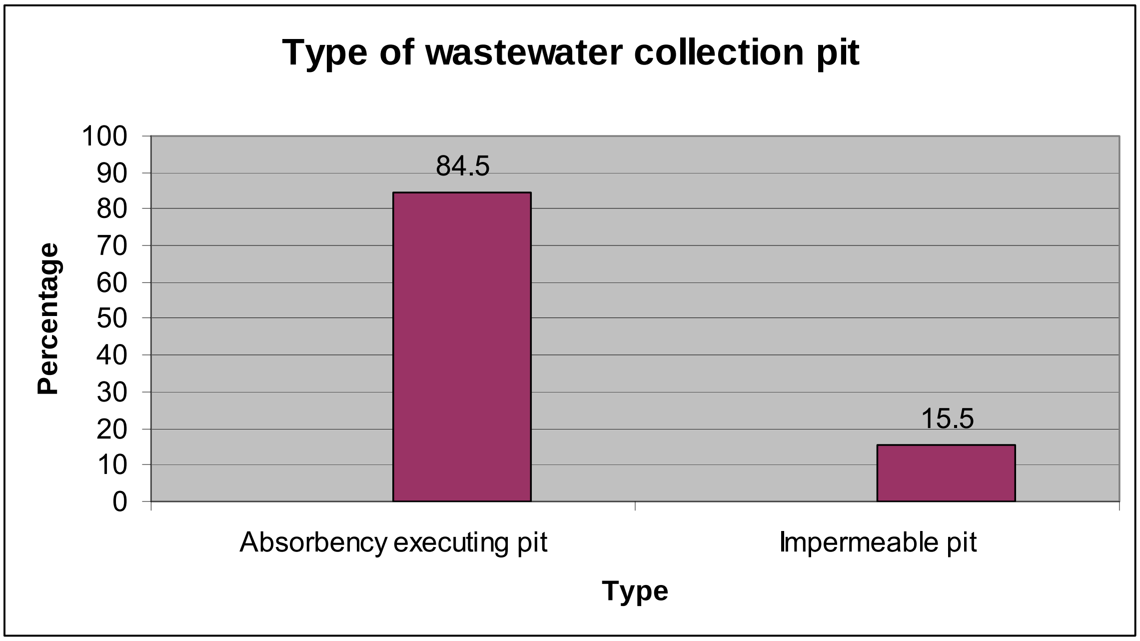


Figure (B18): Sample distribution due to type of collection cesspit

4- The frequency of emptying wastewater collection cesspit :

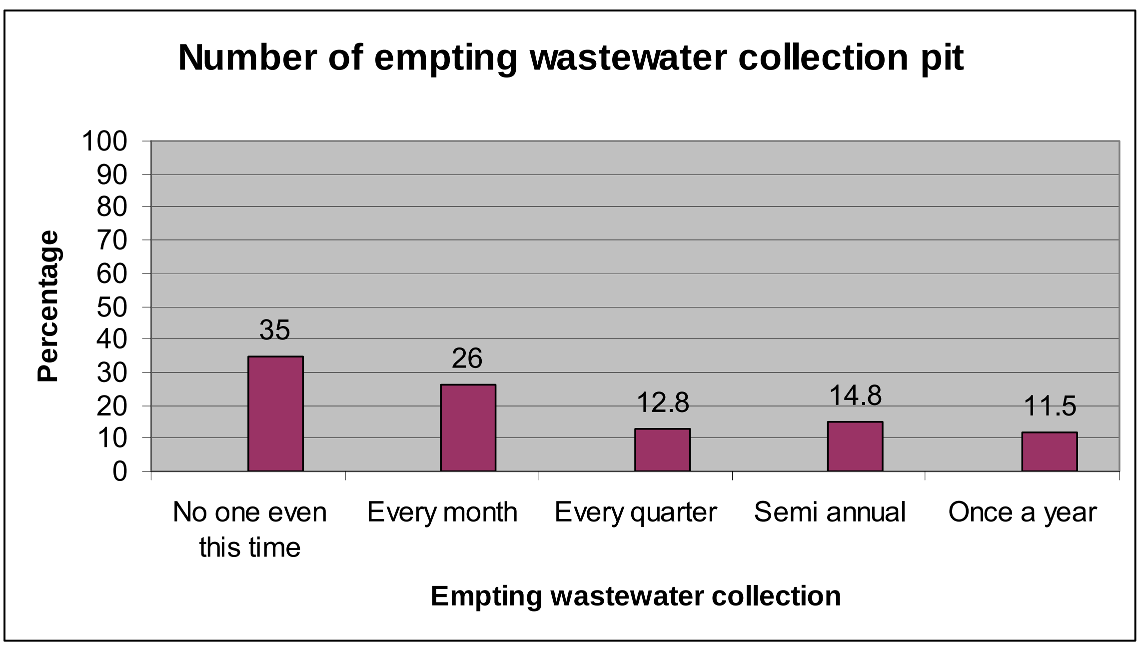


Figure (B19): Sample distribution due to frequency of emptying cesspit

5- Your overall attitude about re-using treated wastewater is

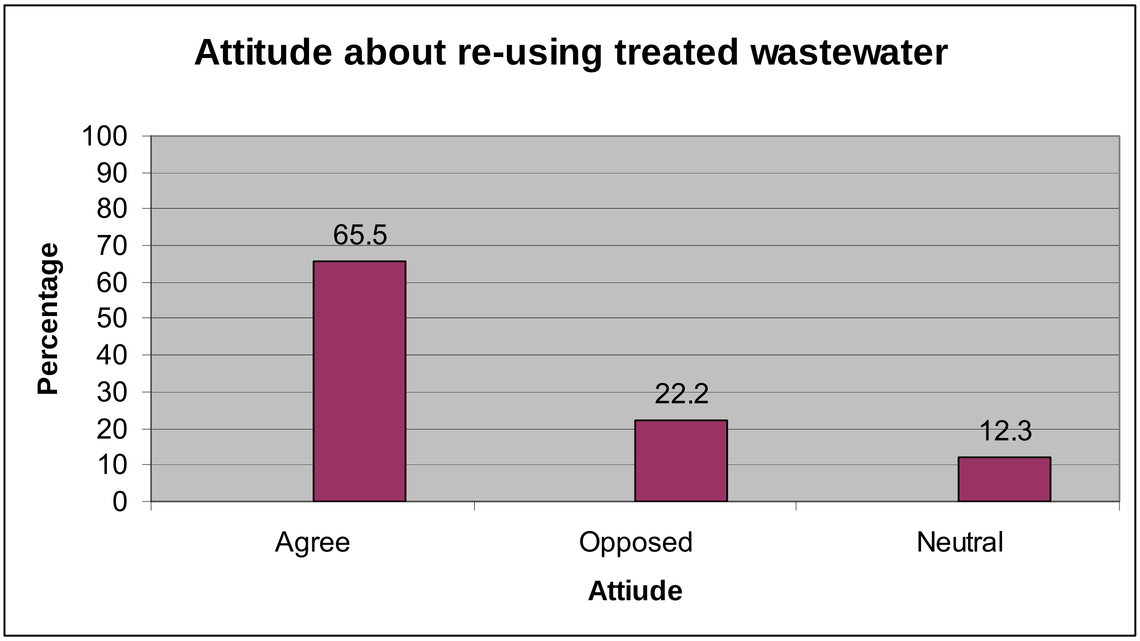


Figure (B20): Sample distribution due to attitude about re-using treated wastewater

6- If you are opposing the reuse of treated wastewater, the reason that prompted you is:

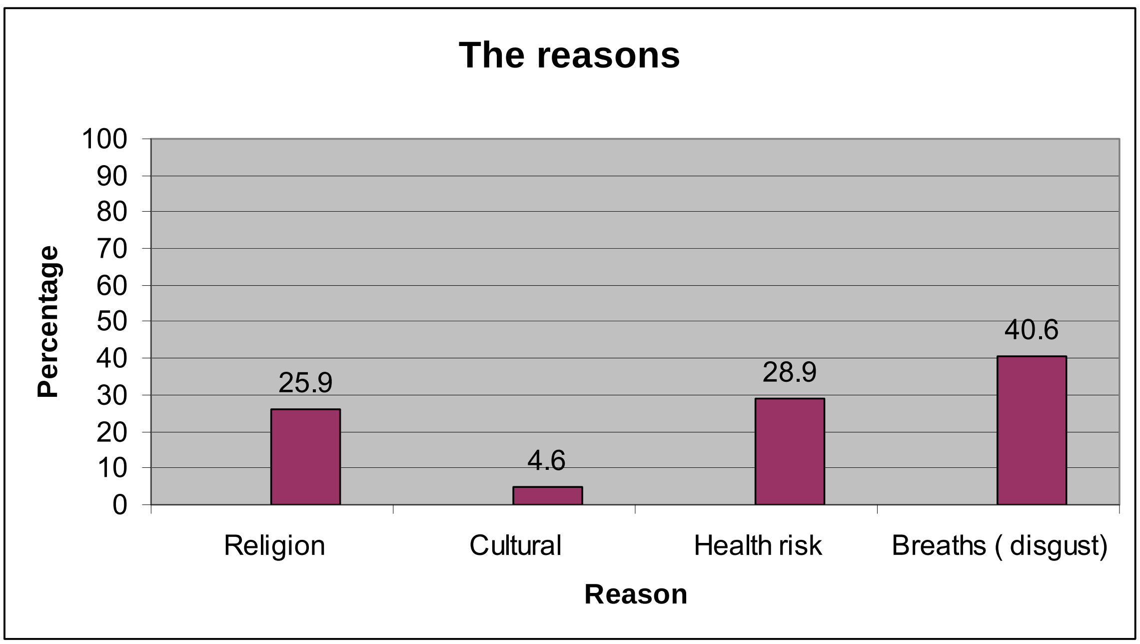


Figure (B21): Sample distribution due to reason of opposing the reuse of treated wastewater

7- Your preference for the reuse of wastewater is in:

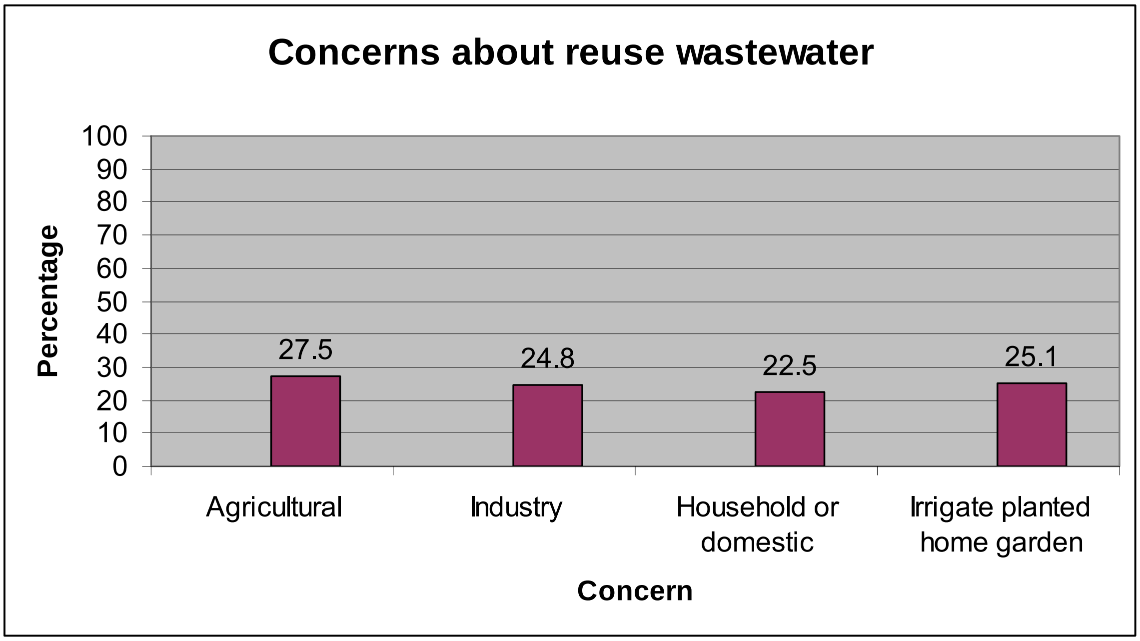
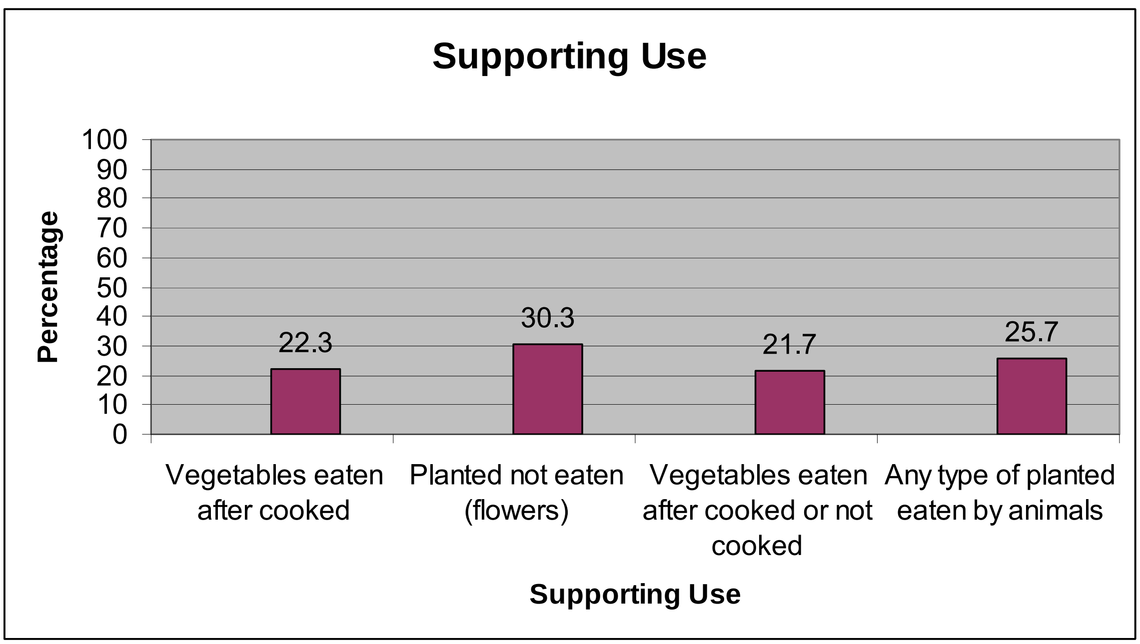


Figure (B22): Sample distribution due to the preference for the reuse of wastewater

8- If you agree to use treated wastewater in irrigation you support use it in:



Figure(B23): Sample distribution due to the supporting use of treated wastewater

9- I agree for using treated wastewater in agriculture because I think that:

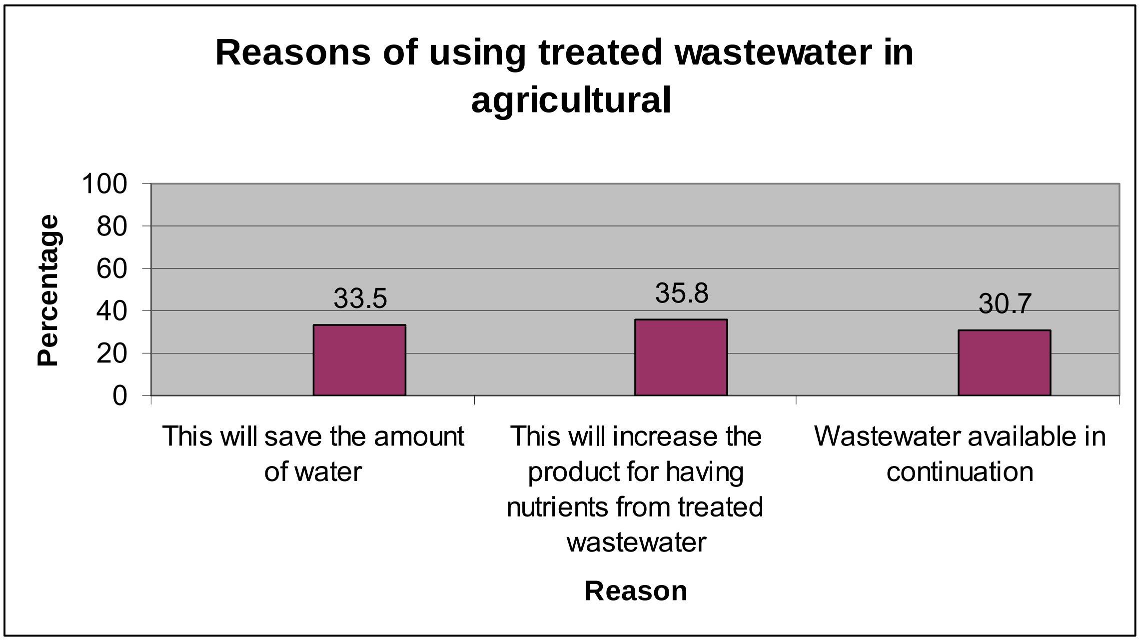


Figure (B24): Sample distribution due to the reason of using treated wastewater in agriculture

10- From your point the most difficulty that can orient the idea of having wastewater treatment plant is:

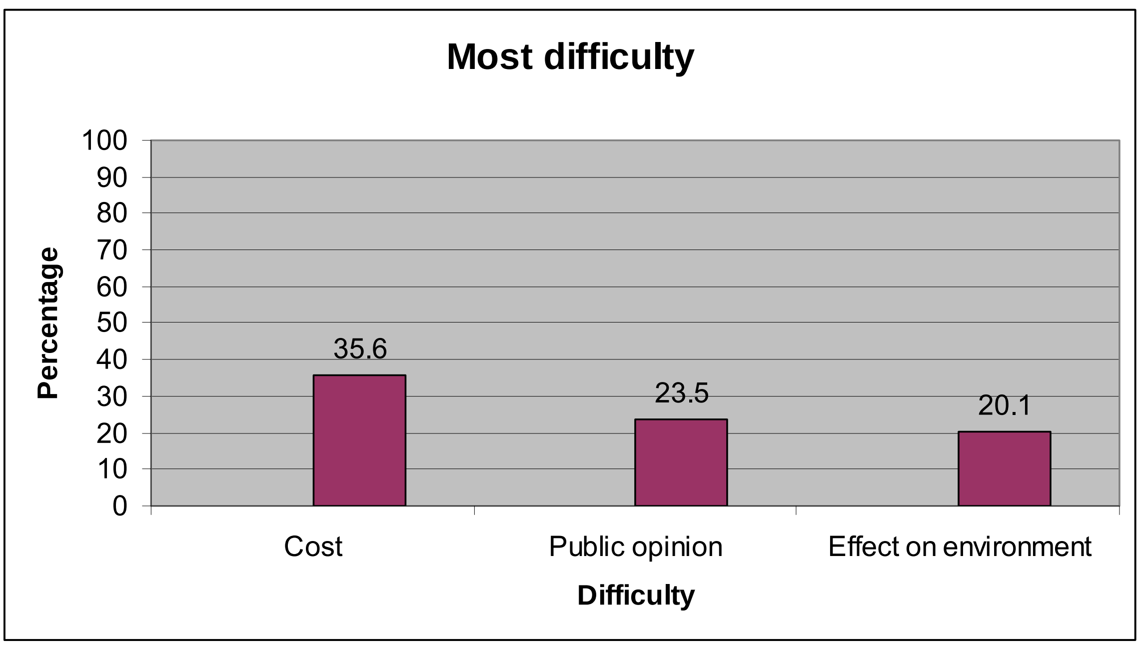


Figure (B25): Sample distribution due to the most difficulty that can discourage the idea of having wastewater treatment plant

11- I agree to financially contribute an amount of ………..NIS for the Treating of wastewater per m^3

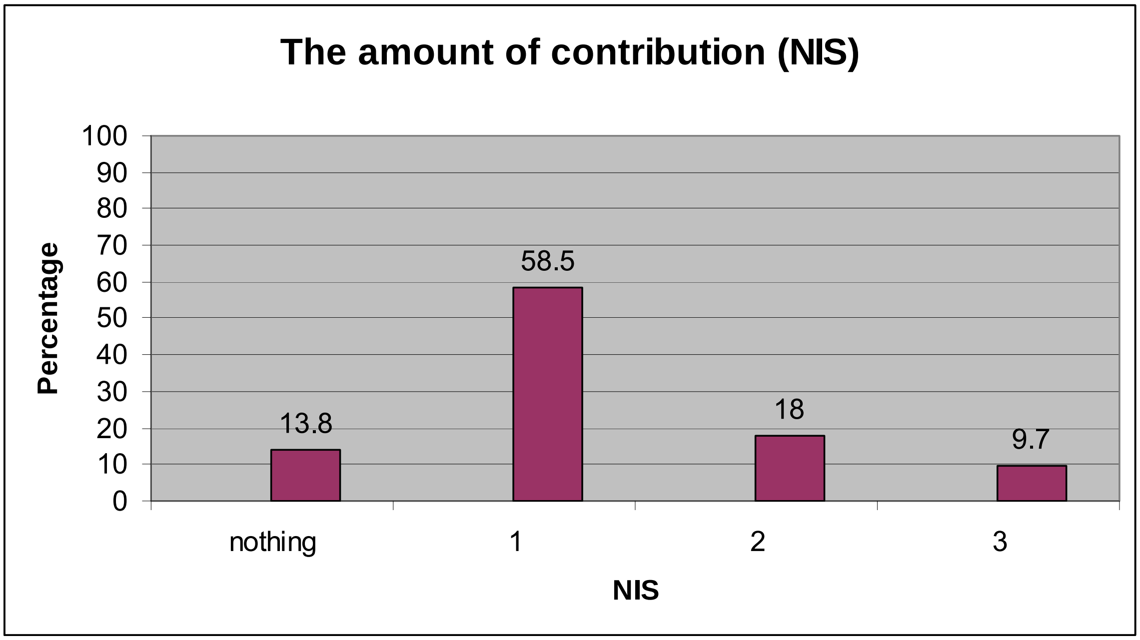


Figure (B26): Sample distribution due to the amount of contribution (NIS)

Appendix C: Calculations for investment and operating cost

CBA Calculations for Option 1

Calculations (2010-2016)	2010	2011	2012	2013	2014	2015	2016
Total population (domestic+industrial)	14,400	14,832	15,277	15,735	16,207	16,694	17,194
Total population in 2035	30150	30150	30150	30150	30150	30150	30150
Total amount of ww. Generated each yr (m^3)	420,480	433,094	446,088	459,462	473,244	487,465	502,065
Total amount of ww. Generated in 2035 (m^3)	880,380	880,380	880,380	880,380	880,380	880,380	880,380
Total amounts of treated ww. For reuse /yr (m^3)	315,360	324,821	334,566	344,597	354,933	365,599	376,549
availability during dry season (m^3)	157,680	162,410	167,283	172,298	177,467	182,799	188,274
availability during rainy season (m^3)	157,680	162,410	167,283	172,298	177,467	182,799	188,274
land area that can be irrigated (supp.) in rainy seas.(du)	451	464	478	492	507	522	538
land area that can be irrigated (full) in dry seas. (du)	225	232	239	246	254	261	269
excess amounts of treated ww. In rainy season (m^3)	78,840	81,205	83,642	86,149	88,733	91,400	94,137
excess amounts of treated ww. In dry season (m^3)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	113	116	119	123	127	131	134
Total land area (du)	338	348	358	369	380	392	403
land area of olives for ww. Irrigation (du)	60	60	60	60	60	60	70
land area of barely & fodders for ww. Irrigation (du)	278	288	298	309	320	332	333
Investment Costs							
investment cost (AS) ($)	6,308,492	0	0	0	0	0	0
investment cost (TF) ($)	5,450,064	0	0	0	0	0	0
investment cost (AL) ($)	5,106,214	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	116,735	0	0	0	0	0	0
Storage investment cost ($)	413,779	0	0	0	0	0	0
Conveyance investment cost ($)	234,000	0	0	0	0	0	0
Total investment cost (AS) ($)	7,073,005	0	0	0	0	0	0
Total investment cost (TF) ($)	6,214,577	0	0	0	0	0	0
Total investment cost (AL) ($)	5,870,727	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	406,188	406,188	406,188	406,188	406,188	406,188	406,188
Annual investment cost (TF) over 25 yrs ($)	356,890	356,890	356,890	356,890	356,890	356,890	356,890
Annual investment cost (AL) over 25 yrs ($)	337,143	337,143	337,143	337,143	337,143	337,143	337,143
Investment cost (AS) ($/$m^3$)	0.97	0.94	0.91	0.88	0.86	0.83	0.81
Investment cost (TF) ($/$m^3$)	0.85	0.82	0.80	0.78	0.75	0.73	0.71

Investment cost (AL) ($/m³)	0.80	0.78	0.76	0.73	0.71	0.69	0.67
O&M costs							
O&M costs (AS) ($)	127,883	130,172	132,501	134,870	137,283	139,744	142,240
O&M costs (TF) ($)	98,470	100,232	102,026	103,850	105,708	107,603	109,525
O&M costs (AL) ($)	51,589	52,512	53,451	54,407	55,381	56,373	57,380
O&M costs (Chlorine Disinfection) ($) 2010	10,329	10,395	10,463	10,533	10,605	10,679	10,755
O&M costs (Chlorine Disinfection) ($)	16,093	63,753	65,237	66,761	68,329	69,940	78,742
Storage O&M costs ($)	20,689	20,896	21,105	21,316	21,529	21,744	21,962
Conveyance O&M costs ($)	23,400	23,634	23,870	24,109	24,350	24,594	24,840
Surface irrigation costs ($)	135,154	136,506	137,871	139,250	140,642	142,049	143,469
Total annual O&M costs (AS) ($)	323,219	374,960	380,584	386,306	392,134	398,070	411,253
Total annual O&M costs (TF) ($)	293,806	345,021	350,109	355,286	360,559	365,929	378,537
Total annual O&M costs (AL) ($)	246,924	297,300	301,534	305,843	310,231	314,700	326,393
O&M costs (AS) ($/m³)	0.77	0.87	0.85	0.84	0.83	0.82	0.82
O&M costs (TF) ($/m³)	0.70	0.80	0.78	0.77	0.76	0.75	0.75
O&M costs (AL) ($/m³)	0.59	0.69	0.68	0.67	0.66	0.65	0.65
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.73	1.80	1.76	1.72	1.69	1.65	1.63
Total cost (TF) ($/m³)	1.55	1.62	1.58	1.55	1.52	1.48	1.46
Total cost (AL) ($/m³)	1.39	1.46	1.43	1.40	1.37	1.34	1.32
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.57	0.56	0.55	0.54	0.53	0.52	0.51
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.17	1.25	1.22	1.19	1.16	1.13	1.12
With TF ($/m³)	0.98	1.06	1.04	1.01	0.99	0.97	0.96
With AL ($/m³)	0.82	0.91	0.89	0.86	0.84	0.82	0.82
Benefits							
Economic Benefits ($)	157,680	162,410	167,283	172,298	177,467	182,799	188,274
Crop Production ($)	77,745	79,925	82,170	84,480	86,861	89,318	92,691
Total Benefit to farmers ($/m³)	0.75	0.75	0.75	0.75	0.74	0.74	0.75

(Option 1 Continued)

Calculations (2017-2023)	2017	2018	2019	2020	2021	2022	2023
Total population (domestic+industrial)	17,710	18,241	18,789	19,352	19,933	20,531	21,147
Total population in 2035	30150	30150	30150	30150	30150	30150	30150
Total amount of ww. Generated each yr (m^3)	517,132	532,637	548,639	565,078	582,044	599,505	617,492
Total amount of ww. Generated in 2035 (m^3)	880,380	880,380	880,380	880,380	880,380	880,380	880,380
Total amounts of treated ww. For reuse /yr (m^3)	387,849	399,478	411,479	423,809	436,533	449,629	463,119
availability during dry season (m^3)	193,925	199,739	205,740	211,904	218,266	224,814	231,560
availability during rainy season (m^3)	193,925	199,739	205,740	211,904	218,266	224,814	231,560
land area that can be irrigated (supp.) in rainy seas.(du)	554	571	588	605	624	642	662
land area that can be irrigated (full) in dry seas. (du)	277	285	294	303	312	321	331
excess amounts of treated ww. In rainy season (m^3)	96,962	99,869	102,870	105,952	109,133	112,407	115,780
excess amounts of treated ww. In dry season (m^3)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	139	143	147	151	156	161	165
Total land area (du)	416	428	441	454	468	482	496
land area of olives for ww. Irrigation (du)	70	70	70	70	70	70	80
land area of barely & fodders for ww. Irrigation (du)	346	358	371	384	398	412	416
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	406,188	406,188	406,188	406,188	406,188	406,188	406,188
Annual investment cost (TF) over 25 yrs ($)	356,890	356,890	356,890	356,890	356,890	356,890	356,890
Annual investment cost (AL) over 25 yrs ($)	337,143	337,143	337,143	337,143	337,143	337,143	337,143

Investment cost (AS) ($/m³)	0.79	0.76	0.74	0.72	0.70	0.68	0.66
Investment cost (TF) ($/m³)	0.69	0.67	0.65	0.63	0.61	0.60	0.58
Investment cost (AL) ($/m³)	0.65	0.63	0.61	0.60	0.58	0.56	0.55
O&M costs							
O&M costs (AS) ($)	144,786	147,376	150,016	152,698	155,432	158,213	161,044
O&M costs (TF) ($)	111,486	113,479	115,513	117,577	119,683	121,824	124,004
O&M costs (AL) ($)	58,407	59,452	60,517	61,599	62,702	63,824	64,966
O&M costs (Chlorine Disinfection) ($) 2010	10,834	10,915	10,998	11,084	11,173	11,264	11,358
O&M costs (Chlorine Disinfection) ($)	80,698	82,710	84,778	86,904	89,024	91,201	93,436
Storage O&M costs ($)	22,181	22,403	22,627	22,853	23,082	23,313	23,546
Conveyance O&M costs ($)	25,088	25,339	25,592	25,848	26,107	26,368	26,631
Surface irrigation costs ($)	144,904	146,353	147,816	149,294	150,787	152,295	153,818
Total annual O&M costs (AS) ($)	417,657	424,180	430,830	437,598	444,432	451,390	458,476
Total annual O&M costs (TF) ($)	384,357	390,284	396,326	402,477	408,683	415,001	421,436
Total annual O&M costs (AL) ($)	331,278	336,257	341,331	346,499	351,702	357,001	362,397
O&M costs (AS) ($/m³)	0.81	0.80	0.79	0.77	0.76	0.75	0.74
O&M costs (TF) ($/m³)	0.74	0.73	0.72	0.71	0.70	0.69	0.68
O&M costs (AL) ($/m³)	0.64	0.63	0.62	0.61	0.60	0.60	0.59
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.59	1.56	1.53	1.49	1.46	1.43	1.40
Total cost (TF) ($/m³)	1.43	1.40	1.37	1.34	1.32	1.29	1.26
Total cost (AL) ($/m³)	1.29	1.26	1.24	1.21	1.18	1.16	1.13
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.50	0.49	0.48	0.47	0.46	0.45	0.44
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.10	1.07	1.05	1.03	1.00	0.98	0.96
With TF ($/m³)	0.94	0.92	0.90	0.88	0.86	0.84	0.82
With AL ($/m³)	0.80	0.78	0.76	0.74	0.73	0.71	0.69
Benefits							
Economic Benefits ($)	193,925	199,739	205,740	211,904	218,266	224,814	231,560
Crop Production ($)	95,294	97,973	100,737	103,577	106,508	109,525	113,483
Total Benefit to farmers ($/m³)	0.75	0.75	0.74	0.74	0.74	0.74	0.75

(Option 1 Continued)

Calculations (2024-2030)	2024	2025	2026	2027	2028	2029	2030
Total population (domestic+industrial)	21,781	22,435	23,108	23,801	24,515	25,250	26,008
Total population in 2035	30150	30150	30150	30150	30150	30150	30150
Total amount of ww. Generated each yr (m³)	636,005	655,102	674,754	694,989	715,838	737,300	759,434
Total amount of ww. Generated in 2035 (m³)	880,380	880,380	880,380	880,380	880,380	880,380	880,380
Total amounts of treated ww. For reuse /yr (m³)	477,004	491,327	506,065	521,242	536,879	552,975	569,575
availability during dry season (m³)	238,502	245,663	253,033	260,621	268,439	276,488	284,788
availability during rainy season (m³)	238,502	245,663	253,033	260,621	268,439	276,488	284,788
land area that can be irrigated (supp.) in rainy seas.(du)	681	702	723	745	767	790	814
land area that can be irrigated (full) in dry seas. (du)	341	351	361	372	383	395	407
excess amounts of treated ww. In rainy season (m³)	119,251	122,832	126,516	130,310	134,220	138,244	142,394
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	170	175	181	186	192	197	203
Total land area (du)	511	526	542	558	575	592	610
land area of olives for ww. Irrigation (du)	80	80	80	80	90	90	90
land area of barely & fodders for ww. Irrigation (du)	431	446	462	478	485	502	520
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	406,188	406,188	406,188	406,188	406,188	406,188	406,188
Annual investment cost (TF) over 25 yrs ($)	356,890	356,890	356,890	356,890	356,890	356,890	356,890

Annual investment cost (AL) over 25 yrs ($)	337,143	337,143	337,143	337,143	337,143	337,143	337,143
Investment cost (AS) ($/m³)	0.64	0.62	0.60	0.58	0.57	0.55	0.53
Investment cost (TF) ($/m³)	0.56	0.54	0.53	0.51	0.50	0.48	0.47
Investment cost (AL) ($/m³)	0.53	0.51	0.50	0.49	0.47	0.46	0.44
O&M costs							
O&M costs (AS) ($)	163,924	166,860	169,845	172,884	175,977	179,124	182,331
O&M costs (TF) ($)	126,222	128,482	130,781	133,120	135,502	137,925	140,395
O&M costs (AL) ($)	66,128	67,312	68,516	69,742	70,990	72,259	73,553
O&M costs (Chlorine Disinfection) ($) 2010	11,454	11,554	11,656	11,762	11,870	11,982	12,097
O&M costs (Chlorine Disinfection) ($)	95,731	98,087	100,505	102,988	105,535	108,149	110,830
Storage O&M costs ($)	23,781	24,019	24,259	24,502	24,747	24,994	25,244
Conveyance O&M costs ($)	26,898	27,167	27,438	27,713	27,990	28,270	28,552
Surface irrigation costs ($)	155,356	156,910	158,479	160,064	161,664	163,281	164,914
Total annual O&M costs (AS) ($)	465,691	473,043	480,527	488,150	495,913	503,818	511,872
Total annual O&M costs (TF) ($)	427,988	434,665	441,463	448,387	455,439	462,620	469,936
Total annual O&M costs (AL) ($)	367,894	373,495	379,198	385,008	390,926	396,954	403,094
O&M costs (AS) ($/m³)	0.73	0.72	0.71	0.70	0.69	0.68	0.67
O&M costs (TF) ($/m³)	0.67	0.66	0.65	0.65	0.64	0.63	0.62
O&M costs (AL) ($/m³)	0.58	0.57	0.56	0.55	0.55	0.54	0.53
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.37	1.34	1.31	1.29	1.26	1.23	1.21
Total cost (TF) ($/m³)	1.23	1.21	1.18	1.16	1.13	1.11	1.09
Total cost (AL) ($/m³)	1.11	1.08	1.06	1.04	1.02	1.00	0.97
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.43	0.42	0.42	0.41	0.40	0.39	0.38
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	0.94	0.92	0.90	0.88	0.86	0.84	0.82
With TF ($/m³)	0.80	0.78	0.77	0.75	0.74	0.72	0.70
With AL ($/m³)	0.68	0.66	0.65	0.63	0.62	0.60	0.59
Benefits							
Economic Benefits ($)	238,502	245,663	253,033	260,621	268,439	276,488	284,788
Crop Production ($)	116,681	119,981	123,376	126,872	131,324	135,032	138,856

Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(Option 1 Continued)

Calculations (2031-2035)	2031	2032	2033	2034	2035
Total population (domestic+industrial)	26,788	27,592	28,420	29,272	30,150
Total population in 2035	30150	30150	30150	30150	30150
Total amount of ww. Generated each yr (m³)	782,210	805,686	829,864	854,742	880,380
Total amount of ww. Generated in 2035 (m³)	880,380	880,380	880,380	880,380	880,380
Total amounts of treated ww. For reuse /yr (m³)	586,657	604,265	622,398	641,057	660,285
availability during dry season (m³)	293,329	302,132	311,199	320,528	330,143
availability during rainy season (m³)	293,329	302,132	311,199	320,528	330,143
land area that can be irrigated (supp.) in rainy seas.(du)	838	863	889	916	943
land area that can be irrigated (full) in dry seas. (du)	419	432	445	458	472
excess amounts of treated ww. In rainy season (m³)	146,664	151,066	155,600	160,264	165,071
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	210	216	222	229	236
Total land area (du)	629	647	667	687	707
land area of olives for ww. Irrigation (du)	90	100	100	100	100
land area of barely & fodders for ww. Irrigation (du)	539	547	567	587	607
Investment Costs					
investment cost (AS) ($)	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0

Annual investment cost (AS) over 25 yrs ($)	406,188	406,188	406,188	406,188	406,188
Annual investment cost (TF) over 25 yrs ($)	356,890	356,890	356,890	356,890	356,890
Annual investment cost (AL) over 25 yrs ($)	337,143	337,143	337,143	337,143	337,143
Investment cost (AS) ($/m³)	0.52	0.50	0.49	0.48	0.46
Investment cost (TF) ($/m³)	0.46	0.44	0.43	0.42	0.41
Investment cost (AL) ($/m³)	0.43	0.42	0.41	0.39	0.38
O&M costs					
O&M costs (AS) ($)	185,593	188,915	192,296	195,735	199,236
O&M costs (TF) ($)	142,906	145,465	148,068	150,716	153,412
O&M costs (AL) ($)	74,869	76,209	77,573	78,960	80,373
O&M costs (Chlorine Disinfection) ($) 2010	12,216	12,338	12,464	12,594	12,727
O&M costs (Chlorine Disinfection) ($)	113,581	116,403	119,297	122,264	125,306
Storage O&M costs ($)	25,497	25,752	26,009	26,269	26,532
Conveyance O&M costs ($)	28,838	29,126	29,418	29,712	30,009
Surface irrigation costs ($)	166,563	168,229	169,911	171,610	173,326
Total annual O&M costs (AS) ($)	520,071	528,425	536,931	545,590	554,410
Total annual O&M costs (TF) ($)	477,385	484,975	492,703	500,571	508,585
Total annual O&M costs (AL) ($)	409,348	415,719	422,208	428,816	435,546
O&M costs (AS) ($/m³)	0.66	0.66	0.65	0.64	0.63
O&M costs (TF) ($/m³)	0.61	0.60	0.59	0.59	0.58
O&M costs (AL) ($/m³)	0.52	0.52	0.51	0.50	0.49
Total unit cost (Investment + O&M) ($/m³)					
Total cost (AS) ($/m³)	1.18	1.16	1.14	1.11	1.09
Total cost (TF) ($/m³)	1.07	1.04	1.02	1.00	0.98
Total cost (AL) ($/m³)	0.95	0.93	0.92	0.90	0.88
Tariffs					
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.38	0.37	0.36	0.36	0.35
Tariffs to paid by households (might need subsidy by municipalities)					
With AS ($/m³)	0.81	0.79	0.77	0.76	0.74
With TF ($/m³)	0.69	0.68	0.66	0.65	0.63
With AL ($/m³)	0.58	0.57	0.55	0.54	0.53
Benefits					

Economic Benefits ($)	293,329	302,132	311,199	320,528	330,143
Crop Production ($)	142,791	147,697	151,874	156,172	160,601
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74

CBA Calculations for Option 2

Calculations (2010-2016)	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**
Total population (domestic+industrial)	9,600	9,888	10,185	10,490	10,805	11,129	11,463
Total population in 2035	20,100	20,100	20,100	20,100	20,100	20,100	20,100
Total amount of ww. Generated each yr (m³)	280,320	288,730	297,402	306,308	315,506	324,967	334,720
Total amount of ww. Generated in 2035 (m³)	586,920	586,920	586,920	586,920	586,920	586,920	586,920
Total amounts of treated ww. For reuse /yr (m³)	210,240	216,547	223,052	229,731	236,630	243,725	251,040
availability during dry season (m³)	105,120	108,274	111,526	114,866	118,315	121,863	125,520
availability during rainy season (m³)	105,120	108,274	111,526	114,866	118,315	121,863	125,520
land area that can be irrigated (supp.) in rainy seas.(du)	300	309	319	328	338	348	359
land area that can be irrigated (full) in dry seas. (du)	150	155	159	164	169	174	179
excess amounts of treated ww. In rainy season (m³)	52,560	54,137	55,763	57,433	59,157	60,931	62,760
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	75	77	80	82	85	87	90
Total land area (du)	225	232	239	246	254	261	269
land area of olives for ww. Irrigation (du)	60	60	60	60	60	60	70
land area of barely & fodders for ww. Irrigation (du)	165	172	179	186	194	201	199
Investment Costs							
investment cost (AS) ($)	4,579,451	0	0	0	0	0	0
investment cost (TF) ($)	3,956,303	0	0	0	0	0	0
investment cost (AL) ($)	3,706,696	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	103,821	0	0	0	0	0	0
Storage investment cost ($)	275,852	0	0	0	0	0	0
Conveyance investment cost ($)	234000	0	0	0	0	0	0
Total investment cost (AS) ($)	5,193,124	0	0	0	0	0	0

Total investment cost (TF) ($)	4,569,976	0	0	0	0	0	0
Total investment cost (AL) ($)	4,320,369	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	298,230	298,230	298,230	298,230	298,230	298,230	298,230
Annual investment cost (TF) over 25 yrs ($)	262,444	262,444	262,444	262,444	262,444	262,444	262,444
Annual investment cost (AL) over 25 yrs ($)	248,110	248,110	248,110	248,110	248,110	248,110	248,110
Investment cost (AS) ($/m³)	1.06	1.03	1.00	0.97	0.95	0.92	0.89
Investment cost (TF) ($/m³)	0.94	0.91	0.88	0.86	0.83	0.81	0.78
Investment cost (AL) ($/m³)	0.89	0.86	0.83	0.81	0.79	0.76	0.74
O&M costs							
O&M costs (AS) ($)	100,267	102,061	103,890	105,745	107,639	109,565	111,526
O&M costs (TF) ($)	77,206	78,587	79,995	81,424	82,882	84,365	85,875
O&M costs (AL) ($)	40,448	41,172	41,910	42,658	43,422	44,199	44,990
O&M costs (Chlorine Disinfection) ($) 2010	9,596	9,640	9,686	9,732	9,780	9,830	9,881
O&M costs (Chlorine Disinfection) ($)	14,951	63,753	65,237	66,761	68,329	69,940	78,742
Storage O&M costs ($)	13,793	13,931	14,070	14,211	14,353	14,496	14,641
Conveyance O&M costs ($)	23,400	23,634	23,870	24,109	24,350	24,594	24,840
Surface irrigation costs ($)	90,103	91,004	91,914	92,833	93,761	94,699	95,646
Total annual O&M costs (AS) ($)	242,514	294,383	298,981	303,659	308,433	313,293	325,395
Total annual O&M costs (TF) ($)	219,452	270,909	275,086	279,338	283,676	288,094	299,744
Total annual O&M costs (AL) ($)	182,695	233,493	237,001	240,572	244,215	247,928	258,859
O&M costs (AS) ($/m³)	0.87	1.02	1.01	0.99	0.98	0.96	0.97
O&M costs (TF) ($/m³)	0.78	0.94	0.92	0.91	0.90	0.89	0.90
O&M costs (AL) ($/m³)	0.65	0.81	0.80	0.79	0.77	0.76	0.77
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.93	2.05	2.01	1.96	1.92	1.88	1.86
Total cost (TF) ($/m³)	1.72	1.85	1.81	1.77	1.73	1.69	1.68
Total cost (AL) ($/m³)	1.54	1.67	1.63	1.60	1.56	1.53	1.51
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.61	0.59	0.58	0.57	0.56	0.55	0.54
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.32	1.46	1.43	1.39	1.36	1.33	1.32
With TF ($/m³)	1.11	1.25	1.23	1.20	1.17	1.15	1.14
With AL ($/m³)	0.93	1.07	1.05	1.02	1.00	0.98	0.98

Benefits							
Economic Benefits ($)	105,120	108,274	111,526	114,866	118,315	121,863	125,520
Crop Production ($)	53,530	54,983	56,482	58,020	59,609	61,244	63,779
Total Benefit to farmers ($/m³)	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Option 2 Continued

Calculations (2017-2023)	**2017**	**2018**	**2019**	**2020**	**2012**	**2022**	**2023**
Total population (domestic+industrial)	11,807	12,161	12,526	12,902	13,289	13,687	14,098
Total population in 2035	20,100	20,100	20,100	20,100	20,100	20,100	20,100
Total amount of ww. Generated each yr (m³)	344,764	355,101	365,759	376,738	388,039	399,660	411,662
Total amount of ww. Generated in 2035 (m³)	586,920	586,920	586,920	586,920	586,920	586,920	586,920
Total amounts of treated ww. For reuse /yr (m³)	258,573	266,326	274,319	282,554	291,029	299,745	308,746
availability during dry season (m³)	129,287	133,163	137,160	141,277	145,515	149,873	154,373
availability during rainy season (m³)	129,287	133,163	137,160	141,277	145,515	149,873	154,373
land area that can be irrigated (supp.) in rainy seas.(du)	369	380	392	404	416	428	441
land area that can be irrigated (full) in dry seas. (du)	185	190	196	202	208	214	221
excess amounts of treated ww. In rainy season (m³)	64,643	66,581	68,580	70,638	72,757	74,936	77,187
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	92	95	98	101	104	107	110
Total land area (du)	277	285	294	303	312	321	331
land area of olives for ww. Irrigation (du)	70	70	70	70	70	70	80
land area of barely & fodders for ww. Irrigation (du)	207	215	224	233	242	251	251
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0

Annual investment cost (AS) over 25 yrs ($)	298,230	298,230	298,230	298,230	298,230	298,230	298,230
Annual investment cost (TF) over 25 yrs ($)	262,444	262,444	262,444	262,444	262,444	262,444	262,444
Annual investment cost (AL) over 25 yrs ($)	248,110	248,110	248,110	248,110	248,110	248,110	248,110
Investment cost (AS) ($/m³)	0.87	0.84	0.82	0.79	0.77	0.75	0.72
Investment cost (TF) ($/m³)	0.76	0.74	0.72	0.70	0.68	0.66	0.64
Investment cost (AL) ($/m³)	0.72	0.70	0.68	0.66	0.64	0.62	0.60
O&M costs							
O&M costs (AS) ($)	113,522	115,552	117,621	119,727	121,869	124,046	126,267
O&M costs (TF) ($)	87,412	88,975	90,568	92,190	93,839	95,515	97,226
O&M costs (AL) ($)	45,795	46,614	47,449	48,298	49,162	50,041	50,937
O&M costs (Chlorine Disinfection) ($) 2010	9,933	9,988	10,043	10,101	10,160	10,220	10,283
O&M costs (Chlorine Disinfection) ($)	80,698	82,710	84,778	86,904	89,024	91,201	93,436
Storage O&M costs ($)	14,788	14,935	15,085	15,236	15,388	15,542	15,697
Conveyance O&M costs ($)	25,088	25,339	25,592	25,848	26,107	26,368	26,631
Surface irrigation costs ($)	96,602	97,568	98,544	99,530	100,525	101,530	102,545
Total annual O&M costs (AS) ($)	330,698	336,105	341,620	347,244	352,912	358,686	364,577
Total annual O&M costs (TF) ($)	304,588	309,528	314,567	319,707	324,882	330,156	335,536
Total annual O&M costs (AL) ($)	262,971	267,167	271,448	275,816	280,206	284,681	289,247
O&M costs (AS) ($/m³)	0.96	0.95	0.93	0.92	0.91	0.90	0.89
O&M costs (TF) ($/m³)	0.88	0.87	0.86	0.85	0.84	0.83	0.82
O&M costs (AL) ($/m³)	0.76	0.75	0.74	0.73	0.72	0.71	0.70
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.82	1.79	1.75	1.71	1.68	1.64	1.61
Total cost (TF) ($/m³)	1.64	1.61	1.58	1.55	1.51	1.48	1.45
Total cost (AL) ($/m³)	1.48	1.45	1.42	1.39	1.36	1.33	1.31
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.53	0.52	0.51	0.50	0.49	0.48	0.47
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.30	1.27	1.24	1.22	1.19	1.17	1.14
With TF ($/m³)	1.12	1.09	1.07	1.05	1.03	1.00	0.98
With AL ($/m³)	0.95	0.93	0.91	0.89	0.87	0.85	0.84
Benefits							
Economic Benefits ($)	129,287	133,163	137,160	141,277	145,515	149,873	154,373

Crop Production ($)	65,514	67,300	69,141	71,038	72,991	74,998	77,922
Total Benefit to farmers ($/m³)	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Option 2 Continued

Caculations (2024-2030)	**2024**	**2025**	**2026**	**2027**	**2028**	**2029**	**2030**
Total population (domestic+industrial)	14,521	14,956	15,405	15,867	16,343	16,834	17,339
Total population in 2035	20,100	20,100	20,100	20,100	20,100	20,100	20,100
Total amount of ww. Generated each yr (m³)	424,013	436,715	449,826	463,316	477,216	491,553	506,299
Total amount of ww. Generated in 2035 (m³)	586,920	586,920	586,920	586,920	586,920	586,920	586,920
Total amounts of treated ww. For reuse /yr (m³)	318,010	327,536	337,370	347,487	357,912	368,665	379,724
availability during dry season (m³)	159,005	163,768	168,685	173,744	178,956	184,332	189,862
availability during rainy season (m³)	159,005	163,768	168,685	173,744	178,956	184,332	189,862
land area that can be irrigated (supp.) in rainy seas.(du)	454	468	482	496	511	527	542
land area that can be irrigated (full) in dry seas. (du)	227	234	241	248	256	263	271
excess amounts of treated ww. In rainy season (m³)	79,502	81,884	84,342	86,872	89,478	92,166	94,931
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	114	117	120	124	128	132	136
Total land area (du)	341	351	361	372	383	395	407
land area of olives for ww. Irrigation (du)	80	80	80	80	90	90	90
land area of barely & fodders for ww. Irrigation (du)	261	271	281	292	293	305	317
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	298,230	298,230	298,230	298,230	298,230	298,230	298,230
Annual investment cost (TF) over 25 yrs ($)	262,444	262,444	262,444	262,444	262,444	262,444	262,444
Annual investment cost (AL) over 25 yrs ($)	248,110	248,110	248,110	248,110	248,110	248,110	248,110

Investment cost (AS) ($/m³)	0.70	0.68	0.66	0.64	0.62	0.61	0.59
Investment cost (TF) ($/m³)	0.62	0.60	0.58	0.57	0.55	0.53	0.52
Investment cost (AL) ($/m³)	0.59	0.57	0.55	0.54	0.52	0.50	0.49
O&M costs							
O&M costs (AS) ($)	128,527	130,823	133,166	135,548	137,973	140,446	142,959
O&M costs (TF) ($)	98,966	100,734	102,538	104,372	106,240	108,143	110,078
O&M costs (AL) ($)	51,848	52,775	53,720	54,681	55,659	56,656	57,670
O&M costs (Chlorine Disinfection) ($) 2010	10,348	10,414	10,483	10,553	10,626	10,700	10,777
O&M costs (Chlorine Disinfection) ($)	95,731	98,087	100,505	102,988	105,535	108,149	110,830
Storage O&M costs ($)	15,854	16,013	16,173	16,335	16,498	16,663	16,830
Conveyance O&M costs ($)	26,898	27,167	27,438	27,713	27,990	28,270	28,552
Surface irrigation costs ($)	103,571	104,607	105,653	106,709	107,776	108,854	109,943
Total annual O&M costs (AS) ($)	370,581	376,697	382,935	389,293	395,773	402,382	409,113
Total annual O&M costs (TF) ($)	341,020	346,607	352,307	358,117	364,039	370,079	376,233
Total annual O&M costs (AL) ($)	293,902	298,648	303,489	308,425	313,458	318,592	323,825
O&M costs (AS) ($/m³)	0.87	0.86	0.85	0.84	0.83	0.82	0.81
O&M costs (TF) ($/m³)	0.80	0.79	0.78	0.77	0.76	0.75	0.74
O&M costs (AL) ($/m³)	0.69	0.68	0.67	0.67	0.66	0.65	0.64
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.58	1.55	1.51	1.48	1.45	1.43	1.40
Total cost (TF) ($/m³)	1.42	1.39	1.37	1.34	1.31	1.29	1.26
Total cost (AL) ($/m³)	1.28	1.25	1.23	1.20	1.18	1.15	1.13
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.46	0.45	0.44	0.43	0.43	0.42	0.41
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.12	1.09	1.07	1.05	1.03	1.01	0.99
With TF ($/m³)	0.96	0.94	0.92	0.91	0.89	0.87	0.85
With AL ($/m³)	0.82	0.80	0.78	0.77	0.75	0.74	0.72
Benefits							
Economic Benefits ($)	159,005	163,768	168,685	173,744	178,956	184,332	189,862
Crop Production ($)	80,056	82,250	84,515	86,846	90,098	92,575	95,122
Total Benefit to farmers ($/m³)	0.75	0.75	0.75	0.75	0.75	0.75	0.75

Option 2 Continued

Caculations (2031-2035)	**2031**	**2032**	**2033**	**2034**	**2035**
Total population (domestic+industrial)	17,859	18,395	18,946	19,515	20,100
Total population in 2035	20,100	20,100	20,100	20,100	20,100
Total amount of ww. Generated each yr (m^3)	521,483	537,134	553,223	569,838	586,920
Total amount of ww. Generated in 2035 (m^3)	586,920	586,920	586,920	586,920	586,920
Total amounts of treated ww. For reuse /yr (m^3)	391,112	402,851	414,917	427,379	440,190
availability during dry season (m^3)	195,556	201,425	207,459	213,689	220,095
availability during rainy season (m^3)	195,556	201,425	207,459	213,689	220,095
land area that can be irrigated (supp.) in rainy seas.(du)	559	576	593	611	629
land area that can be irrigated (full) in dry seas. (du)	279	288	296	305	314
excess amounts of treated ww. In rainy season (m^3)	97,778	100,713	103,729	106,845	110,048
excess amounts of treated ww. In dry season (m^3)	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	140	144	148	153	157
Total land area (du)	419	432	445	458	472
land area of olives for ww. Irrigation (du)	90	100	100	100	100
land area of barely & fodders for ww. Irrigation (du)	329	332	345	358	372
Investment Costs					
investment cost (AS) ($)	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	298,230	298,230	298,230	298,230	298,230
Annual investment cost (TF) over 25 yrs ($)	262,444	262,444	262,444	262,444	262,444
Annual investment cost (AL) over 25 yrs ($)	248,110	248,110	248,110	248,110	248,110
Investment cost (AS) ($/$m^3$)	0.57	0.56	0.54	0.52	0.51
Investment cost (TF) ($/$m^3$)	0.50	0.49	0.47	0.46	0.45

Investment cost (AL) ($/m³)	0.48	0.46	0.45	0.44	0.42
O&M costs					
O&M costs (AS) ($)	145,516	148,121	150,767	153,468	156,212
O&M costs (TF) ($)	112,047	114,053	116,091	118,170	120,283
O&M costs (AL) ($)	58,702	59,753	60,820	61,910	63,017
O&M costs (Chlorine Disinfection) ($) 2010	10,857	10,938	11,022	11,109	11,198
O&M costs (Chlorine Disinfection) ($)	113,581	116,403	119,297	122,264	125,306
Storage O&M costs ($)	16,998	17,168	17,340	17,513	17,688
Conveyance O&M costs ($)	28,838	29,126	29,418	29,712	30,009
Surface irrigation costs ($)	111,042	112,152	113,274	114,407	115,551
Total annual O&M costs (AS) ($)	415,975	422,971	430,095	437,363	444,766
Total annual O&M costs (TF) ($)	382,506	388,903	395,419	402,066	408,837
Total annual O&M costs (AL) ($)	329,161	334,602	340,148	345,805	351,570
O&M costs (AS) ($/m³)	0.80	0.79	0.78	0.77	0.76
O&M costs (TF) ($/m³)	0.73	0.72	0.71	0.71	0.70
O&M costs (AL) ($/m³)	0.63	0.62	0.61	0.61	0.60
Total unit cost (Investment + O&M) ($/m³)					
Total cost (AS) ($/m³)	1.37	1.34	1.32	1.29	1.27
Total cost (TF) ($/m³)	1.24	1.21	1.19	1.17	1.14
Total cost (AL) ($/m³)	1.11	1.08	1.06	1.04	1.02
Tariffs					
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.40	0.39	0.39	0.38	0.37
Tariffs to paid by households (might need subsidy by municipalities)					
With AS ($/m³)	0.97	0.95	0.93	0.91	0.90
With TF ($/m³)	0.84	0.82	0.80	0.79	0.77
With AL ($/m³)	0.71	0.69	0.68	0.66	0.65
Benefits					
Economic Benefits ($)	195,556	201,425	207,459	213,689	220,095
Crop Production ($)	97,745	101,299	104,079	106,950	109,901
Total Benefit to farmers ($/m³)	0.75	0.75	0.75	0.75	0.75

CBA Calculations for option3

Calculations (2010-2016)	2010	2011	2012	2013	2014	2015	2016
Total population (domestic+industrial)	17,900	18,437	18,990	19,560	20,147	20,751	21,374
Total population in 2035	37,479	37,479	37,479	37,479	37,479	37,479	37,479
Total amount of ww. Generated each yr (m³)	522,680	538,360	554,508	571,152	588,292	605,929	624,121
Total amount of ww. Generated in 2035 (m³)	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387
Total amounts of treated ww. For reuse /yr (m³)	392,010	403,770	415,881	428,364	441,219	454,447	468,091
availability during dry season (m³)	196,005	201,885	207,941	214,182	220,610	227,223	234,045
availability during rainy season (m³)	196,005	201,885	207,941	214,182	220,610	227,223	234,045
land area that can be irrigated (supp.) in rainy seas.(du)	560	577	594	612	630	649	669
land area that can be irrigated (full) in dry seas. (du)	280	288	297	306	315	325	334
excess amounts of treated ww. In rainy season (m³)	98,003	100,943	103,970	107,091	110,305	113,612	117,023
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	140	144	149	153	158	162	167
Total land area (du)	420	433	446	459	473	487	502
land area of olives for ww. Irrigation (du)	60	60	60	60	60	60	70
land area of barely & fodders for ww. Irrigation (du)	360	373	386	399	413	427	432
Investment Costs							
investment cost (AS) ($)	7,491,574	0	0	0	0	0	0
investment cost (TF) ($)	6,472,158	0	0	0	0	0	0
investment cost (AL) ($)	6,063,824	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	126,135	0	0	0	0	0	0
Storage investment cost ($)	514,362	0	0	0	0	0	0
Conveyance investment cost ($)	234000	0	0	0	0	0	0
Total investment cost (AS) ($)	8,366,071	0	0	0	0	0	0
Total investment cost (TF) ($)	7,346,655	0	0	0	0	0	0
Total investment cost (AL) ($)	6,938,321	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	480,446	480,446	480,446	480,446	480,446	480,446	480,446
Annual investment cost (TF) over 25 yrs ($)	421,903	421,903	421,903	421,903	421,903	421,903	421,903
Annual investment cost (AL) over 25 yrs ($)	398,453	398,453	398,453	398,453	398,453	398,453	398,453
Investment cost (AS) ($/m³)	0.92	0.89	0.87	0.84	0.82	0.79	0.77

Investment cost (TF) ($/m³)	0.81	0.78	0.76	0.74	0.72	0.70	0.68
Investment cost (AL) ($/m³)	0.76	0.74	0.72	0.70	0.68	0.66	0.64
O&M costs							
O&M costs (AS) ($)	145,716	148,324	150,977	153,680	156,431	159,228	162,079
O&M costs (TF) ($)	112,202	114,209	116,253	118,334	120,452	122,606	124,801
O&M costs (AL) ($)	58,783	59,834	60,905	61,995	63,105	64,233	65,384
O&M costs (Chlorine Disinfection) ($) 2010	10,863	10,945	11,029	11,116	11,205	11,297	11,392
O&M costs (Chlorine Disinfection) ($)	16,924	63,753	65,237	66,761	68,329	69,940	78,742
Storage O&M costs ($)	25,718	25,975	26,235	26,497	26,762	27,030	27,300
Conveyance O&M costs ($)	23,400	23,634	23,870	24,109	24,350	24,594	24,840
Surface irrigation costs ($)	168,004	169,684	171,381	173,095	174,826	176,574	178,340
Total annual O&M costs (AS) ($)	379,763	431,370	437,701	444,143	450,698	457,366	471,301
Total annual O&M costs (TF) ($)	346,248	397,256	402,976	408,796	414,719	420,744	434,023
Total annual O&M costs (AL) ($)	292,829	342,881	347,628	352,458	357,372	362,371	374,605
O&M costs (AS) ($/m³)	0.73	0.80	0.79	0.78	0.77	0.75	0.76
O&M costs (TF) ($/m³)	0.66	0.74	0.73	0.72	0.70	0.69	0.70
O&M costs (AL) ($/m³)	0.56	0.64	0.63	0.62	0.61	0.60	0.60
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.65	1.69	1.66	1.62	1.58	1.55	1.52
Total cost (TF) ($/m³)	1.47	1.52	1.49	1.45	1.42	1.39	1.37
Total cost (AL) ($/m³)	1.32	1.38	1.35	1.31	1.28	1.26	1.24
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.55	0.54	0.53	0.52	0.51	0.50	0.49
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.09	1.15	1.12	1.10	1.07	1.05	1.03
With TF ($/m³)	0.92	0.98	0.96	0.93	0.91	0.89	0.88
With AL ($/m³)	0.77	0.83	0.81	0.79	0.77	0.75	0.75
Benefits							
Economic Benefits ($)	196,005	201,885	207,941	214,182	220,610	227,223	234,045
Crop Production ($)	95,402	98,111	100,901	103,777	106,738	109,785	113,778
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(Option 3 continued)

Caculations (2017-2023)	**2017**	**2018**	**2019**	**2020**	**2021**	**2022**	**2023**
Total population (domestic+industrial)	22,015	22,675	23,355	24,056	24,778	25,521	26,287
Total population in 2035	37,479	37,479	37,479	37,479	37,479	37,479	37,479
Total amount of ww. Generated each yr (m³)	642,838	662,110	681,966	702,435	723,518	745,213	767,580
Total amount of ww. Generated in 2035 (m³)	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387
Total amounts of treated ww. For reuse /yr (m³)	482,129	496,583	511,475	526,826	542,638	558,910	575,685
availability during dry season (m³)	241,064	248,291	255,737	263,413	271,319	279,455	287,843
availability during rainy season (m³)	241,064	248,291	255,737	263,413	271,319	279,455	287,843
land area that can be irrigated (supp.) in rainy seas.(du)	689	709	731	753	775	798	822
land area that can be irrigated (full) in dry seas. (du)	344	355	365	376	388	399	411
excess amounts of treated ww. In rainy season (m³)	120,532	124,146	127,869	131,707	135,660	139,727	143,921
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	172	177	183	188	194	200	206
Total land area (du)	517	532	548	564	581	599	617
land area of olives for ww. Irrigation (du)	70	70	70	70	70	70	80
land area of barely & fodders for ww. Irrigation (du)	447	462	478	494	511	529	537
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	480,446	480,446	480,446	480,446	480,446	480,446	480,446
Annual investment cost (TF) over 25 yrs ($)	421,903	421,903	421,903	421,903	421,903	421,903	421,903
Annual investment cost (AL) over 25 yrs ($)	398,453	398,453	398,453	398,453	398,453	398,453	398,453

Investment cost (AS) ($/m³)	0.75	0.73	0.70	0.68	0.66	0.64	0.63
Investment cost (TF) ($/m³)	0.66	0.64	0.62	0.60	0.58	0.57	0.55
Investment cost (AL) ($/m³)	0.62	0.60	0.58	0.57	0.55	0.53	0.52
O&M costs							
O&M costs (AS) ($)	164,979	167,929	170,932	173,992	177,107	180,275	183,502
O&M costs (TF) ($)	127,034	129,305	131,618	133,974	136,373	138,812	141,297
O&M costs (AL) ($)	66,553	67,743	68,955	70,189	71,446	72,724	74,025
O&M costs (Chlorine Disinfection) ($) 2010	11,490	11,590	11,694	11,800	11,910	12,023	12,140
O&M costs (Chlorine Disinfection) ($)	80,698	82,710	84,778	86,904	89,024	91,201	93,436
Storage O&M costs ($)	27,573	27,849	28,127	28,409	28,693	28,980	29,270
Conveyance O&M costs ($)	25,088	25,339	25,592	25,848	26,107	26,368	26,631
Surface irrigation costs ($)	180,123	181,925	183,744	185,581	187,437	189,311	191,205
Total annual O&M costs (AS) ($)	478,461	485,751	493,174	500,735	508,368	516,135	524,044
Total annual O&M costs (TF) ($)	440,516	447,128	453,860	460,717	467,633	474,672	481,838
Total annual O&M costs (AL) ($)	380,036	385,566	391,196	396,931	402,706	408,584	414,567
O&M costs (AS) ($/m³)	0.74	0.73	0.72	0.71	0.70	0.69	0.68
O&M costs (TF) ($/m³)	0.69	0.68	0.67	0.66	0.65	0.64	0.63
O&M costs (AL) ($/m³)	0.59	0.58	0.57	0.57	0.56	0.55	0.54
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.49	1.46	1.43	1.40	1.37	1.34	1.31
Total cost (TF) ($/m³)	1.34	1.31	1.28	1.26	1.23	1.20	1.18
Total cost (AL) ($/m³)	1.21	1.18	1.16	1.13	1.11	1.08	1.06
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.48	0.47	0.46	0.46	0.45	0.44	0.43
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.01	0.99	0.96	0.94	0.92	0.90	0.88
With TF ($/m³)	0.86	0.84	0.82	0.80	0.78	0.77	0.75
With AL ($/m³)	0.73	0.71	0.69	0.68	0.66	0.65	0.63
Benefits							
Economic Benefits ($)	241,064	248,291	255,737	263,413	271,319	279,455	287,843
Crop Production ($)	117,012	120,341	123,772	127,308	130,951	134,699	139,413
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(Option3 continued)

Calculations (2024-2030)	2024	2025	2026	2027	2028	2029	2030
Total population (domestic+industrial)	27,075	27,888	28,724	29,586	30,474	31,388	32,329
Total population in 2035	37,479	37,479	37,479	37,479	37,479	37,479	37,479
Total amount of ww. Generated each yr (m^3)	790,590	814,330	838,741	863,911	889,841	916,530	944,007
Total amount of ww. Generated in 2035 (m^3)	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387
Total amounts of treated ww. For reuse /yr (m^3)	592,943	610,747	629,056	647,933	667,381	687,397	708,005
availability during dry season (m^3)	296,471	305,374	314,528	323,967	333,690	343,699	354,003
availability during rainy season (m^3)	296,471	305,374	314,528	323,967	333,690	343,699	354,003
land area that can be irrigated (supp.) in rainy seas.(du)	847	872	899	926	953	982	1,011
land area that can be irrigated (full) in dry seas. (du)	424	436	449	463	477	491	506
excess amounts of treated ww. In rainy season (m^3)	148,236	152,687	157,264	161,983	166,845	171,849	177,001
excess amounts of treated ww. In dry season (m^3)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	212	218	225	231	238	245	253
Total land area (du)	635	654	674	694	715	736	759
land area of olives for ww. Irrigation (du)	80	80	80	80	90	90	90
land area of barely & fodders for ww. Irrigation (du)	555	574	594	614	625	646	669
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	480,446	480,446	480,446	480,446	480,446	480,446	480,446

Annual investment cost (TF) over 25 yrs ($)	421,903	421,903	421,903	421,903	421,903	421,903	421,903
Annual investment cost (AL) over 25 yrs ($)	398,453	398,453	398,453	398,453	398,453	398,453	398,453
Investment cost (AS) ($/m³)	0.61	0.59	0.57	0.56	0.54	0.52	0.51
Investment cost (TF) ($/m³)	0.53	0.52	0.50	0.49	0.47	0.46	0.45
Investment cost (AL) ($/m³)	0.50	0.49	0.48	0.46	0.45	0.43	0.42
O&M costs							
O&M costs (AS) ($)	186,783	190,128	193,528	196,992	200,518	204,105	207,755
O&M costs (TF) ($)	143,823	146,399	149,017	151,684	154,399	157,161	159,972
O&M costs (AL) ($)	75,349	76,699	78,070	79,467	80,890	82,337	83,809
O&M costs (Chlorine Disinfection) ($) 2010	12,260	12,383	12,510	12,641	12,776	12,915	13,058
O&M costs (Chlorine Disinfection) ($)	95,731	98,087	100,505	102,988	105,535	108,149	110,830
Storage O&M costs ($)	29,562	29,858	30,156	30,458	30,763	31,070	31,381
Conveyance O&M costs ($)	26,898	27,167	27,438	27,713	27,990	28,270	28,552
Surface irrigation costs ($)	193,117	195,048	196,998	198,968	200,958	202,967	204,997
Total annual O&M costs (AS) ($)	532,091	540,288	548,626	557,119	565,764	574,562	583,516
Total annual O&M costs (TF) ($)	489,131	496,558	504,115	511,811	519,645	527,618	535,732
Total annual O&M costs (AL) ($)	420,657	426,858	433,168	439,594	446,135	452,793	459,570
O&M costs (AS) ($/m³)	0.67	0.66	0.65	0.64	0.64	0.63	0.62
O&M costs (TF) ($/m³)	0.62	0.61	0.60	0.59	0.58	0.58	0.57
O&M costs (AL) ($/m³)	0.53	0.52	0.52	0.51	0.50	0.49	0.49
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.28	1.25	1.23	1.20	1.18	1.15	1.13
Total cost (TF) ($/m³)	1.15	1.13	1.10	1.08	1.06	1.04	1.01
Total cost (AL) ($/m³)	1.04	1.01	0.99	0.97	0.95	0.93	0.91
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.42	0.41	0.40	0.40	0.39	0.38	0.37
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	0.86	0.84	0.82	0.80	0.79	0.77	0.75
With TF ($/m³)	0.73	0.72	0.70	0.68	0.67	0.65	0.64
With AL ($/m³)	0.62	0.60	0.59	0.57	0.56	0.55	0.53
Benefits							
Economic Benefits ($)	296,471	305,374	314,528	323,967	333,690	343,699	354,003

Crop Production ($)	143,389	147,490	151,707	156,056	161,386	165,997	170,744
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(Option 3 continued)

Calculations (2031-2035)	2031	2032	2033	2034	2035
Total population (domestic+industrial)	33,299	34,298	35,327	36,387	37,479
Total population in 2035	37,479	37,479	37,479	37,479	37,479
Total amount of ww. Generated each yr (m³)	972,331	1,001,502	1,031,548	1,062,500	1,094,387
Total amount of ww. Generated in 2035 (m³)	1,094,387	1,094,387	1,094,387	1,094,387	1,094,387
Total amounts of treated ww. For reuse /yr (m³)	729,248	751,126	773,661	796,875	820,790
availability during dry season (m³)	364,624	375,563	386,831	398,438	410,395
availability during rainy season (m³)	364,624	375,563	386,831	398,438	410,395
land area that can be irrigated (supp.) in rainy seas.(du)	1,042	1,073	1,105	1,138	1,173
land area that can be irrigated (full) in dry seas. (du)	521	537	553	569	586
excess amounts of treated ww. In rainy season (m³)	182,312	187,782	193,415	199,219	205,198
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	260	268	276	285	293
Total land area (du)	781	805	829	854	879
land area of olives for ww. Irrigation (du)	90	100	100	100	100
land area of barely & fodders for ww. Irrigation (du)	691	705	729	754	779
Investment Costs					
investment cost (AS) ($)	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0

Annual investment cost (AS) over 25 yrs ($)	480,446	480,446	480,446	480,446	480,446
Annual investment cost (TF) over 25 yrs ($)	421,903	421,903	421,903	421,903	421,903
Annual investment cost (AL) over 25 yrs ($)	398,453	398,453	398,453	398,453	398,453
Investment cost (AS) ($/m³)	0.49	0.48	0.47	0.45	0.44
Investment cost (TF) ($/m³)	0.43	0.42	0.41	0.40	0.39
Investment cost (AL) ($/m³)	0.41	0.40	0.39	0.38	0.36
O&M costs					
O&M costs (AS) ($)	211,473	215,257	219,109	223,030	227,023
O&M costs (TF) ($)	162,834	165,748	168,714	171,734	174,808
O&M costs (AL) ($)	85,309	86,836	88,390	89,971	91,582
O&M costs (Chlorine Disinfection) ($) 2010	13,205	13,357	13,513	13,674	13,839
O&M costs (Chlorine Disinfection) ($)	113,581	116,403	119,297	122,264	125,306
Storage O&M costs ($)	31,695	32,012	32,332	32,655	32,982
Conveyance O&M costs ($)	28,838	29,126	29,418	29,712	30,009
Surface irrigation costs ($)	207,047	209,118	211,209	213,321	215,454
Total annual O&M costs (AS) ($)	592,634	601,916	611,364	620,982	630,773
Total annual O&M costs (TF) ($)	543,995	552,407	560,969	569,685	578,558
Total annual O&M costs (AL) ($)	466,470	473,494	480,645	487,923	495,333
O&M costs (AS) ($/m³)	0.61	0.60	0.59	0.58	0.58
O&M costs (TF) ($/m³)	0.56	0.55	0.54	0.54	0.53
O&M costs (AL) ($/m³)	0.48	0.47	0.47	0.46	0.45
Total unit cost (Investment + O&M) ($/m³)					
Total cost (AS) ($/m³)	1.10	1.08	1.06	1.04	1.02
Total cost (TF) ($/m³)	0.99	0.97	0.95	0.93	0.91
Total cost (AL) ($/m³)	0.89	0.87	0.85	0.83	0.82
Tariffs					
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.37	0.36	0.35	0.35	0.34
Tariffs to paid by households (might need subsidy by municipalities)					
With AS ($/m³)	0.74	0.72	0.71	0.69	0.68
With TF ($/m³)	0.63	0.61	0.60	0.59	0.57
With AL ($/m³)	0.52	0.51	0.50	0.49	0.48
Benefits					

Economic Benefits ($)	364,624	375,563	386,831	398,438	410,395
Crop Production ($)	175,638	181,527	186,718	192,066	197,575
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74

CBA Calculations for option4

Calculation (2010-2016)	2010	2011	2012	2013	2014	2015	2016
Total population (domestic+industrial)	24,000	24,720	25,462	26,225	27,012	27,823	28,657
Total population in 2035	50,251	50,251	50,251	50,251	50,251	50,251	50,251
Total amount of ww. Generated each yr (m³)	700,800	721,824	743,490	765,770	788,750	812,432	836,784
Total amount of ww. Generated in 2035 (m³)	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329
Total amounts of treated ww. For reuse /yr (m³)	525,600	541,368	557,618	574,328	591,563	609,324	627,588
availability during dry season (m³)	262,800	270,684	278,809	287,164	295,781	304,662	313,794
availability during rainy season (m³)	262,800	270,684	278,809	287,164	295,781	304,662	313,794
land area that can be irrigated (supp.) in rainy seas.(du)	751	773	797	820	845	870	897
land area that can be irrigated (full) in dry seas. (du)	375	387	398	410	423	435	448
excess amounts of treated ww. In rainy season (m³)	131,400	135,342	139,404	143,582	147,891	152,331	156,897
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	188	193	199	205	211	218	224
Total land area. (du)	563	580	597	615	634	653	672
land area of olives for ww. Irrigation (du)	60	60	60	60	60	60	70
land area of barely & fodders for ww. Irrigation (du)	503	520	537	555	574	593	602
Investment Costs							
investment cost (AS) ($)	9,444,654	0	0	0	0	0	0
investment cost (TF) ($)	8,159,473	0	0	0	0	0	0
investment cost (AL) ($)	7,644,684	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	142,483	0	0	0	0	0	0
Storage investment cost ($)	689,645	0	0	0	0	0	0

Conveyance investment cost ($)	234000	0	0	0	0	0	0
Pump investment costs ($)	15600	0	0	0	0	0	0
Total investment cost (AS) ($)	10,526,382	0	0	0	0	0	0
Total investment cost (TF) ($)	9,241,201	0	0	0	0	0	0
Total investment cost (AL) ($)	8,726,412	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	604,508	604,508	604,508	604,508	604,508	604,508	604,508
Annual investment cost (TF) over 25 yrs ($)	530,702	530,702	530,702	530,702	530,702	530,702	530,702
Annual investment cost (AL) over 25 yrs ($)	501,139	501,139	501,139	501,139	501,139	501,139	501,139
Investment cost (AS) ($/m³)	0.86	0.84	0.81	0.79	0.77	0.74	0.72
Investment cost (TF) ($/m³)	0.76	0.74	0.71	0.69	0.67	0.65	0.63
Investment cost (AL) ($/m³)	0.72	0.69	0.67	0.65	0.64	0.62	0.60
O&M costs							
O&M costs (AS) ($)	173,749	176,858	180,025	183,242	186,522	189,862	193,257
O&M costs (TF) ($)	133,787	136,181	138,619	141,097	143,622	146,194	148,808
O&M costs (AL) ($)	70,091	71,345	72,623	73,921	75,244	76,591	77,961
O&M costs (Chlorine Disinfection) ($) 2010	11,792	11,902	12,014	12,130	12,250	12,373	12,500
O&M costs (Chlorine Disinfection) ($)	18,371	63,753	65,237	66,761	68,329	69,940	78,742
Storage O&M costs ($)	34,482	34,827	35,175	35,527	35,882	36,241	36,604
Conveyance O&M costs ($)	23,400	23,634	23,870	24,109	24,350	24,594	24,840
Pump O&M costs($)	19,026	19,597	20,185	20,790	21,414	22,057	22,718
Surface irrigation costs ($)	225,257	227,510	229,785	232,083	234,403	236,748	239,115
Total annual O&M costs (AS) ($)	494,287	546,179	554,278	562,512	570,901	579,442	595,275
Total annual O&M costs (TF) ($)	454,324	505,502	512,872	520,367	528,001	535,774	550,826
Total annual O&M costs (AL) ($)	390,629	440,666	446,876	453,191	459,623	466,171	479,979
O&M costs (AS) ($/m³)	0.71	0.76	0.75	0.73	0.72	0.71	0.71
O&M costs (TF) ($/m³)	0.65	0.70	0.69	0.68	0.67	0.66	0.66
O&M costs (AL) ($/m³)	0.56	0.61	0.60	0.59	0.58	0.57	0.57
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.57	1.59	1.56	1.52	1.49	1.46	1.43
Total cost (TF) ($/m³)	1.41	1.44	1.40	1.37	1.34	1.31	1.29
Total cost (AL) ($/m³)	1.27	1.30	1.28	1.25	1.22	1.19	1.17
Tariffs							

Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.54	0.53	0.52	0.51	0.50	0.49	0.48
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	1.03	1.07	1.04	1.02	0.99	0.97	0.95
With TF ($/m³)	0.87	0.91	0.89	0.86	0.84	0.82	0.81
With AL ($/m³)	0.73	0.78	0.76	0.74	0.72	0.70	0.69
Benefits							
Economic Benefits ($)	262,800	270,684	278,809	287,164	295,781	304,662	313,794
Crop Production ($)	126,176	129,808	133,551	137,400	141,371	145,462	150,519
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(Option4 continued)

Calculations (2017-2023)	2017	2018	2019	2020	2021	2022	2023
Total population (domestic+industrial)	29,517	30,402	31,315	32,254	33,222	34,218	35,245
Total population in 2035	50,251	50,251	50,251	50,251	50,251	50,251	50,251
Total amount of ww. Generated each yr (m³)	861,896	887,738	914,398	941,817	970,082	999,166	1,029,154
Total amount of ww. Generated in 2035 (m³)	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329
Total amounts of treated ww. For reuse /yr (m³)	646,422	665,804	685,799	706,363	727,562	749,374	771,866
availability during dry season (m³)	323,211	332,902	342,899	353,181	363,781	374,687	385,933
availability during rainy season (m³)	323,211	332,902	342,899	353,181	363,781	374,687	385,933
land area that can be irrigated (supp.) in rainy seas.(du)	923	951	980	1,009	1,039	1,071	1,103
land area that can be irrigated (full) in dry seas. (du)	462	476	490	505	520	535	551
excess amounts of treated ww. In rainy season (m³)	161,606	166,451	171,450	176,591	181,890	187,344	192,966
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	231	238	245	252	260	268	276
Total land area. (du)	693	713	735	757	780	803	827
land area of olives for ww. Irrigation (du)	70	70	70	70	70	70	80
land area of barely & fodders for ww. Irrigation (du)	623	643	665	687	710	733	747
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0

investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Pump investment costs ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	604,508	604,508	604,508	604,508	604,508	604,508	604,508
Annual investment cost (TF) over 25 yrs ($)	530,702	530,702	530,702	530,702	530,702	530,702	530,702
Annual investment cost (AL) over 25 yrs ($)	501,139	501,139	501,139	501,139	501,139	501,139	501,139
Investment cost (AS) ($/m³)	0.70	0.68	0.66	0.64	0.62	0.61	0.59
Investment cost (TF) ($/m³)	0.62	0.60	0.58	0.56	0.55	0.53	0.52
Investment cost (AL) ($/m³)	0.58	0.56	0.55	0.53	0.52	0.50	0.49
O&M costs							
O&M costs (AS) ($)	196,716	200,234	203,821	207,466	211,180	214,956	218,804
O&M costs (TF) ($)	151,471	154,180	156,942	159,749	162,608	165,516	168,479
O&M costs (AL) ($)	79,356	80,775	82,222	83,693	85,191	86,714	88,266
O&M costs (Chlorine Disinfection) ($) 2010	12,631	12,765	12,904	13,046	13,193	13,345	13,500
O&M costs (Chlorine Disinfection) ($)	80,698	82,710	84,778	86,904	89,024	91,201	93,436
Storage O&M costs ($)	36,970	37,339	37,713	38,090	38,471	38,855	39,244
Conveyance O&M costs ($)	25,088	25,339	25,592	25,848	26,107	26,368	26,631
Pump O&M costs($)	23,400	24,102	24,826	25,570	26,337	27,127	27,941
Surface irrigation costs ($)	241,506	243,921	246,360	248,824	251,312	253,825	256,364
Total annual O&M costs (AS) ($)	604,378	613,645	623,089	632,702	642,431	652,332	662,420
Total annual O&M costs (TF) ($)	559,133	567,591	576,211	584,985	593,859	602,893	612,095
Total annual O&M costs (AL) ($)	487,018	494,186	501,491	508,929	516,442	524,091	531,883
O&M costs (AS) ($/m³)	0.70	0.69	0.68	0.67	0.66	0.65	0.64
O&M costs (TF) ($/m³)	0.65	0.64	0.63	0.62	0.61	0.60	0.59
O&M costs (AL) ($/m³)	0.57	0.56	0.55	0.54	0.53	0.52	0.52
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.40	1.37	1.34	1.31	1.29	1.26	1.23
Total cost (TF) ($/m³)	1.26	1.24	1.21	1.18	1.16	1.13	1.11

Total cost (AL) ($/m³)	1.15	1.12	1.10	1.07	1.05	1.03	1.00
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.47	0.46	0.45	0.44	0.43	0.43	0.42
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	0.93	0.91	0.89	0.87	0.85	0.83	0.81
With TF ($/m³)	0.79	0.78	0.76	0.74	0.73	0.71	0.69
With AL ($/m³)	0.68	0.66	0.64	0.63	0.61	0.60	0.59
Benefits							
Economic Benefits ($)	323,211	332,902	342,899	353,181	363,781	374,687	385,933
Crop Production ($)	154,858	159,323	163,929	168,666	173,549	178,574	184,605
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(Option 4 Continued)

Calculations (2024-2030)	2024	2025	2026	2027	2028	2029	2030
Total population (domestic+industrial)	36,302	37,391	38,513	39,668	40,858	42,084	43,347
Total population in 2035	50,251	50,251	50,251	50,251	50,251	50,251	50,251
Total amount of ww. Generated each yr (m³)	1,060,018	1,091,817	1,124,580	1,158,306	1,193,054	1,228,853	1,265,732
Total amount of ww. Generated in 2035 (m³)	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329
Total amounts of treated ww. For reuse /yr (m³)	795,014	818,863	843,435	868,729	894,790	921,640	949,299
availability during dry season (m³)	397,507	409,431	421,717	434,365	447,395	460,820	474,650
availability during rainy season (m³)	397,507	409,431	421,717	434,365	447,395	460,820	474,650
land area that can be irrigated (supp.) in rainy seas.(du)	1,136	1,170	1,205	1,241	1,278	1,317	1,356
land area that can be irrigated (full) in dry seas. (du)	568	585	602	621	639	658	678
excess amounts of treated ww. In rainy season (m³)	198,753	204,716	210,859	217,182	223,698	230,410	237,325
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	284	292	301	310	320	329	339
Total land area. (du)	852	877	904	931	959	987	1,017
land area of olives for ww. Irrigation (du)	80	80	80	80	90	90	90

land area of barely & fodders for ww. Irrigation (du)	772	797	824	851	869	897	927
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Pump investment costs ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	604,508	604,508	604,508	604,508	604,508	604,508	604,508
Annual investment cost (TF) over 25 yrs ($)	530,702	530,702	530,702	530,702	530,702	530,702	530,702
Annual investment cost (AL) over 25 yrs ($)	501,139	501,139	501,139	501,139	501,139	501,139	501,139
Investment cost (AS) ($/m³)	0.57	0.55	0.54	0.52	0.51	0.49	0.48
Investment cost (TF) ($/m³)	0.50	0.49	0.47	0.46	0.44	0.43	0.42
Investment cost (AL) ($/m³)	0.47	0.46	0.45	0.43	0.42	0.41	0.40
O&M costs							
O&M costs (AS) ($)	222,718	226,703	230,760	234,888	239,091	243,370	247,726
O&M costs (TF) ($)	171,493	174,561	177,685	180,864	184,100	187,395	190,749
O&M costs (AL) ($)	89,845	91,453	93,090	94,755	96,450	98,176	99,934
O&M costs (Chlorine Disinfection) ($) 2010	13,661	13,826	13,996	14,171	14,351	14,537	14,728
O&M costs (Chlorine Disinfection) ($)	95,731	98,087	100,505	102,988	105,535	108,149	110,830
Storage O&M costs ($)	39,636	40,033	40,433	40,837	41,246	41,658	42,075
Conveyance O&M costs ($)	26,898	27,167	27,438	27,713	27,990	28,270	28,552
Pump O&M costs($)	28,779	29,642	30,532	31,448	32,391	33,363	34,364
Surface irrigation costs ($)	258,927	261,517	264,132	266,773	269,441	272,135	274,857
Total annual O&M costs (AS) ($)	672,689	683,148	693,800	704,647	715,693	726,945	738,404
Total annual O&M costs (TF) ($)	621,464	631,007	640,726	650,623	660,702	670,970	681,427
Total annual O&M costs (AL) ($)	539,817	547,898	556,130	564,514	573,053	581,751	590,612
O&M costs (AS) ($/m³)	0.63	0.63	0.62	0.61	0.60	0.59	0.58

O&M costs (TF) ($/m³)	0.59	0.58	0.57	0.56	0.55	0.55	0.54
O&M costs (AL) ($/m³)	0.51	0.50	0.49	0.49	0.48	0.47	0.47
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.20	1.18	1.15	1.13	1.11	1.08	1.06
Total cost (TF) ($/m³)	1.09	1.06	1.04	1.02	1.00	0.98	0.96
Total cost (AL) ($/m³)	0.98	0.96	0.94	0.92	0.90	0.88	0.86
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.41	0.40	0.39	0.39	0.38	0.37	0.36
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	0.80	0.78	0.76	0.74	0.73	0.71	0.70
With TF ($/m³)	0.68	0.66	0.65	0.63	0.62	0.61	0.59
With AL ($/m³)	0.57	0.56	0.55	0.53	0.52	0.51	0.50
Benefits							
Economic Benefits ($)	397,507	409,431	421,717	434,365	447,395	460,820	474,650
Crop Production ($)	189,937	195,431	201,091	206,918	213,771	219,956	226,328
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(option 4 continued)

Calculations (2031-2035)	2031	2032	2033	2034	2035
Total population (domestic+industrial)	44,647	45,986	47,366	48,787	50,251
Total population in 2035	50,251	50,251	50,251	50,251	50,251
Total amount of ww. Generated each yr (m³)	1,303,692	1,342,791	1,383,087	1,424,580	1,467,329
Total amount of ww. Generated in 2035 (m³)	1,467,329	1,467,329	1,467,329	1,467,329	1,467,329
Total amounts of treated ww. For reuse /yr (m³)	977,769	1,007,093	1,037,315	1,068,435	1,100,497
availability during dry season (m³)	488,885	503,547	518,658	534,218	550,248
availability during rainy season (m³)	488,885	503,547	518,658	534,218	550,248
land area that can be irrigated (supp.) in rainy seas.(du)	1,397	1,439	1,482	1,526	1,572
land area that can be irrigated (full) in dry seas. (du)	698	719	741	763	786
excess amounts of treated ww. In rainy season (m³)	244,442	251,773	259,329	267,109	275,124

excess amounts of treated ww. In dry season (m³)	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	349	360	370	382	393
Total land area. (du)	1,048	1,079	1,111	1,145	1,179
land area of olives for ww. Irrigation (du)	90	100	100	100	100
land area of barely & fodders for ww. Irrigation (du)	958	979	1,011	1,045	1,079
Investment Costs					
investment cost (AS) ($)	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0
Pump investment costs ($)	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	604,508	604,508	604,508	604,508	604,508
Annual investment cost (TF) over 25 yrs ($)	530,702	530,702	530,702	530,702	530,702
Annual investment cost (AL) over 25 yrs ($)	501,139	501,139	501,139	501,139	501,139
Investment cost (AS) ($/m³)	0.46	0.45	0.44	0.42	0.41
Investment cost (TF) ($/m³)	0.41	0.40	0.38	0.37	0.36
Investment cost (AL) ($/m³)	0.38	0.37	0.36	0.35	0.34
O&M costs					
O&M costs (AS) ($)	252,157	256,668	261,262	265,937	270,697
O&M costs (TF) ($)	194,161	197,635	201,172	204,772	208,437
O&M costs (AL) ($)	101,721	103,541	105,394	107,280	109,200
O&M costs (Chlorine Disinfection) ($) 2010	14,925	15,127	15,336	15,551	15,772
O&M costs (Chlorine Disinfection) ($)	113,581	116,403	119,297	122,264	125,306
Storage O&M costs ($)	42,496	42,921	43,350	43,783	44,221
Conveyance O&M costs ($)	28,838	29,126	29,418	29,712	30,009
Pump O&M costs($)	35,395	36,456	37,550	38,677	39,837
Surface irrigation costs ($)	277,605	280,381	283,185	286,017	288,877

Total annual O&M costs (AS) ($)	750,072	761,955	774,062	786,390	798,947
Total annual O&M costs (TF) ($)	692,076	702,922	713,972	725,224	736,687
Total annual O&M costs (AL) ($)	599,636	608,828	618,194	627,733	637,451
O&M costs (AS) ($/m³)	0.58	0.57	0.56	0.55	0.54
O&M costs (TF) ($/m³)	0.53	0.52	0.52	0.51	0.50
O&M costs (AL) ($/m³)	0.46	0.45	0.45	0.44	0.43
Total unit cost (Investment + O&M) ($/m³)					
Total cost (AS) ($/m³)	1.04	1.02	1.00	0.98	0.96
Total cost (TF) ($/m³)	0.94	0.92	0.90	0.88	0.86
Total cost (AL) ($/m³)	0.84	0.83	0.81	0.79	0.78
Tariffs					
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.36	0.35	0.34	0.34	0.33
Tariffs to paid by households (might need subsidy by municipalities)					
With AS ($/m³)	0.68	0.67	0.65	0.64	0.63
With TF ($/m³)	0.58	0.57	0.56	0.55	0.53
With AL ($/m³)	0.49	0.48	0.47	0.46	0.45
Benefits					
Economic Benefits ($)	488,885	503,547	518,658	534,218	550,248
Crop Production ($)	232,886	240,491	247,453	254,622	262,007
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74

CBA Calculations for option 5

Calculations (2010-2016)	2010	20111	2012	2013	2014	2015	2016
Total population (domestic+industrial)	27,500	28,325	29,175	30,050	30,951	31,880	32,836
Total population in 2035	57,579	57,579	57,579	57,579	57,579	57,579	57,579
Total amount of ww. Generated each yr (m^3)	803,000	827,090	851,910	877,460	903,769	930,896	958,811
Total amount of ww. Generated in 2035 (m^3)	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307
Total amounts of treated ww. For reuse /yr (m^3)	602,250	620,318	638,933	658,095	677,827	698,172	719,108
availability during dry season (m^3)	301,125	310,159	319,466	329,048	338,913	349,086	359,554
availability during rainy season (m^3)	301,125	310,159	319,466	329,048	338,913	349,086	359,554
land area that can be irrigated (supp.) in rainy seas.(du)	860	886	913	940	968	997	1,027
land area that can be irrigated (full) in dry seas. (du)	430	443	456	470	484	499	514
excess amounts of treated ww. In rainy season (m^3)	150,563	155,079	159,733	164,524	169,457	174,543	179,777
excess amounts of treated ww. In dry season (m^3)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	215	222	228	235	242	249	257
Total land area (du)	645	665	685	705	726	748	770
land area of olives for ww. Irrigation (du)	60	60	60	60	60	60	70
land area of barely & fodders for ww. Irrigation (du)	585	605	625	645	666	688	700
Investment Costs							
investment cost (AS) ($)	10,517,003	0	0	0	0	0	0
investment cost (TF) ($)	9,085,902	0	0	0	0	0	0
investment cost (AL) ($)	8,512,664	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	151,843	0	0	0	0	0	0
Storage investment cost ($)	790,214	0	0	0	0	0	0
Conveyance investment cost ($)	234000	0	0	0	0	0	0
Pump investment costs ($)	2070	0	0	0	0	0	0
Total investment cost (AS) ($)	11,695,130	0	0	0	0	0	0
Total investment cost (TF) ($)	10,264,030	0	0	0	0	0	0
Total investment cost (AL) ($)	9,690,791	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	671,626	671,626	671,626	671,626	671,626	671,626	671,626
Annual investment cost (TF) over 25 yrs ($)	589,441	589,441	589,441	589,441	589,441	589,441	589,441
Annual investment cost (AL) over 25 yrs ($)	556,522	556,522	556,522	556,522	556,522	556,522	556,522

Investment cost (AS) ($/m³)	0.84	0.81	0.79	0.77	0.74	0.72	0.70
Investment cost (TF) ($/m³)	0.73	0.71	0.69	0.67	0.65	0.63	0.61
Investment cost (AL) ($/m³)	0.69	0.67	0.65	0.63	0.62	0.60	0.58
O&M costs							
O&M costs (AS) ($)	188,537	191,910	195,345	198,840	202,396	206,019	209,704
O&M costs (TF) ($)	145,173	147,771	150,416	153,107	155,845	158,635	161,472
O&M costs (AL) ($)	76,056	77,417	78,803	80,213	81,647	83,109	84,595
O&M costs (Chlorine Disinfection) ($) 2010	12,324	12,450	12,579	12,712	12,849	12,990	13,135
O&M costs (Chlorine Disinfection) ($)	19,201	63,753	65,237	66,761	68,329	69,940	78,742
Storage O&M costs ($)	39,511	39,906	40,305	40,708	41,115	41,526	41,941
Conveyance O&M costs ($)	23,400	23,634	23,870	24,109	24,350	24,594	24,840
Pump O&M costs ($)	19,095	19,668	20,259	20,866	21,492	22,137	22,801
Surface irrigation costs ($)	258,107	260,688	263,295	265,928	268,587	271,273	273,986
Total annual O&M costs (AS) ($)	547,851	599,560	608,311	617,212	626,269	635,489	652,014
Total annual O&M costs (TF) ($)	504,488	555,420	563,382	571,479	579,718	588,105	603,782
Total annual O&M costs (AL) ($)	435,371	485,067	491,769	498,585	505,520	512,579	526,905
O&M costs (AS) ($/m³)	0.68	0.72	0.71	0.70	0.69	0.68	0.68
O&M costs (TF) ($/m³)	0.63	0.67	0.66	0.65	0.64	0.63	0.63
O&M costs (AL) ($/m³)	0.54	0.59	0.58	0.57	0.56	0.55	0.55
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.52	1.54	1.50	1.47	1.44	1.40	1.38
Total cost (TF) ($/m³)	1.36	1.38	1.35	1.32	1.29	1.26	1.24
Total cost (AL) ($/m³)	1.24	1.26	1.23	1.20	1.18	1.15	1.13
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.53	0.52	0.51	0.50	0.49	0.48	0.47
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	0.99	1.01	0.99	0.97	0.94	0.92	0.91
With TF ($/m³)	0.83	0.86	0.84	0.82	0.80	0.78	0.77
With AL ($/m³)	0.70	0.74	0.72	0.70	0.68	0.67	0.66
Benefits							
Economic Benefits ($)	301,125	310,159	319,466	329,048	338,913	349,086	359,554
Crop Production ($)	143,833	147,995	152,283	156,697	161,242	165,929	171,602

Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(option 5 continued)

Calculations (2017-2023)	2017	2018	2019	2020	2021	2022	2023
Total population (domestic+industrial)	33,822	34,836	35,881	36,958	38,066	39,208	40,385
Total population in 2035	57,579	57,579	57,579	57,579	57,579	57,579	57,579
Total amount of ww. Generated each yr (m³)	987,602	1,017,211	1,047,725	1,079,174	1,111,527	1,144,874	1,179,242
Total amount of ww. Generated in 2035 (m³)	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307
Total amounts of treated ww. For reuse /yr (m³)	740,702	762,908	785,794	809,380	833,645	858,655	884,432
availability during dry season (m³)	370,351	381,454	392,897	404,690	416,823	429,328	442,216
availability during rainy season (m³)	370,351	381,454	392,897	404,690	416,823	429,328	442,216
land area that can be irrigated (supp.) in rainy seas.(du)	1,058	1,090	1,123	1,156	1,191	1,227	1,263
land area that can be irrigated (full) in dry seas. (du)	529	545	561	578	595	613	632
excess amounts of treated ww. In rainy season (m³)	185,175	190,727	196,448	202,345	208,411	214,664	221,108
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	265	272	281	289	298	307	316
Total land area (du)	794	817	842	867	893	920	948
land area of olives for ww. Irrigation (du)	70	70	70	70	70	70	80
land area of barely & fodders for ww. Irrigation (du)	724	747	772	797	823	850	868
Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0

investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Pump investment costs ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	671,626	671,626	671,626	671,626	671,626	671,626	671,626
Annual investment cost (TF) over 25 yrs ($)	589,441	589,441	589,441	589,441	589,441	589,441	589,441
Annual investment cost (AL) over 25 yrs ($)	556,522	556,522	556,522	556,522	556,522	556,522	556,522
Investment cost (AS) ($/m³)	0.68	0.66	0.64	0.62	0.60	0.59	0.57
Investment cost (TF) ($/m³)	0.60	0.58	0.56	0.55	0.53	0.51	0.50
Investment cost (AL) ($/m³)	0.56	0.55	0.53	0.52	0.50	0.49	0.47
O&M costs							
O&M costs (AS) ($)	213,460	217,277	221,164	225,124	229,149	233,250	237,426
O&M costs (TF) ($)	164,364	167,303	170,297	173,346	176,445	179,602	182,818
O&M costs (AL) ($)	86,111	87,650	89,219	90,816	92,440	94,094	95,779
O&M costs (Chlorine Disinfection) ($) 2010	13,284	13,438	13,597	13,760	13,928	14,101	14,280
O&M costs (Chlorine Disinfection) ($)	80,698	82,710	84,778	86,904	89,024	91,201	93,436
Storage O&M costs ($)	42,361	42,784	43,212	43,644	44,081	44,522	44,967
Conveyance O&M costs ($)	25,088	25,339	25,592	25,848	26,107	26,368	26,631
Pump O&M costs ($)	23,485	24,189	24,915	25,663	26,432	27,225	28,043
Surface irrigation costs ($)	276,726	279,493	282,288	285,111	287,962	290,842	293,750
Total annual O&M costs (AS) ($)	661,818	671,793	681,950	692,294	702,755	713,407	724,253
Total annual O&M costs (TF) ($)	612,722	621,819	631,082	640,516	650,051	659,760	669,645
Total annual O&M costs (AL) ($)	534,468	542,166	550,004	557,986	566,046	574,251	582,605
O&M costs (AS) ($/m³)	0.67	0.66	0.65	0.64	0.63	0.62	0.61
O&M costs (TF) ($/m³)	0.62	0.61	0.60	0.59	0.58	0.58	0.57
O&M costs (AL) ($/m³)	0.54	0.53	0.52	0.52	0.51	0.50	0.49
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.35	1.32	1.29	1.26	1.24	1.21	1.18
Total cost (TF) ($/m³)	1.22	1.19	1.16	1.14	1.12	1.09	1.07

Total cost (AL) ($/m³)	1.10	1.08	1.06	1.03	1.01	0.99	0.97
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.46	0.46	0.45	0.44	0.43	0.42	0.41
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	0.89	0.87	0.85	0.83	0.81	0.79	0.77
With TF ($/m³)	0.75	0.74	0.72	0.70	0.69	0.67	0.65
With AL ($/m³)	0.64	0.62	0.61	0.59	0.58	0.57	0.55
Benefits							
Economic Benefits ($)	370,351	381,454	392,897	404,690	416,823	429,328	442,216
Crop Production ($)	176,576	181,691	186,963	192,397	197,986	203,747	210,535
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(Option 5 continued)

Calculations (2024-2030)	2024	2025	2026	2027	2028	2029	2030
Total population (domestic+industrial)	41,596	42,844	44,129	45,453	46,817	48,221	49,668
Total population in 2035	57,579	57,579	57,579	57,579	57,579	57,579	57,579
Total amount of ww. Generated each yr (m³)	1,214,603	1,251,045	1,288,567	1,327,228	1,367,056	1,408,053	1,450,306
Total amount of ww. Generated in 2035 (m³)	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307
Total amounts of treated ww. For reuse /yr (m³)	910,952	938,284	966,425	995,421	1,025,292	1,056,040	1,087,729
availability during dry season (m³)	455,476	469,142	483,213	497,710	512,646	528,020	543,865
availability during rainy season (m³)	455,476	469,142	483,213	497,710	512,646	528,020	543,865
land area that can be irrigated (supp.) in rainy seas.(du)	1,301	1,340	1,381	1,422	1,465	1,509	1,554
land area that can be irrigated (full) in dry seas. (du)	651	670	690	711	732	754	777
excess amounts of treated ww. In rainy season (m³)	227,738	234,571	241,606	248,855	256,323	264,010	271,932
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	325	335	345	356	366	377	388
Total land area (du)	976	1,005	1,035	1,067	1,099	1,131	1,165
land area of olives for ww. Irrigation (du)	80	80	80	80	90	90	90
land area of barely & fodders for ww. Irrigation (du)	896	925	955	987	1,009	1,041	1,075

Investment Costs							
investment cost (AS) ($)	0	0	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0	0	0
Pump investment costs ($)	0	0	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	671,626	671,626	671,626	671,626	671,626	671,626	671,626
Annual investment cost (TF) over 25 yrs ($)	589,441	589,441	589,441	589,441	589,441	589,441	589,441
Annual investment cost (AL) over 25 yrs ($)	556,522	556,522	556,522	556,522	556,522	556,522	556,522
Investment cost (AS) ($/m³)	0.55	0.54	0.52	0.51	0.49	0.48	0.46
Investment cost (TF) ($/m³)	0.49	0.47	0.46	0.44	0.43	0.42	0.41
Investment cost (AL) ($/m³)	0.46	0.44	0.43	0.42	0.41	0.40	0.38
O&M costs							
O&M costs (AS) ($)	241,673	245,997	250,398	254,879	259,441	264,082	268,808
O&M costs (TF) ($)	186,088	189,418	192,807	196,257	199,770	203,343	206,982
O&M costs (AL) ($)	97,492	99,236	101,012	102,819	104,660	106,532	108,438
O&M costs (Chlorine Disinfection) ($) 2010	14,463	14,652	14,846	15,047	15,253	15,465	15,684
O&M costs (Chlorine Disinfection) ($)	95,731	98,087	100,505	102,988	105,535	108,149	110,830
Storage O&M costs ($)	45,417	45,871	46,329	46,793	47,261	47,733	48,211
Conveyance O&M costs ($)	26,898	27,167	27,438	27,713	27,990	28,270	28,552
Pump O&M costs ($)	28,883	29,750	30,642	31,562	32,509	33,484	34,489
Surface irrigation costs ($)	296,688	299,654	302,651	305,677	308,734	311,822	314,940
Total annual O&M costs (AS) ($)	735,289	746,526	757,964	769,612	781,470	793,539	805,829
Total annual O&M costs (TF) ($)	679,704	689,947	700,373	710,990	721,798	732,800	744,004
Total annual O&M costs (AL) ($)	591,108	599,765	608,578	617,552	626,688	635,989	645,460
O&M costs (AS) ($/m³)	0.61	0.60	0.59	0.58	0.57	0.56	0.56
O&M costs (TF) ($/m³)	0.56	0.55	0.54	0.54	0.53	0.52	0.51

O&M costs (AL) ($/m³)	0.49	0.48	0.47	0.47	0.46	0.45	0.45
Total unit cost (Investment + O&M) ($/m³)							
Total cost (AS) ($/m³)	1.16	1.13	1.11	1.09	1.06	1.04	1.02
Total cost (TF) ($/m³)	1.04	1.02	1.00	0.98	0.96	0.94	0.92
Total cost (AL) ($/m³)	0.94	0.92	0.90	0.88	0.87	0.85	0.83
Tariffs							
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.41	0.40	0.39	0.38	0.37	0.37	0.36
Tariffs to paid by households (might need subsidy by municipalities)							
With AS ($/m³)	0.75	0.74	0.72	0.70	0.69	0.67	0.66
With TF ($/m³)	0.64	0.63	0.61	0.60	0.58	0.57	0.56
With AL ($/m³)	0.54	0.53	0.51	0.50	0.49	0.48	0.47
Benefits							
Economic Benefits ($)	455,476	469,142	483,213	497,710	512,646	528,020	543,865
Crop Production ($)	216,644	222,940	229,423	236,102	243,833	250,916	258,216
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74	0.74	0.74

(option5 continued)

Calculations (2031-2035)	20231	20232	2033	2034	2035
Total population (domestic+industrial)	51,158	52,693	54,274	55,902	57,579
Total population in 2035	57,579	57,579	57,579	57,579	57,579
Total amount of ww. Generated each yr (m³)	1,493,814	1,538,636	1,584,801	1,632,338	1,681,307
Total amount of ww. Generated in 2035 (m³)	1,681,307	1,681,307	1,681,307	1,681,307	1,681,307
Total amounts of treated ww. For reuse /yr (m³)	1,120,360	1,153,977	1,188,601	1,224,254	1,260,980
availability during dry season (m³)	560,180	576,988	594,300	612,127	630,490
availability during rainy season (m³)	560,180	576,988	594,300	612,127	630,490
land area that can be irrigated (supp.) in rainy seas.(du)	1,601	1,649	1,698	1,749	1,801

land area that can be irrigated (full) in dry seas. (du)	800	824	849	874	901
excess amounts of treated ww. In rainy season (m³)	280,090	288,494	297,150	306,063	315,245
excess amounts of treated ww. In dry season (m³)	0	0	0	0	0
additional land area irrigated by stored ww. From rainy seas. (du)	400	412	425	437	450
Total land area (du)	1,200	1,236	1,274	1,312	1,351
land area of olives for ww. Irrigation (du)	90	100	100	100	100
land area of barely & fodders for ww. Irrigation (du)	1,110	1,136	1,174	1,212	1,251
Investment Costs					
investment cost (AS) ($)	0	0	0	0	0
investment cost (TF) ($)	0	0	0	0	0
investment cost (AL) ($)	0	0	0	0	0
investment cost (Chlorine Disinfection) ($)	0	0	0	0	0
Storage investment cost ($)	0	0	0	0	0
Conveyance investment cost ($)	0	0	0	0	0
Pump investment costs ($)	0	0	0	0	0
Total investment cost (AS) ($)	0	0	0	0	0
Total investment cost (TF) ($)	0	0	0	0	0
Total investment cost (AL) ($)	0	0	0	0	0
Annual investment cost (AS) over 25 yrs ($)	671,626	671,626	671,626	671,626	671,626
Annual investment cost (TF) over 25 yrs ($)	589,441	589,441	589,441	589,441	589,441
Annual investment cost (AL) over 25 yrs ($)	556,522	556,522	556,522	556,522	556,522
Investment cost (AS) ($/m³)	0.45	0.44	0.42	0.41	0.40
Investment cost (TF) ($/m³)	0.39	0.38	0.37	0.36	0.35
Investment cost (AL) ($/m³)	0.37	0.36	0.35	0.34	0.33
O&M costs					
O&M costs (AS) ($)	273,618	278,515	283,499	288,571	293,734
O&M costs (TF) ($)	210,686	214,457	218,294	222,200	226,176
O&M costs (AL) ($)	110,379	112,354	114,365	116,411	118,494
O&M costs (Chlorine Disinfection) ($) 2010	15,909	16,141	16,379	16,625	16,878
O&M costs (Chlorine Disinfection) ($)	113,581	116,403	119,297	122,264	125,306
Storage O&M costs ($)	48,693	49,180	49,671	50,168	50,670
Conveyance O&M costs ($)	28,838	29,126	29,418	29,712	30,009

Pump O&M costs ($)	35,523	36,589	37,687	38,817	39,982
Surface irrigation costs ($)	318,089	321,270	324,483	327,728	331,005
Total annual O&M costs (AS) ($)	818,342	831,083	844,055	857,260	870,706
Total annual O&M costs (TF) ($)	755,410	767,025	778,850	790,889	803,147
Total annual O&M costs (AL) ($)	655,103	664,922	674,920	685,100	695,465
O&M costs (AS) ($/m³)	0.55	0.54	0.53	0.53	0.52
O&M costs (TF) ($/m³)	0.51	0.50	0.49	0.48	0.48
O&M costs (AL) ($/m³)	0.44	0.43	0.43	0.42	0.41
Total unit cost (Investment + O&M) ($/m³)					
Total cost (AS) ($/m³)	1.00	0.98	0.96	0.94	0.92
Total cost (TF) ($/m³)	0.90	0.88	0.86	0.85	0.83
Total cost (AL) ($/m³)	0.81	0.79	0.78	0.76	0.74
Tariffs					
Tariffs to be paid by farmers (Only O&M costs) ($/m³)	0.35	0.35	0.34	0.33	0.33
Tariffs to paid by households (might need subsidy by municipalities)					
With AS ($/m³)	0.64	0.63	0.62	0.60	0.59
With TF ($/m³)	0.55	0.54	0.52	0.51	0.50
With AL ($/m³)	0.46	0.45	0.44	0.43	0.42
Benefits					
Economic Benefits ($)	560,180	576,988	594,300	612,127	630,490
Crop Production ($)	265,733	274,327	282,303	290,516	298,976
Total Benefit to farmers ($/m³)	0.74	0.74	0.74	0.74	0.74

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جامعة النجاح الوطنية
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تحليل الجدوى الاقتصادية لإعادة استخدام المياه العادمة المعالجة للري في مدينة طوباس

إعداد
رماء محمد صالح

إشراف
د. محمد المصري
د. لوري مكنيل

قدمت هذه الأطروحة استكمالا لمتطلبات درجة الماجستير في هندسة المياه والبيئة بكلية الدراسات العليا في جامعة النجاح الوطنية في نابلس ، فلسطين

2009

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أعداد

رماء محمد الحاج أحمد صالح

إشراف

د. محمد المصري

د. لوري مكنيل

الملخص

تعاني فلسطين من نقص في كميات المياه بسبب الزيادة في عدد السكان والتغير في نمط الحياة والأوضاع السياسية والجفاف الناتج عن التغيرات المناخية. تعتبر المياه العادمة المعالجة أحد المصادر التي يمكن استخدامها في الزراعة مما يؤدي إلى زيادة مساحات الأراضي الزراعية وتقليل التلوث الناتج عن المياه العادمة.

هناك نقص في كميات المياه في مدينة طوباس نتيجة لزيادة الطلب على المياه للاستخدام المنزلي والزراعي كما أنه يتم التخلص من المياه العادمة بطرحها في الوادي مما يؤدي لأثار سلبية على المياه الجوفية لذلك تعتبر أعادة استخدام المياه العادمة أحد الحلول لمعالجة هذا النقص والتخلص من مشكلة التلوث.

نهدف من خلال هذا البحث دراسة ملائمة استخدام المياه العادمة في طوباس من خلال توزيع استبيان لمعرفة الرأي العام تجاه أعادة استخدام المياه العادمة المعالجة ومن ثم تحليل الجدوى الاقتصادية لإعادة استخدام المياه العادمة المعالجة من خلال تصميم برنامج لحساب الفوائد والتكلفة لإعادة استخدام المياه العادمة المعالجة .

في هذا البحث تم دراسة خمسة خيارات لمعالجة المياه العادمة في طوباس .إنشاء محطة لمعالجة المياه العادمة لكل من شمال طوباس، جنوب طوباس، شمال طوباس وقرية تياسير، كل طوباس وقرية

تياسير على الترتيب. ركزت الدراسة على ثلاثة أنظمة لمعالجة المياه العادمة من خلال استخدام الحمأة المنشطة والتقطير بالفلتر والبرك المهواه .

أظهرت نتائج تحليل الاستبيان أن غالبية المستطلعين يوافقون على بناء محطة تنقية مياه عادمة في طوباس كما أظهرت الحسابات أن تكلفة معالجة المياه العادمة باستخدام الحمأة المنشطة (دولار/م^3) للخمس خيارات في عام 2010: 1.73، 1.93، 1.65، 1.57 و 1.52 على الترتيب. أما تكلفة معالجة المياه العادمة باستخدام التقطير بالفلتر (دولار/م^3) في عام 2010 فهي: 1.55، 1.72، 1.47، 1.41 و 1.36. أما تكلفة معالجة المياه العادمة باستخدام البرك المهواه (دولار/م^3) في عام 2010 فهي: 1.39، 1.54، 1.32، 1.27، و 1.24 على الترتيب.