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Fresh Water Swaps: Potential for Wastewater Reuse
A Case Study of Alexandria, Egypt

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MSc Thesis ES.10.03

April 2010

UNESCO-IHE
Institute for Water Education

SWITCH

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Master of Science Thesis

by

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This research is done for the partial fulfilment of requirements for the Master of Science degree at the

UNESCO-IHE Institute for Water Education, Delft, the Netherlands

Delft

April, 2010

The findings, interpretations and conclusions expressed in this study do neither necessarily reflect the views of the UNESCO-IHE Institute for Water Education, nor of the individual members of the MSc committee, nor of their respective employers.

This work is dedicated to my beloved parents

Abstract

Secondary towns are confronted with the challenge of rapid pollution growth, particularly in the developing countries. This has resulted in unplanned urban expansion, bringing in more rural areas within the boundaries of cities and causing many administrative conflicts and poor services delivery. This situation is more alarming in the context of water scarce countries. The escalating living standards with increasing water demand and the need to expend agriculture land to meet the food requirements, has resulted in water competition between various water competitors. Another challenge that developing countries are confronted with is the safe disposal of increasing urban wastewater. This study focuses on the reuse of urban wastewater by assessing the scope, financial constraints and social perception of acceptability on wastewater reuse. The overall aim of conducting this research is to explore scope for freshwater swaps in Alexandria, Egypt.

Alexandria urban wastewater requires huge investments to upgrade the level of treatment to an extent where it can be reused. The current cost recovery system emplaced is not even enough to recover even the operation and maintenance costs. Also only technological solutions available at ground are not enough to treat wastewater to comply the National Standards set my Ministry of Health and Population. Social perception about wastewater reuse also play crucial role, because in many societies due cultural, religious or any other reason wastewater reuse is not encouraged. The study after assessing the public perception on wastewater reuse, proposes conjunctive water management to deal the wastewater and water scarcity problem.

Based on the finding from the case study of Alexandria, the study concludes with some suggestions on policy options for sustainable wastewater reuse and also adds to the theory used in this study.

Keywords: population growth, water scarcity, wastewater reuse, freshwater swaps

Acknowledgements

First of all, I acknowledge the divine guidance of the Lord God (*Allah*) Almighty during the course of my study and research. His Name shall be praised forever!

I would like to acknowledge and thank the Dutch Government especially the Netherlands Fellowship Program (NFP) for financially supporting me during my one and half years of Master in Environmental Sciences program at UNESCO-IHE.

Many intellectuals contributed in various ways in the completion of this study, I may not be able to mention all of them, but I am deeply grateful to all and I apologize for not naming all of them here.

I would like to express my sincere and heartfelt gratitude to my mentor Dr. Mathew Kurian, who through his knowledge and experience always guided me throughout this research; above all, his friendly behavior really impressed me. Without his assistance this research would have not been complete.

I would also like to acknowledge my kind supervisor, Prof. Meine Pieter van Dijk, who gave me valuable suggestions during our progress meetings and always guided me beside his busy schedule. I am also deep grateful to Dr. Peter van der Steen and SWITCH project for financially supporting this research.

My special thanks to Mohamed Elrawady and Eng. Ayman Ramadan for their love and support during my stay in Egypt. I am really thankful to all Egyptians for their kind hospitality.

I would also like to express my warm thanks to all UNESCO-IHE friends, especially to Mariska, Egina, Nikola, Milan, Violeta and Ermal, whose friendship and love made my students life unforgettable in Delft.

Finally, I take this opportunity to THANK my wife for her continuous support and love, especially when our daughter “ZALA” was missing my part of love. Likewise, I am greatly thankful to my parents and all my relatives for their support, encouragement and love.

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AGOSD	Alexandria General Organization for Sanitary Drainage
AWCO	Alexandria Water Company
AWGA	Alexandria Water General Authority
ASDC	Alexandria Sanitary Drainage Company
BBC	British Broadcast Centre
BOD	Biological Oxygen Demand
COD	Chemical Oxygen Demand
CPR	Common Pool Resources
EEAA	Egyptian Environmental Affairs Agency
EHD	Environmental Health Department
EMOHC	Environmental Monitoring and Occupational Health Centre
GOFI	General Organization for Industrialisation
HCWW	Holding Company for Water and Wastewater
HDR	Human Development Report
IESIA	Integrated Environmental and Social Impact Assessment
IWRM	Integrated Water Resources Managment
MALR	Ministry of Agriculture and Land Reclamation
MHNCPU	Ministry of Housing New Communities and Public Utilities
MHP	Ministry of Health and Population
MIMW	Ministry of Industry and Mineral Wealth
MSEA	Ministry of State for Environment Affairs
MWRI	Ministry of Water Resources and Irrigation
NRI	Nile Research Institute
NWRC	National Water Research Centre
NWQS	National Wastewater Quality Standards
RS	Resource System
RU	Resource Unit
SES	Socio-Ecological Systems
SWERI	Soil, Water and Environment Research Institute
TDS	Total Dissolved Salts
TSS	Total Suspended Solids
UFRB	Urban Function in Rural Development
UNDP	United Nations Development Program
USAID	United States Aid for International Development
WES	Water Supply and Sanitation
WTP	Water Treatment Plant
WWTP	Wastewater Treatment Plant

1 Introduction

"*And We created from Water every living thing"* Al-Quran

The additional burden of three billion people over existing population in the next 50 years, with almost all of them living in cities is termed as the "Urban tsunami" (Swart, 2003). However the fact is that already more than 1 billion people lack access to safe drinking water and 2.6 billion people lack access to safe sanitation (HDR, 2006; Rijsberman, 2004). By 2025 it is projected that global water supply needs will increase by at least 50 percents (UNDP, 2004). This evidently constitutes to water crises and will lead to water competition among various water users, like agriculture and household water supply need, and it is more likely that the political economic considerations will reduce the share of future water needs for agriculture which will eventually create food supply problems (Kurian et al., 2009). Closely linked to the water supply, provision of sanitation services and managing urban wastewater will be another governance challenge particularly in the developing countries (Rijsberman, 2004).

The expansion of cities mainly due to population growth and rural urban migration has brought changes in the rural urban linkages. Unclear rural-urban boundaries has resulted in lack of water supply and sanitation services provision and governance challenges in Peri-urban areas particularly in developing countries. Usually Peri-urban areas lacks basic services like water supply and sanitation mainly due to existing institutional gap or even sometime overlapping responsibilities, Also municipal authorities are often not very strong in such locations. Peri-urban areas are termed as gray areas because of the non clarity of role and responsibilities of private, public and civil societies (Allen et al., 2006; Allen et al., 2009).

Another big governance challenge is to manage increasing urban wastewater and also to deal with the increasing competition for water. Many cities receive raw water for urban water supply from their hinterlands zones of influence. Within the cities then there is always a direct water competition between the households and industries particularly when industrial cooling water needs are huge, that terms water as geopolitical entity (Dietz, 2009). Outside the urban boundaries competition with rural (domestic and agriculture) consumers will further increase if the political favour remained with the urban water consumer. Above all the climate change has added additional concerns of water quantity and quality (Kurian et al., 2009) .This situation has pushed water practitioners to reassess the productive use of domestic wastewater.

Studies conducted shows that domestic wastewater contributes more than the industrial to overall wastewater generated, further to this 80 to 90 percent of the urban water supplied returns as wastewater in sewers (Kurian et al., 2009; Rijsberman, 2004). In most cases this wastewater pollutes surrounding freshwater bodies without any reuse and results high environmental and human health costs.

There is high potential to catch this 80 to 90 percent of urban wastewater, treat it and reuse it for various uses. One reuse could be non potable purposes, which can be agriculture reuse. In many countries vegetable are irrigated with urban wastewater, which serves as a primary food supply source for urban population and is also livelihood source for many poor in Peri-urban

areas. Furthermore it helps to cop with the challenge of urban wastewater to large extent. FAO in 2003 has estimated 20 million hectares of agriculture land in 50 countries that is either directly or indirectly irrigated with wastewater (Rijsberman, 2004).There are enormous direct benefit attached to reusing domestic wastewater after its proper collection, treatment. Many other economic wide benefits will come from the freshwater swaps. Freshwater swaps is referred to the water freed up due to the reuse of treated wastewater, that could be used to meet the high value water supply demand by constructing more freshwater facilities in the urban vicinities (Kurian et al., 2009)

In many cases governments ignoring social support are only seeking technological solutions for urban wastewater, which does not always turns out to be prudent solutions. Both are equally important in the management of wastewater, it is important to mentally prepare the society to reuse their treated toilets excreta after it leaves their homes (Drechsel et al., 2010). In many societies due to religious, cultural or many other reasons people are not willing to reuse their toilet wastewater, and in most cases this wastewater either untreated or partially treated flows into the nearby lakes or freshwater sources. This results in the contamination of such resources and thus affects the livelihood of those who are connected to these resources. Usually these resources are huge and have a large number of beneficiaries and such resources are also termed as Common Pool Resources (Ostrom, 1990). In order to prevent depletion of such resources, a robust resource management regime is required. A regime that requires multi-level nested framework, like resources system, resource units, governance system and users for analysing outcomes of complex Socio-Ecological Systems (SES) (Ostrom, 2009).

1.1 Problem Statement

Many developing countries seek technical solutions to deal with urban wastewater but socio-economic and water governance dimensions play equally important role. In many developing countries the urban wastewater generated ends in to freshwater sources. This not only diminishes freshwater availability but also badly affects the livelihood of those for whom this resource is a mean of income. Freshwater stress is accelerating due to increasing water demand for the growing population and escalating living standards, expansion of agriculture land and also the available freshwater is decreasing due to its exposure to urban wastewater pollution, deteriorating its quality. All those problems acts as driving force to draw the attention of governments to urban wastewater treatment, but the treatment of urban wastewater to an extent where it can be reused is another concern in poor developing countries. Only technical solution will not be enough to solve this problem, societal norms/behaviours consideration are also important so that to understand their general perception and willingness to reuse wastewater.

Another governance concern related to population growth is rapid urbanization and expansion of secondary cities. The expansion of cities particularly in developing countries where the rural-urban linkages are not clear has left the inhabitants of Peri-urban areas in the middle of no where. They often lack basic services like water supply and sanitation. The dynamic nature of Peri-urban areas has raised many governance challenges and often the services provision organization's roles and responsibilities are less clear or overlapping. For simplicity a problem tree has been developed, in which water scarcity is defined as the problem and has viewed from the causes and effects perspective.

1.2 Research Objectives

The general objective of this research is to explore freshwater swaps and assess wastewater reuse potential in Alexandria, Egypt. The research also intends to explore the community perception of wastewater reuse and the contribution of Peri-urban areas in cost recovery against the water supply and sanitation services they gets.

More specific objectives of this research are:

- To explore freshwater swaps and potential for wastewater reuse in Alexandria
- To explore community perception about wastewater reuse

1.3 Thesis Structure

The thesis is structure in such away that the Introduction chapter broadly describes the wastewater problems and potential to reuse. Background chapter give site specific relevant information and describe the roles and responsibilities of various actors and their duties involved in wastewater management in Alexandria, Egypt. Background chapter actually provide a base for this study. This is followed with Theory and Methodology Used chapter, which briefly discuss various theories and methods used to carryout this study. The data collected from the field is analysed in the Finding and Discussion chapter. Conclusions of this study are listed in the final chapter entitled Conclusions.

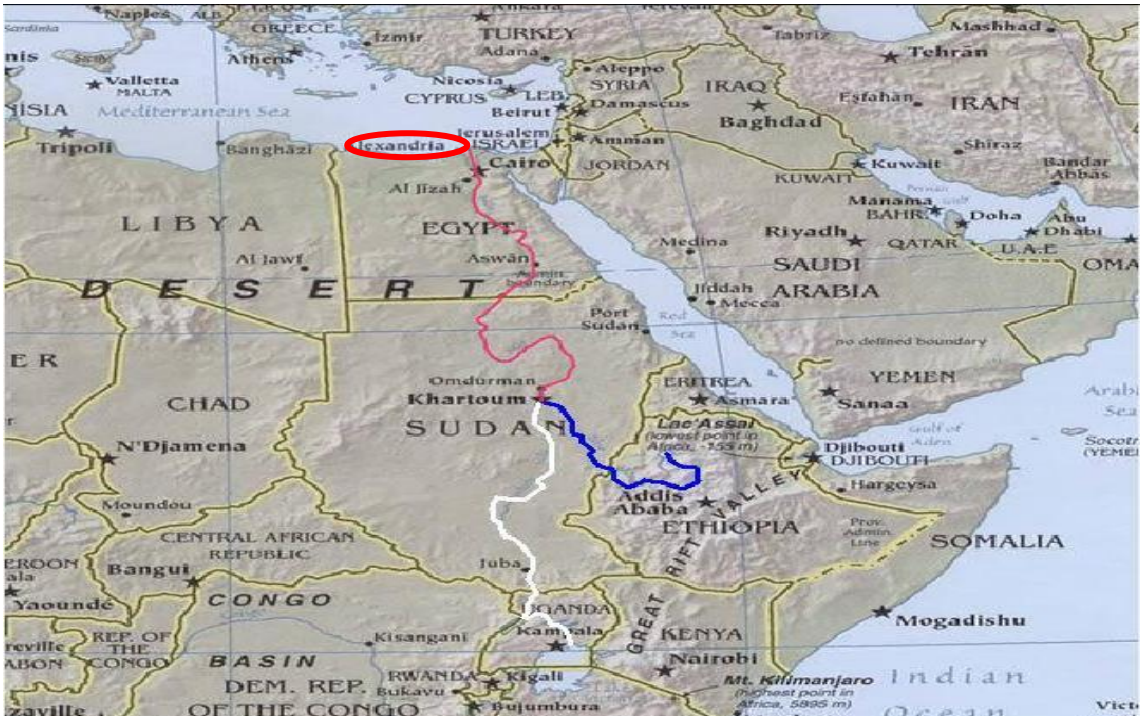
Thesis Structure	
Chapters 1	Introduction
Chapter 2	Background
Chapter 3	Theory and Methodology Used
Chapter 4	Findings and Discussion
Chapter 5	Conclusions

2 Background

2.1 Nile Basin and Egypt

River Nile, which is the world longest (about 6,671 km) river, is providing life to vast Nile basin for centuries. It has two main sources the While Nile which rises at Lake Victoria and the Blue Nile which generates in the Ethiopian highlands. Both Blue and White Nile meets at Khartoum, Sudan and flow northwards in to Egypt and then ends into the Mediterranean Sea. The whole river basin has an area of 3,349,000km2 (NBI, 2009), which is shared by nine other countries with Egypt, where Egypt is the most downstream country.

Figure 2-1: Overview of Nile Basin



Egypt, the" land of civilization" is located in the northeast corner of Africa and partly in south-western Asia. It is bounded in south by Sudan, from east by Red Sea with about 1,941 km and Palestine and Israel. In the west it share border with Libya and Mediterranean Sea bounds Egypt from north. Its geographical coordinates are 27 00 N, 30 00 E and has a total area of around 1 million square kilometers of which desert and uninhabited lands represents about 95 %(EEAA, 2008). The total population of Egypt is about 75 million; Alexandria is second densely populated city after Cairo. More than 95% percent of Egypt's population resides along River Nile (Shalaby & Tateishi, 2007). Nile Basin represents about 326,751 square kilometers in Egypt, which reflects dependency as much as 96.9%, higher than any other Nile riparian country (Karyabwite, 2000). And this is why it is widely documented that "Egypt is gift of Nile".

Although Egypt is located in low water availability climatic zone but still it is Africa's largest water consumer i-e 61.7km3/year (UNEP, 2008). The average per capita water consumption based on estimates is 210lit/cap/day (FAO, 2003). Agriculture sector get about 85% of the available water share, which also contribute to 18% of the gross domestic products (GDP) and accounts for about 31% of the total employment. There is growing pressure on the freshwater resources; the current nationwide figure of available per capita freshwater resources is 1000m3/year (Attia, 2004), which would mean that Egypt is a water scarce[1] county.

2.1.1 Alexandria:

Alexandria is one of the oldest cities in the world, founded in 331BC by Alexander the Great and remained the capital of Egypt for over 1000 years (Aziz, 2002). It is one of the most downstream cities located in the north western border of the Nile Delta. Alexandria is bordering Mediterranean from the north, Al Beheira Governorate from the south, Abu Qir Bay in the east and El Hamman town in the west. Administratively Alexandria Governorate consists of three cities i-e Alexandria, Borg El Arab City and Centre and New Borg El Arab.

The Temperature ranges from 19 Celsius in January till 30.5 Celsius in August. Monthly mean relative humidity varies between a minimum of 64.7 % in April to a maximum of 71.3% in July, average wind speed is 13km/hr. Average annual rainfall ranges between 170-190 mm in coastal areas, with highest rainfall in one day is 64.4mm (SWITCH, 2007).

The population is 4.281 million but being an attractive summer destination for the tourists it attracts 2 million people in summer, Total area of Alexandria is 2680 square kilometres and is divided into six districts i-e Montazah district, Eastern district, Middle district, Western district, Customs district, El-Ameriah district. There are 30 informal settlements in Alexandria, which are inhabitant by1.36 million inhabitants, 9 in Al Montazah district, 8 in Amiriya district, 5 in East district, 2 in Central district, 5 in West district, 1 in Borg Al Arab Markaz and City (SWITCH, 2008). Out of the total area water represent 8%, agriculture 27%, desert 53% and urban area is about 12% (Helally & Kassem, 2009).

2.1.2 Study Site Description:

To carryout this study, fours sites highlighted in figure 2.2 where selected. The four sites chosen for this study are based on their administrative status with different poverty level of the inhabitants living in those sites.

[1] When per capita freshwater availability is less than or equal to 1000 m3/year, country is termed water scarce country, and less than 1700-1000 m3/year is termed as water stress condition,(Karyabwite, 2000)

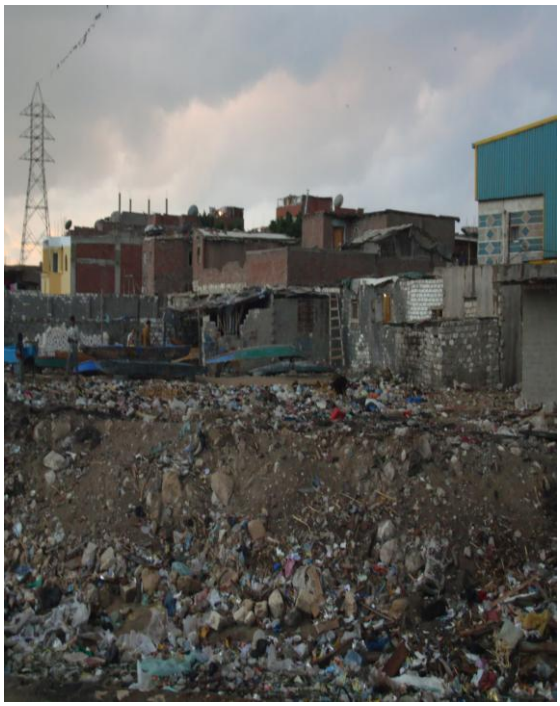
Figure 2-2: Map of Study Site

A short description of the study sites selected for this study is given below.

2.1.2.1 Samouha

Samouha is like the heart of Alexandria, it is one of the modern areas of Alexandria. It is covered mostly with shopping centre, hotel and huge residential building. Samouha has an area of about 920,000m2 and its population is approximately 31,000 people. Most people staying in Samouha are comparatively rich. Residential areas are expensive and 100% of the houses are connected to water supply and sanitation lines.

Figure 2-3: Ma'wa El Sayadeen (Dec, 2010)



2.1.2.2 Ma'wa El Sayadeen

Ma'wa El Sayadeen is a Peri-Urban area, located next to the Lake Maryout. Its area is about 65 feddans~ 273,000m2. the estimated population is about 10,564 inhabitants. It is surrounded by Highway entrance from the East, by Lake Maryout from the west, Tarek Street from North and Elkabbary Road from the southern border.

Almost all people are connect to water supply connection, till now the domestic sewage was entering lake Maryout (Box 1) through a local build up sewage line, but now an on going project is in operation phase to connect them to the main sewage line. Up to now there is only one locally build main sewer line, which flows into the lake Maryout without any treatment.

2.1.2.3 Abo Soliaman

Abo Soliamon is a small informal town in the East of Alexandria, its area: 270,000m2 and has population of about 12,500 inhabitants approximately. Almost all houses are connected to water supply and sanitation network. It appeared during the community interviews that people were not satisfied from the water supply and sanitation services.

2.1.2.4 Ezbet Abdel Moniem

Ezbet Abdel Moniem is another small informal settlement, just next to El-Nozha water supply Company. It has an area of about 370,000m2 and its population is approximately 6000 people. It has narrow streets with mostly three floor congested building. Most people have started living here since 1970s and are relatively poor people.

All the above sites described above are receiving water from the Alexandria Water Company and most receives sanitation services from Alexandria General Organization for Sanitary Drainage.

2.2 Alexandria Water Supply System

Alexandria has a history of private water supply system, but in 1961 the water supply companies were nationalized and became a general authority. Later in 2004 it became company named Alexandria Water Company which is under a centralized Holding company of water and wastewater (El-Din et al., 2009). Alexandria is the only exception where Wastewater Companies are separate from water supply companies. A schematic diagram of Alexandria's urban water system is shown in figure 2.4. As shown in the diagram Alexandria is receiving fresh water mainly from Mahmoudia canal, which is located at the northern edge of Baheira Governorate. Mahmoudia canal is 77.1 kilometres long freshwater canal and also irrigate a net area of about 55,020 ha (El-Shorbagy, 2000). The total area served by Mahmoudia canal is about 117,600 ha in both Alexandria and Beheira governorate (see figure 4.2). After entering Alexandria the water passes through eight water treatment plants before reaching to consumers, which are listed in the table below. In Alexandria water supply companies are producing about 2.5 to 3 million m3 daily, which varies in different season. Like in summer due to huge number of tourists, the water demands increases and thus the production too.

The major water treatment companies are shown in figure 4.2 later in chapter 4.

Table 2-1: Water supply companies and their production capacity in Alexandria

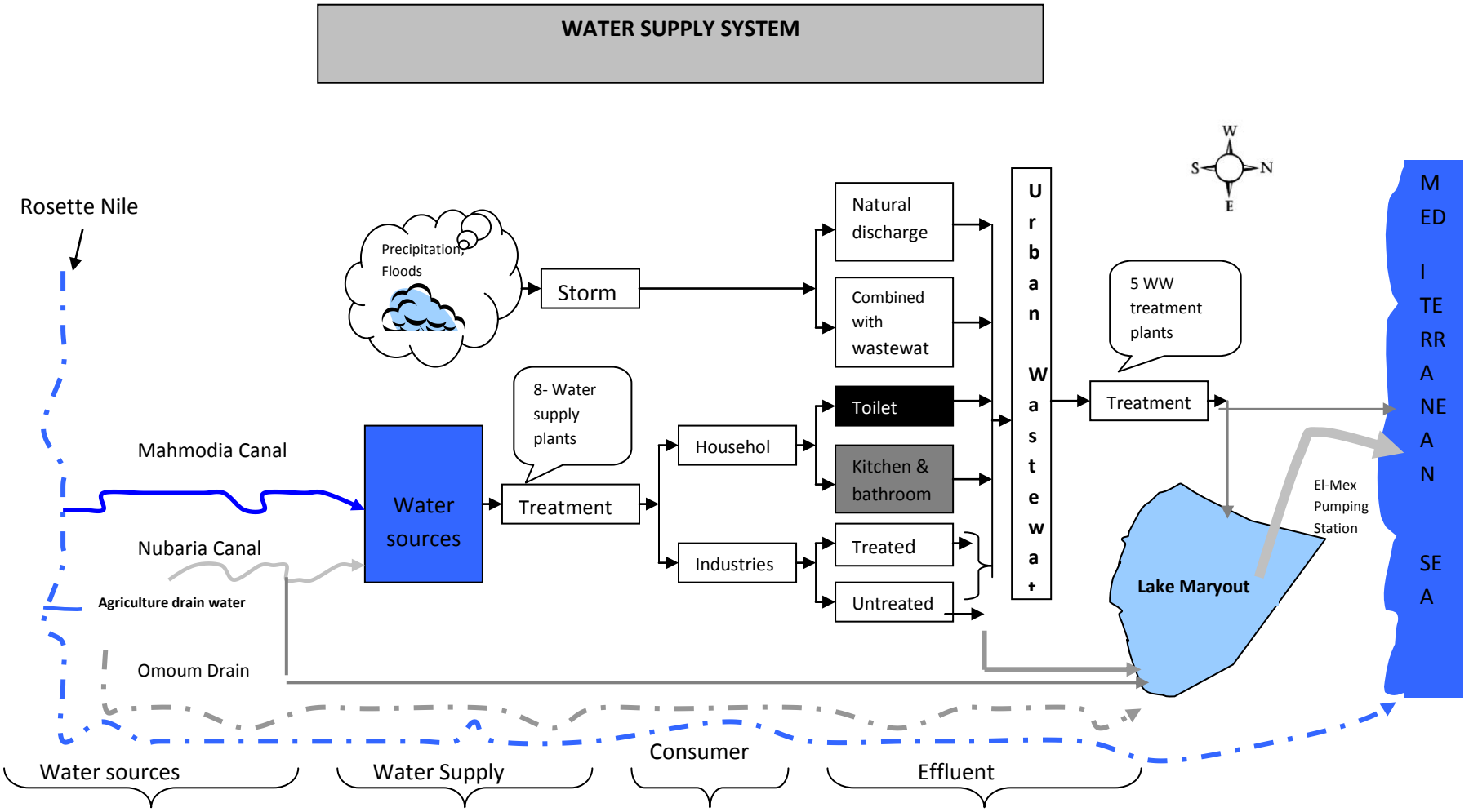
Water Treatment plant	Production(m3/day)	Water Treatment Plants	Production(m3/day)
El Sayouif	940,000	Rond Point	620,000
El Mamoura	240,000	Forn el garia	50,000
El Nozha	200,000	Borg el ararb	566,000
El Manshia	380,000	El Noubaria	510,000

Source: (WDMS, 2009)

The urban wastewater in Alexandria is the combination of storm water, household wastewater and industrial wastewater. Most of the urban wastewater either directly or after treatment enters to the lake Maryout. About 47000m3/day of industrial wastewater is directly discharged into Lake Maryout (Mahgoub, 2007), from where it is pumped out to Mediterranean Sea through El-Mex pumping station.

Alexandria being the most downstream governorate on the River Nile is receiving fresh water only from Tratul Mahmoudia canal. Water stress is growing due constant population growth, labor influx and expansion of agriculture land. Further more freshwater sources are under constant thread of point and non point source pollution. This has raised water quantity concerns among the water user, Already there are serious water shortage for the additional reclaimed agriculture land in upper Nubariya. All this reveals that future water competition is inevitable.

Figure 2-4: Alexandria Water Supply System



2.3 Water Competition

The growing demand of agriculture and domestic water use has resulted in water competition. The Alexandria Water company's data shows that in last four years 28.4 million m3 of water production has increased (El-Din et al, 2009). Agriculture water use is also increasing, The General Authority for Rehabilitation projects and Agriculture Development (DARPAD) is planning to reclaim about 287,000 Feddans (equal to 120,540 m2) under its agriculture expansion policy, which would require at least an estimated 1.6 billion m3/year (Kassem & Hillaly, 2009). Also traditionally farmers are free in what to grow and are getting free of charge water (MWRI, 2005). The Agriculture sector has also the blessing of government, because agriculture sector accounts for about 20 % of the country's GDP and about 34% of the population employments (Kassem & Hillaly, 2009).

Fresh water contamination due to open discharge of partially or untreated waste water is another striking issue limiting the availability of freshwater. It is estimated that overall shortage for 2015 is about 1.6 billion m3/year.Under such circumstances where freshwater demand is growing, freshwater is declining and ground water is saline being a coastal city, reusing urban wastewater for non potable purpose could reduce water competition to large extend. But wastewater reuse along side the technical dimension requires the financial support and social acceptability to reuse it.

2.4 Alexandria Wastewater

Currently Alexandria is producing about 1.4 Million m3 urban wastewater per day, the need increases up to 1.9 Million m3 per day in summer. If the population growth remains same it will reach to 3.2 million m3 in the year 2037 (Kassem & Hillaly, 2009). As shown in figure 2.4, wastewater in Alexandria is the combination of household wastewater, Agriculture drain, industrial wastewater and storm water. Total Industrial wastewater flow is about 308,000m3/day, which makes about 5% of the total wastewater discharge in Alexandria. Domestic wastewater contributes a huge portion to the total wastewater produced.

There are four operating wastewater treatment plants in Alexandria, and eight proposed plants. The operational ones are briefly described below.

2.4.1 East Wastewater Treatment Plant

East wastewater treatment plant is the first biggest primary treatment plant established in year 1993; with a peak capacity of 525,000 m3/day.East wastewater treatment plant daily receives 450,000 m3 of industrial wastewater, with 50,0000m3/day of industrial wastewater which makes about 10% of the total industrial wastewater generated (Kassem & Hillaly, 2009). As reflects from its name East wastewater treatment plant provides services to eastern zone of Alexandria. The treatment processes that take place in this plant are coarse screening, grit removal, primary clarification, scum removal and pumping of sludge to West wastewater treatment plant (Kassem & Hillaly, 2009). The effluent from the East wastewater treatment plant end in the lake Maryout

through El-Qala drain, though it does not comply the National Standards codes of open water discharge, set as per the article 66 of the Law 48[2] for the year 1982.

2.4.2 West Wastewater Treatment Plant

The West wastewater treatment plant also started operating in year 1993. It was designed for the capacity of 462,000m3/day with a peak design capacity of 719,000 m3/day. West wastewater treatment plant receives about 350,000 m3 of wastewater daily, with 210,000 m3/day of industrial wastewater which makes about 66% of the total wastewater the plant is receiving. The service area ranges from western and central zone of Alexandria. The process that are carried out in West wastewater treatment plant are coarse screening, influent pumping, grit removal, immediate screening , primary clarification, scum removal, and sludge pumping(Kassem & Hillaly, 2009). The effluent quality of West wastewater treatment plant also does not meets the nation standards for reuse, and its discharge point is also Lake Maryout.

2.4.3 Iskan Moubarak

Iskan Moubarak is the first secondary wastewater treatment plant established in 2005. It is located in Amriya district (see map 2.2). It has a design capacity of 15,000m3/day. This treatment plant is using advance treatment technology for treatment like Micro Filtration Membrane, Extended Aeration Activated Sludge method[3] using mechanical surface aerators and the same Extended Aeration Activated Sludge method using diffuser and blowers (Kassem & Hillaly, 2009). As shown in the table effluent of the treatment plant is in compliance with Article 66 of the Law 48 for the year 1982. The effluent of this wastewater treatment plant discharges into El Amriya drain without any reuse.

2.4.4 El Hannovile

This treatment plant is located in Hish district in the south near Dekhila port. Its design capacity is 50,000m3/day. The treatment plant is secondary treatment plant with the type of treatments of Extended Aeration Activated Sludge using mechanical surface aerator and using diffusers and blowers (Kassem & Hillaly, 2009).

Other treatment plant under construction and planned like Km 26, Khorshid & Zawayda, El-Seiouf, New Borg El Arab are all doing secondary treatment by advance technology, and the effluent quality is as per the standard to be released in surface water.

[2] Article 66 of the Law 48 for the year 1982 forbid any discharge in to surface water if TSS, BOD, COD and Grease & Oil level is above 50 mg/L, 60 mg/L, 80 mg/L and 10 mg/L respectively.

[3] The activated sludge process is a biological wastewater treatment method in which carbonaceous organic matter of wastewater is consumed by microorganisms for life-sustaining processes (e.g. growth, reproduction, digestion, movement, etc.). The activated sludge process preferably occurs in an aerobic environment where oxygen is consumed during the utilization and degradation of organic materials and by-products of carbon dioxide and water are formed

2.5 Tariff System

Alexandria Sanitary Drainage Company (ASDCO) is responsible to collect, treat and make necessary arrangements for the safe disposal of urban wastewater in Alexandria governorate (AbuZeid & Elrawady, 2007). ASDCO is an independent and financially self-sustained organization. It is the sub-branch of Holding Company for Waste Water (HCWW), established in 2004 under Ministry of Housing. Alexandria is the only exception in Egypt where water supply and wastewater treatment companies are separate but have combine billing[4] system for both water supply and sanitation services.

The current tariff system by Alexandria Water Company (AWCO) divides the user into six categories mentioned in the table below.

Table 2-2: WES Tariff System in Alexandria

Sector	Categories	Tariff (LE)
A- Domestic	Category 1 (0-10) m3	0.23
	Category 2 (11-20) m3	0.23
	Category 3 (21-30) m3	0.25
	Category 4 (>30) m3	0.35
B- Governmental	One Category	0.80
C- Commercial	Category 1	0.70
	Category 2	0.80
D- Investment- Tourism	One Category	1.15
E- Harbour	Category 1	12.0
	Category 2	24.0
	Category 3	28.0
F- Social gathering places like religious centers, youth centre etc	Category 1	0.21
	Category 2	0.42
	Category 3	0.48

Source: Adopted from El-Din et al., 2009

As shown in table domestic user pay 0.23 Egyptian ponds (LE) for the first 20m^3, then from 20 m^3 to 30 m^3 the rate increases to 0.25 LE and beyond 30 m^3 the rate remains 0.35 LE ponds (El-

[4] Water supply and Sanitation bills are collected in one bill after each two month and then 50% of this bill goes to water supply and 50% to wastewater treatment company

Din et al., 2009). During the interviews conducted it revealed that on average a household was paying about 15 to 20 LE per month for both water supply and sanitation services. For the government owned places the rates are even higher as that for commercial users that is 0.70 to 0.80 LE per cubic meters. Religious places, youth centers and other social gathering places the rates ranges from 0.21 till 0.48 LE per cubic meter. For tourism water use the tariff is 1.15 LE for every cubic meter of water. Harbor pays the highest for water use that ranges from 12- 28 LE per cubic meter.

2.6 Organizations

Water and wastewater management includes a bunch of organizations, managing different aspects of water and wastewater. In Alexandria various organizations involved in water and wastewater management are:

2.6.1 Ministry of Water Resources and Irrigation (MWRI)

MWRI is a leading ministry responsible for water management in Egypt. The most important responsibility of this ministry is to manage the Nile River through out the Egypt and it prudent distribution for irrigation, transportation, power generation, urban-rural and industrial uses navigation, fisheries, coastal ecosystem etc. It also issues license for the discharge a certain quantity of wastewater into inland waterways. But often the industries violate the standards (Kassem & Hillaly, 2009). The Ministry handles the water quality monitoring through National Water Research Centre (NWRC), NWRC further use three research institutions to carry this task. Drainage Research Institute is monitoring the quality of drainage water in the Nile system and has developed guidelines for drainage water reuse. Nile Research Institute (NRI) is responsible for monitoring water quality in the Nile river channels, enforcement of pollution control laws affecting the Nile system, assessing and evaluating the new developments that might affect Nile's water quality and operation & maintenance of Nile water quality database. For the ground water quality the Research Institute for Ground Water is responsible (Kassem & Hillaly, 2009).

2.6.2 Ministry of Agriculture and Land Reclamation (MALR)

MALR is also an important government body in managing water resources, since agriculture accounts for 85.6% of the consumptive water use (EEAA, 2009). MALR is responsible to predict crop water need, so that on the base of which MWRI can allocate water, and is working jointly with MWRI in irrigation and drainage improvement projects. MALR is also involved in research on water quality management, policies development for fertilizers use, soil type and monitoring soil and water quality for irrigation through Soil, Water and Environment Research Institution (SWERI) (Kassem & Hillaly, 2009). MALR position is critical in terms of the limited resources of water ability and liberalization of agriculture sector, where farmers has free hand what to grow, and their decisions on what to grow is mostly market driven rather than government policies.

2.6.3 Ministry of State for Environmental Affairs (MoSEA)

From quality aspects of wastewater MoSEA is one of the most important government bodies. MoSEA through its supplementary Egyptian Environmental Affairs Agency (EEAA) which was established under environment law 4/1994 enforces compliance of national environment, health and safely regulations (Kassem & Hillaly, 2009). This is usually carried out in coordination with other government bodies particularly with Ministry of Health and Population. EEAA is responsible

to monitor if industries are obeying the environmental regulation to reduce pollution or not. In case of noncompliance it has the right to issue fines. But this becomes difficult for small industries, usually this does not apply for small industries and also they are rarely monitored. Also due to lack of available resources EEAA of Alexandria governorate are also responsible for Matroh and Bahera governorates (see figure 4.2).

2.6.4 Ministry of Health and Population (MHP)

Ministry of public health is playing a key role in setting quality standards for all water resources in Egypt. Addition to this The Environmental Health Department (EHD) under MHP and The Environmental Monitoring and Occupational Health Center (EMOHC) has different sampling sites to analyze effluents of industries, municipal and wastewater treatment plants (Kassem & Hillaly, 2009).

During the interviews it appeared that data sharing, repetition of the same data collection and coordination among governmental bodies were the key concern.

2.6.5 Ministry of Industry and Mineral Wealth (MIMW)

The General Organization for Industrialization (GOFI) and Environmental Management Department within the MIMW are in charge to control industrial pollution and provide environment friendly and compliance advices under law 93/1962 and its amending Decree 9/1989 regarding pre-treatment of industrial effluent before it contaminate surface water (Kassem & Hillaly, 2009).

2.6.6 Ministry of Housing New Communities and Public Utilities (MHNCPU)

In Egypt unlike many other countries MHNCPU is overall responsible for planning and developing water supply and wastewater treatment facilities. For Alexandria unlike to other governorates where water supply and sanitation services are responsibility of one company, the case is different. Alexandria General Organization for Sanitary Drainage (AGOSD) is responsible for sanitary services while The Alexandria Water General Authority (AWGA) is responsible for water supply (Kassem & Hillaly, 2009).

Addition to the mentioned ministries Ministry of Transport and Ministry of Tourism also play their role to maintain the in-stream flows in the Nile River to provide sufficient depth for commercial and recreational navigation as well as to preserve its aesthetic value too. Ministry of Interior in coordination with line ministries assists in enforcing laws upon request (Kassem & Hillaly, 2009). Beside all above mentioned ministries, three committees i-e Supreme Committee of Nile, Coordinating Committee of Land Reclamation and Inter-Ministerial Committee of Water Planning has been established to ensure coordination among different stakeholders. Addition to this in 2004 under the Presidential Decree Holding Company for Water and Wastewater (HCWW) was established with a responsibility to provide safe drinking water and sanitation services in Greater Cairo (Cairo, Giza, Qalyoubiya) and Alexandria. There are 21 companies functioning under HCWW; most companies are in charge of both water supply and sanitation while in Alexandria it is an exception, where drinking water companies are separated from sanitation companies.

2.7 Water and Wastewater Related Legislation

Article 17 of 48/1982 and Law 12/1984 gives the responsibility of Egypt water resources management to Ministry of Water Resources and Irrigation. While Law 4/1994 on environmental Protection gives influential right to the Ministry of State for Environment Affairs and its subsidiary body the Egyptian Environmental Affairs Agency over the water quality management through Law 4/1994 on environmental Protection (Kassem & Hillaly, 2009).

There are two main legislations for the protection of water and environment in Egypt. The first one is law No. 48 for the year 1982 on the protection of River Nile and watercourses from pollution and the second important legislation is the Law No. 4 for the year 1994 (Kassem & Hillaly, 2009). Other laws regarding governing water management are:

2.7.1 Water Quality Management

The basic legal structure for water quality matters is provided by Law 12/1984 and its supplementary Law 213/1994. The law provides legal direction for the use and maintenance of public and private canals and specifies arrangements for cost recovery in irrigation and drainage works (Kassem & Hillaly, 2009). In addition to Nile surface water delivery this law also concern coastal protection, navigation, flood control, ground water and drainage water.

2.7.2 Protection of Nature Regulation

The Nature protection has the legal support of Law 102/1983 that describes the natural protection areas and avoids any actions that may lead to devastation of the natural environment. This also includes marine and freshwater, and proscribes fines and penalties for violators. Through this law the Government can pursue damage assessments for harms to the environment (Kassem and Hillaly, 2009).

2.7.3 Wastewater Discharge Regulation

The Law 93/1962 controls the discharge of wastewater in sewage systems and provides standards for the effluent to be discharged (Kassem & Hillaly, 2009).

2.7.4 Water Resources and Wastewater Treatment Regulation

Public sources of drinking water are regulated by Law 27/1978. The Ministry of Health and Population is responsible through this law to set standards for drinking water (Kassem & Hillaly, 2009). Ministry of Health and Population is also responsible to set standards for wastewater reuse.

2.7.5 River Nile and Its Waterway Protection Regulation

For the protection of River Nile and its waterways from the discharge of waste and wastewater, Law 48/1982 regulates the effluents that enter to River Nile and its waterways by sets standards for the quality of effluents. This law also identifies the responsibilities of the MWRI and the MHP in monitoring the effluents quality into the Nile River and also its associated drainage system, lakes and groundwater, to ensure that water quality standards are met (Kassem & Hillaly, 2009). This Law also authorizes Ministry of Health and Population to carry out periodic sampling and analysis of wastewater.

2.7.6 Environmental Protection Law

Egyptian Environmental Affairs Agency has legally supported by Law 4/1994 that describes its roles and responsibilities funding source through the Environmental Protection Fund. The law

authorizes use of incentives for managing the environment and supports the provisions of Law 48 regarding the management of water resources (Kassem & Hillaly, 2009).

2.8 Knowledge Gaps:

Many studies have been carried out in Alexandria addressing water supply and sanitation issues but none of them addresses freshwater swaps in a common pool context. There are growing concerns of water competition between agriculture and urban water use, particularly over the water of Tarat ul Mahmoudia canal. Tarat ul Mahmoudia canal is a solo source of freshwater in Alexandria but a huge amount of water is extracted in the upstream for agriculture practices. There is growing demand of water from the same source for both agriculture and urban water supply. Simultaneously wastewater production is also growing in Alexandria with increasing urban water demand, as a common rule of thumb about 80 % of domestic water supply converts into wastewater (Kurian, 2010). The negative affects of this wastewater on the surrounding environment and more particularly on the ground and surface water sources and health has created alarming situation in Alexandria. Currently in Alexandria, Lake Maryout is the wastewater discharge point in Alexandria of about 95% of the urban wastewater, which has badly affected the income of many poor fishermen.

Considering the above mentioned circumstances this research intends to explore the potential for freshwater swaps in Alexandria under three components. The first is the assessment of increasing demands for freshwater and ultimately wastewater production in Alexandria, secondly cost recovery challenges in wastewater treatment and lastly the public perception about wastewater use.

The list of some of the previous studies conducted in Alexandria are given in table 2-3, this chapter is followed by Theory and Method Used chapter, which basically the literature review and discusses various methods used to conduct this study.

Table 2-3: Previous Relevant Studies

Studies	Description	Objectives	Outputs
El-Din (2009)	Water Demand Management Study(2008)	Feasibility Study for Integrated Urban Water Management	Strategy: developing sceneries for future water needs.
European Investment Bank (2000)	Alexandria Effluent and Sludge Reuse Study	Feasibility study and outline design for effluent reuse system	Strategy: Wastewater Reuse for Agriculture
Abdrabo & Martin	Social Inclusion & water services planning & delivery in Maw'a el Sayadeen, Alexandria Egypt	Feasibility study on community demands	Policy: Development priorities for poor communities
The World Bank (2007)	Integrated Environmental & Social Impact Assessment (IESIA)	Ensuring sustainability in wastewater management	Strategy: Providing alternatives for urban sewage mainstreaming environmental consideration
Mahgoub (2007)	MSc-Thesis, Prioritizing Actions in Alexandria's Urban Water System Based on Life Cycle Approach	Possible scenarios for improving environmental performance system	Policy: guidance about full life cycle consequences of the system.

3 Theory and Methodology Used

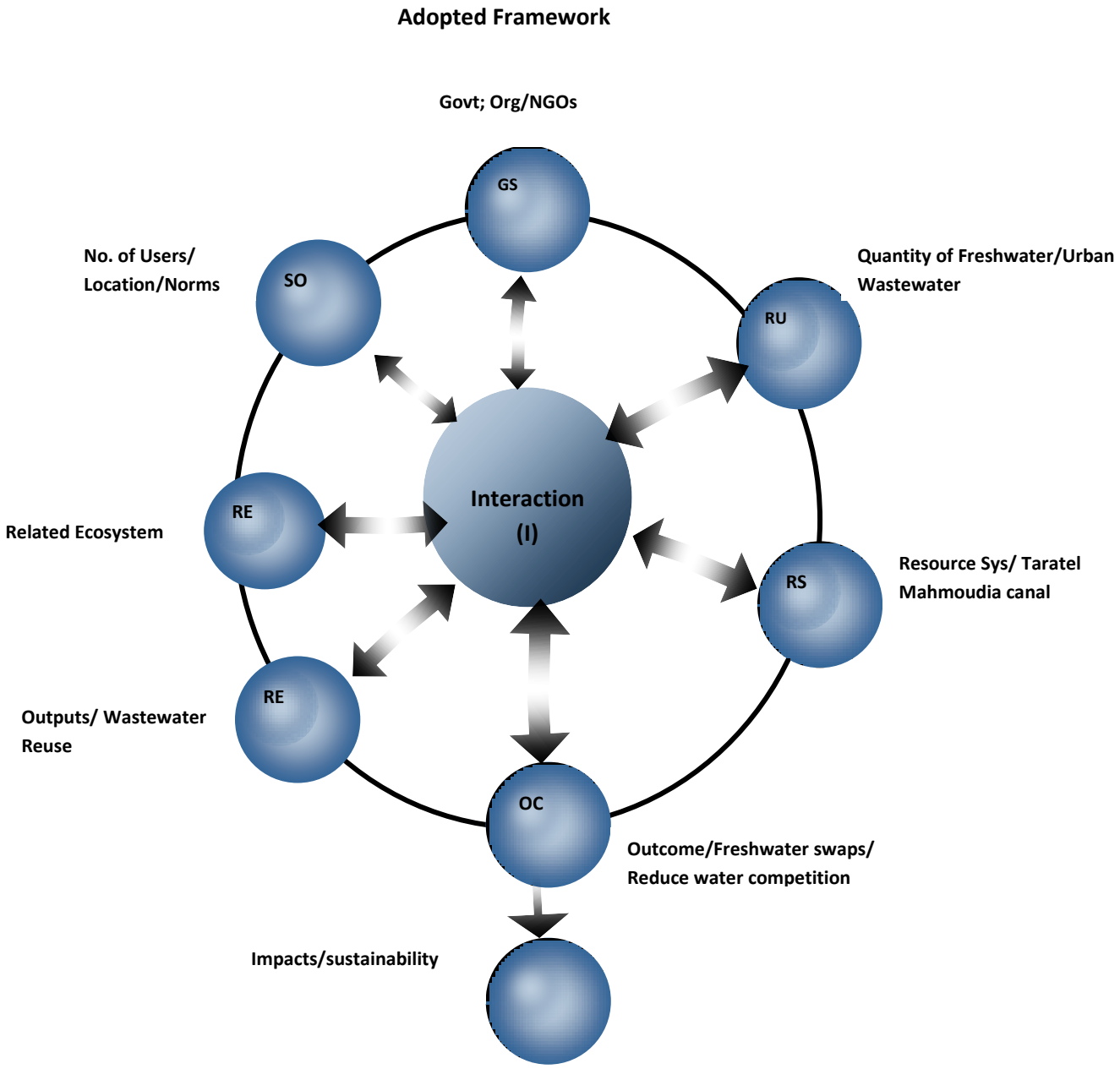
3.1 Theoretical Approach

Wastewater reuse for non-potable purposes is an old practice; particularly recent research shows high potential of wastewater reuse for agriculture (Kurian et al., 2009; Rijsberman, 2004; Ensink et al., 2002). Recently many governments and policy makers started reassessing their water related policies due to the concerns of freshwater shortage because of constantly deteriorating freshwater sources by the inflow of untreated urban wastewater, public health concerns, increasing demand of water for both growing population and agriculture water use and similarly water competition among various water competitors. Recently many countries have had water supply and sanitation related policy changes, which is a part of change in policy paradigm (Menahem, 1998), but the sustainability of those policies can be still questioned, if various water related interdependent variable at multiple levels are not properly assessed and incorporated in to policies. Therefore wider boundaries of problem definition in consultation with all stakeholders is required in policy analysis the of resources like water, where other organizations and actors whose concurrence is necessary in implementation (Gordon et al., 1977)

Water carries different values like economic, social, religious, cultural, environmental and aesthetic which are interdependent and are shared among different users (Keremane, 2007). Many scholarly articles suggest state interventions as a solution to protect water resources while others recommend privatization as solution. Historically communities relying institutions has successful stories of sustainably managing water resources (Ostrom, 1990). Water due to its nature is a complex socio-ecological system which is composed of multiple subsystem and internal variables. Understanding such complex Socio-Ecological Systems (SES) i-e water resources requires a brief analysis of specific variable and understanding of their interrelation. For this it is crucial to have knowledge about specific variables, how they are interrelated and to learn how to dissect and harness those variable (Ostrom, 2009).Though the process of identify the entire variable at various level and analysing their interrelationship is complicated and time consuming, but this can help in achieving sustainable policies.

A framework is essential for data collection, fieldwork and analysis of the finding particularly to organize various set of variables. Ostrom (2009) presented a general framework pointing to four main subsystems of an SES that connects social, economic and political settings with related ecosystems. The subsystems are the resource systems, the resource units, the governance systems and the users. Each subsystem is further composed of several second-level variables (Ostrom, 2009). Adopted framework from Ostrom (2009) with slightly modification will be used in this study.

Figure 3-1: Adopted Framework for Studying Socio-Ecological Systems



Source: **Adopted from Ostrom, (2009)**

The figure provides an overview of the adopted framework form Ostrom (2009). For this study the resource system (RS) is the Taratel Mahmoudia canal, which is a freshwater source for Alexandria. Resource Unit (RU) is the quantity of freshwater extracted from Taratel Mahmoudia for various uses. Many governmental organizations which are described in the background chapter are playing key role in managing water services by developing constitutional rules[5],

[5] Level of decision or choices made at higher level (laws etc) of whether to retain or change a status quo rules

collective choice rules[6] and operational rules[7] for managing water resources. The users of resource, their number and behaviors play crucial role in using and reusing resources. The related ecosystem in which a resource system is functioning can not be detached because they are all interlinked (Ostrom, 2009). The overall objective of using this framework is to assess the potential of wastewater reuse and ultimately the freshwater swaps. A result chain approach of output[8], outcome[9] and impact[10] is also incorporated in to this framework.

3.2 Key Concepts and Theories

3.2.1 Common Pool Resources Management

Common pool resources as defined by Ostrom (1990) are "natural or man made resources that is sufficiently large as to make it impossible to exclude potential beneficiaries from obtaining benefits from its use". She further adds that it is essential for managing common pool resources to distinguish between resource system, resource unit and their dependency.

Resource systems are defined as "stock variables that are capable, under favourable conditions, of producing and maximum quantity of a flow variable without harming the stock or the source system itself". Resource units are "what individuals use from resource systems" (Ostrom, 1990). So as per the definitions, in this study the Tarat ul Mahmoudia canal in Alexandria is the resource system and various actors and users are the resource units.

Since CPRs are shared in use by more than one user therefore its maintenance and improvement is also requires a collective responsibility. In many settings the users of CPRs provides better solutions to their problems, but it also depends on the benefits attached to the resource system. Usually users of CPRs give preference to short term immediate benefits that mean high discount rates so less future value therefore the users will imprudently over extraction of resources immediately as much as they can.

In CPRs situation user are interdependent, they are jointly affected by the actions of each other which leads the users to collective actions for managing the CPRs. Managing CPRs requires knowledge and time appropriation, otherwise resource may fall in short supply if timely actions are not taken. A collective action is also required because of the different type of users and different income level of the users, for example in case water resource, if it deteriorates or fall in short supply, for many users it may not be economically affordable to get water from a private expensive source. This will also stimulate water competition, which could possibly be overcome

[6] Level of decisions or choices made at intermediate level (regulations etc), usually collective choices are made in support of constitutional choices.

[7] Operational choices or rules at the consumer's level, like what mechanism should be adapted to get high cost recovery.

[8] Immediate results after finishing the job/project

[9] Intermediate results within 2 to 5 years of finishing the job/project

[10] Long-term results may take 5 to 10 years

by exploring new water resources or even reusing wastewater for non potable uses after dilution with freshwater and groundwater, which is also termed at conjunctive water use. Conjunctive water management[11] approach is not limiting to any political or institutional boundaries, its not "one-size-fits-all" approach. It may vary under different circumstances (Dudley & Fulton, 2006).

Governments usually use tools like taxes, incentives, tariffs or transfers etc through various laws and regulations to manage common pool resources. But historically the community itself has played vital role in manages such CPRs through their informal institutions. Ostrom (2009) has mentioned certain variables relevant to this study that directly effect likelihood of community to manage CPRs are:

3.2.1.1 Resource Size and Users

The size of resource, which in this case is Mahmoudia canal directly effect the management of resource. Larger the size of resource, most probably larger will be number of resource users. In case of rivers and canal the type of users like agriculture, domestic and industrial is another challenge in the way of its management.

3.2.1.2 Resource Mobility

The mobile nature of resource makes it difficult to manage. Resource like running water in canal or river where there is less interaction between the upstream and a downstream user makes it less likely for the community to manage.

3.2.1.3 Productivity of System:

The productive nature of resource system plays an important role in resources management. Community or governments have to first see some scarcity or decline in fish number in case of water resources before they react.

3.2.1.4 Social Norms and Knowledge about Resource

Knowledge about the recourse and knowing the importance of resource plays vital role in CPRs management. Addition to this user's behavior as a group and mutual trust to prudently use resource is equally important. Social behavior or norm appears in the form of informal institution that has deep roots in every society.

3.2.2 Theory of Institution

Wastewater management though occupies a prominent place in water management polices but still there is lack of a common wastewater reuse regulation. This is mainly due to varying social and economic condition, and because those different states address different policies towards wastewater reuse considering many factors that are state-specific (Keremane 2007). Despite the availability of various wastewater quality standards, in many developing countries still untreated wastewater are used and the regulatory agencies can hardly enforce the available standards (Ensink et al, 2002). It means that developing wastewater standards and providing technological solution can not solve the challenge of wastewater management. Societal and institutional aspects are both crucial for ensuring long term sustainability. Supporting this Livingston et al,

[11] Conjunctive water management incorporates ground water monitoring and evaluation too, there its slightly different from conjunctive water use.

(2004) adds that "successful implementation of new approaches to wastewater management is a multi-faceted challenge requiring input beyond mere technology".

In this section I intend discriminate between institutions and organizations, and formal and informal institutions. It is important to distinguish between institution and organization because usually the terms 'institutions' and 'organizations' are so common in usage that often they are used as synonym, but in fact they have distinct meanings. Additionally both organizations and institutions are interlinked, many organizations represent certain norms which are in fact institutions and mostly organizations are influenced by institutions, like water supply companies in Alexandria are following the articulation of water related polices. For the sake of this study the distinction between institutions and organizations and their links are important because it is also within the scope of this study to analyse the institutional governing mechanisms for the urban wastewater reuse in Alexandria, Egypt.

3.2.3 Institutions and Organisations

North (1991) defines institutions as the humanly devised restrictions or the rules that shapes human action. Therefore institutions are the laws, regulations, organizations, norms, traditions and practices that develop accountability mechanisms, incentives and information to set rules for the resource use (North 1991; Macdonald & Dyack 2004; Keremane 2007). Ostrom (1990) extending the definition of Institutions defines it as "the sets of working rules that are used to determine who is eligible to make decisions in some arena, what action are allowed or constrained, what aggregation rules will be used, what procedure and what payoffs will be assigned to individuals dependent of their actions".

North (1990) argues that institutions are formed particularly to reduce uncertainty in human exchanges and are thus crucial determinants of the efficiency of markets, but he also realises that institutional changes are not easy because individuals make choices on the basis of their mental models which are culturally derived and differ widely (North 1990; Harriss et al., 1995). Adding to this and giving the historical changes reference Bardhan (1989) deems price changes, technological and changes in the cost of information are major sources of institutional changes. In the water context institution are the administrative arrangements and the rules that regulate the use and reuse of water (Macdonald & Dyack 2004).

On the other hand North (1990) defines organization as "purposive entities designed by their creators to maximize wealth, income, or other objectives by the opportunities afforded by the institutional structure of the society" (North, 1990). Keremane (2007), interpreting the same definition defines; organizations are formed to achieve certain set objective by individuals with common purpose and under defined roles (Keremane, 2007). With those definitions of organisation can be any public and private agencies. In this study the organizations managing urban wastewater is studied, particularly the water supply and wastewater treatment companies. The water and wastewater related institutions comprising both formal and informal institutions are also assessed in this study.

3.2.4 Formal and Informal Institutions

Institutional mechanisms are comprised of formal and informal institutions which are supported by organisations for production and exchange of assets (Keremane, 2007; Zenger et al., 2001). In the water supply and wastewater management context all laws, legislation, rules, administrative regulations and court decisions are considered formal institution. Formal institution can be monitored and enforced at least to some extent by those who are directly involved (Ostrom, 1990). On the other hand informal institutions are the accepted rules, norms and pattern of behaviours in a society (Keremane, 2007). Informal institutions have deeper roots in the society and are sometime more trustworthy than the formal ones particularly in the developing countries, where law enforcement is weak. A very good example of informal institution could be the *Miraab*[12] system, which is a traditional system for managing irrigation water in Afghanistan, Iran, and Tajikistan etc. Changes in informal institutions are time consuming and usually decisions on behavioural changes are based on benefits, costs, shared norms and opportunities to either support or not support the status quo rule (Ostrom, 1990). The study of both formal and informal institutions in proper way is crucial for water and wastewater governance, which is an important part of this study.

3.2.5 Water Governance

Governance is broadly referred as "the rules under which power is exercised" or in other words "the mechanisms, processes and institutions through which citizens and groups articulate their interests, exercise their legal rights, meet their obligations, and resolve their differences" (Slaymaker, 2006).Water governance on the other hand usually deals with extraction, treatment, storage, distribution within a current institution and subsequent collection and processing of the generated wastewater. Rogers and Hall (2002) defines water governance as "water governance refers to the range of political, social, economic and administrative systems that are in place to develop and manage water resources, and the delivery of water services, at different levels of society".

Historically, water is governed by societal entities with substantial government involvement but government involvement is crucial because they possess all required resources, expertise and authority to manage water resource (Keremane, 2007). Also with the emerging water issues and modern solutions, which the community might have not experience before requires education and information dissemination to all stakeholders. For example in case of conjunctive water management it is the government responsibility to establish national standard and guidelines in partnership with community and research organization to minimize the negative impacts and encourage social acceptability.

Good water governance despite of integrated water resource management (IWRM) requires the examination of the constitutional contexts to explore the demand for various kinds of information, knowledge and skills required. The polices that supports water governance requires analysis at various levels of the rules, that cumulatively affects the decision taken and outcomes obtains as a result of those decisions (Ostrom, 1990). Also bigger circle of coordination by involving all stakeholders is required for governing mobile resources (Ostrom, 2009) because a

[12] *Miraab* which laterally means " owner of water" is a person who is responsible for maintenance of irrigation system, the farmers give him/her a share of seasonal crop or cash for his/her services.

huge number of users are spread along the resource. For this study the mobile common pool resource is Tarat ul Mahmoudia canal, since this study aims to analyse the wastewater governance in Alexandria, Egypt, therefore an attempt is made to identify various dimension which are related to water governance.

3.2.6 Rural-Urban Interfaces

Since it is within the scope of this study to assess if low cost recovery is made from the Peri-urban areas due to its administrative status, therefore understanding of the rural-urban interface is important. Myint's (1964) dual economic theory that distinguishes urban sector as an engine for the economic growth or modernisation, encouraged many developing countries around the world to adopt this policy of modernisation paradigm and very little attention were paid toward the rural development. This resulted in the pendulum shifts between an urban and rural bias in development theory which lead to a striking separation between the urban and rural planning. In contrast to the previous economic development theory and with increasing awareness, later on the Urban Function in Rural Development (UFRB) (Rondinelli, 1979) approach focused on the growth of small towns as potential engines of regional economic development (Allen et al., 2009). Thus on one hand the expansion of urban industrialisation and on other hand the expansion of rural agriculture production raised challenges of governance in the rural-urban interface.

Wood (2006) has defined rural-urban or Peri-urban interface as "a particular space located between a rural and urban dichotomy (Woods, 2006). The interface emphasize as the place where changes and adjustment often take place (Wood, 2006; Allen, 2003). While other defines interface as a process in which identity and places are being contested to the expanding urban industrialisation influence and rural agriculture productions forces (Masuda et al., 2008; Kaiser & Nikiforova, 2006). At the interaction of both rural and urban forces, a growing level of conflict as the competition for interest also increases (Masuda et al., 2008). Furthermore huge number of people started living n Peri-urban areas due opportunities of non-agricultural jobs in cities, improved transportation and communication and individual locational preference (Sharp, 2002). This has resulted in prominent policy and research challenges to respond to population growth, preserving farmlands and to fulfill their demands too.

3.2.7 Decentralization

Middle East and North African countries which are believed to have a centralized system emplaced are no confronted with the question to either increase their resources to maintain the central control or adopt the decentralization policy. Both centralize and decentralize system has their pro and cons. Decentralization is widely believed as a best policy option in high level of services provision and responsiveness from the community on the matter of tariffs, taxes and monitoring the resources. The proponent of decentralization also argues that it makes government more accountable and responsive to the local needs (Faguet, 2002; Shah, 1998). On the other hand the opponents of decentralization like Crook & Sverrrisson, 1999; Smith, 1985 counter by arguing that the power should remain in the central government due to the fact that local government lack human resources capacity, technical and financial constraints which hamper the provision of appropriate public services (Faguet, 2002). Though the study of Faguet (2002) shows more investment going in the water and sanitation sector after decentralization but still the fact of lack in capacity, financial constraints and more importantly the clarity of role

and responsibility still remains a problem. For example in the case of Peri-urban interface where residence often lacks public services is mainly due to the institutional gap, which also result in low cost recovery in many developing countries.

Cost recovery from water supply and sanitation services highly depends on the tariff rate and the collection procedures. In most cases tariff setting is a political issue (Solome, 2010), Politicians wants the tariff as low as possible to get public support but on the other hand the operation and maintenance costs are regularly increasing. Usually the costs recovered are not enough for the operation and maintenance even and the water supply and sanitation companies asks for fiscal transfers from the central governments. Combine billing of water supply and sanitation is believed that it reduces a lot of paper work and brings down the administrative costs (Solome, 2010). This might be true for developed countries where water supply and sanitation have almost equally coverage while in developing countries usually the sanitation coverage is less that water supply. In this way in the combine billing system even those who are not connected to sanitation network are be paying for the services which they are not getting.

3.3 Propositions

Based on the theory discussed, this study intends to test the follow proposition.

- Scope for freshwater swaps increases when the water demand increases due to increase in population.
- The fiscal accountability is likely to be low when there is lack of government actors or there are overlapping responsibilities.
- When user share common knowledge about wastewater reuse due similar moral and ethical standards then it is likely to affect the freshwater swaps

The overall aim of propositions remains the assessment of freshwater swaps in Alexandria. The propositions are designed in such away to test, first if there is need for freshwater in Alexandra. Secondly to test the financial constraints in wastewater treatment to a level where it can be used, but from the cost recovery dimension particularly from the Peri-urban areas and lastly to test public perception on wastewater reuse. To support all the propositions research questions are designed inline with proposition.

3.4 Research Questions

The research questions designed for this study are:

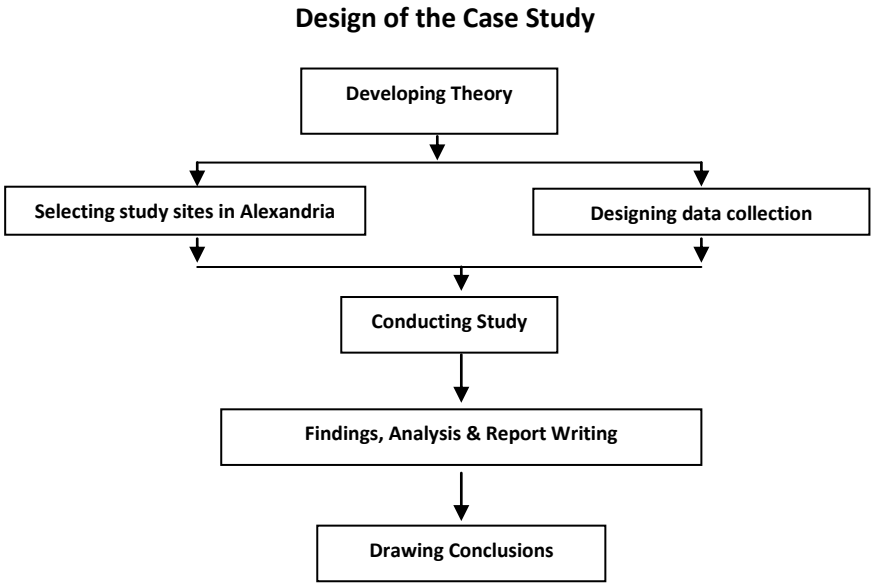
- Is freshwater availability a challenge in Alexandria?
- What is the current status of wastewater treatment and reuse?
- Is low cost recovery from water supply and sanitation services in Peri-Urban affects the fiscal accountability of wastewater treatment plants?
- What is the public perception about wastewater reuse?

3.5 Study Design

A case study strategy has been adapted to carryout this study; case study is one among many ways of conducting research. Case study research method is extensively used in thesis and dissertation research in practice-oriented fields like public policy, management science, urban planning etc (Yin, 1994). Often studies either assess qualitative evidence and methods or quantitative while case study approach brings both qualitative and quantitative evidences and methods together. Case study also helps in development of prior theoretical propositions which guides the researchers in data collection and analysis. Case study approach is more effective when research questions like "how" or "why" is being posed and when the researcher has little control over events (Yin, 1994). Various strategies like explanatory, descriptive or even exploratory can be adopted but this all depends on the type of research question posed, the researcher's extent of control over the actual behavioural events (Yin, 1994, p.4).

In this study since the focus is on formal and informal arrangements of urban wastewater in Alexandria, therefore a case study approach has been adopted. The figure below illustrates the case study method used for this study.

Figure 3-2: Study Design



Source: Adopted from Yin (1994) & Keremane (2007)

One of the important components for case study design is to describe the level and unit of analysis (Yin, 1994, p20). In this study the levels of analysis at community level, at the governorate level and at the national level. The units of analysis in this study are consumers and supplier of water i-e household's individuals, water supply companies and wastewater treatment companies, relevant water and wastewater management authorities. The focus will remain on the wastewater produces and treatment, also it is intended to analyze if the scope for freshwater swaps exists in Alexandria. Hotels and small and mediums industries water use is not part of this study.

3.5.1 Sampling Methods

Purposive sampling method is used for the primary data collection in this study. Purposive sampling is popular for qualitative research and is a form of non-probability sampling (Patton, 1990). Purposive sampling is done by keeping a purpose in mind and it is useful to reach a targeted sample quickly and where proportionality is not a primary concern (Trochim, 2006). Besides purposive sampling snowball sampling technique, which is within the frame of purposive sampling is used for selecting participants for interview and survey in four study areas in Alexandria. Snowball sampling is an approach which is used where it is difficult to locate informants in a population (Patton, 1990).This method is chosen because of the fact that in Egypt the authorities either may not have or were not will to provide information urban wastewater use. Under such circumstances this sampling technique is suitable.

3.5.2 Data Collection

For this study both primary and secondary data is collected. Secondary data is collected from the reliable sources like water companies, regional ministerial departments etc. This includes published report, scientific articles and grey literature[13]. The information received from the secondary sources is both qualitative and quantitative data. The primary data collected through developing questionnaires, semi-structured interviews both face to face and via telephone is also both qualitative and quantitative. The target group for this study is government officials, NGO's officials and community members.

3.5.3 Data Analysis

The data is analyzed inline with the study objectives. For most data analysis Ms. Excel spreadsheet is used, and the data is presented in tabular and graphical forms to observe time series and other patterns. For missing data regression analysis is used to get the best estimates. Regression analysis is widely used to predict times-series data, most commonly it helps to understand how the typical value of a dependent variable changes if the other independent variable is held fixed. Other quantifiable data like open-ended questions, interviews, focus group discussion are processed through quantitative descriptions.

All the theory and methods discussed are used in the findings and discussion chapter.

[13] The Grey literature is defined as "information produced on all levels of government, academics, business and industry in electronic and print formats not controlled by commercial publishing i.e. where publishing is not the primary activity of the producing body"(Luxembourg, 1997- Expanded in New York, 2004)

4 Findings and Discussion

4.1 Demographic Changes

Alexandria has witnessed rapid population growth in the last one century; Historic population trend shows that Alexandria's population has increased ten folds in the last one hundred year. Table 4.1 shows the how population increased over the last one century and its prediction till the year 2037.

Table 4-1: Historic population growth and future predictions

Years	Population	Years	Population
1905	370,000	1986	2,890,000
1907	390,000	1996	3,270,000
1917	487,000	2006	4,325,760
1927	673,000	2009	4,511,771
1937	812,000	2017	5,088,559
1947	975,000	2027	5,957,783
1960	1,530,000	2037	7,108,340
1976	2,290,000		

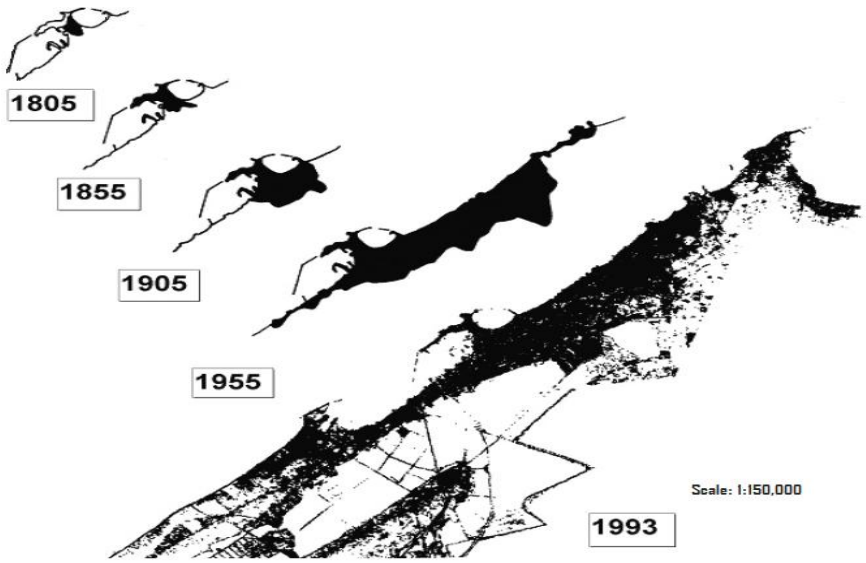
***Source**:* Historic data reference from 1905-1996, Abdou-Azaz (2003) 1986UN Demographic Yearbook 1988, (1996) (2006) Central Agency for Public Mobilization and Statistics, Egypt

Table 4-1 shows the population trend excluding summer population. Every year Alexandria receives about 2 millions tourists. The increasing population as shown in Table 4.1 has only put pressure on the available water resources but has also played vital role in shaping the present Alexandria in terms of its expansion.

4.2 Land Use Changes

Population growth in Alexandria has resulted both spatial and quantitative changes. Spatial changes appeared in the form of new features like the establishment of ports (Dekhila Port), power station (Sidi Krir), recreational villages etc. Spatial changes also appeared in existing features, like large portion of Lake Maryout is claimed to meet the accelerated demand of land for the growing population. Some parts of Lake Maryout turned to be saline to produce salt. Figure 4.1 shows the satellite image of how spatial changes occurred over time.

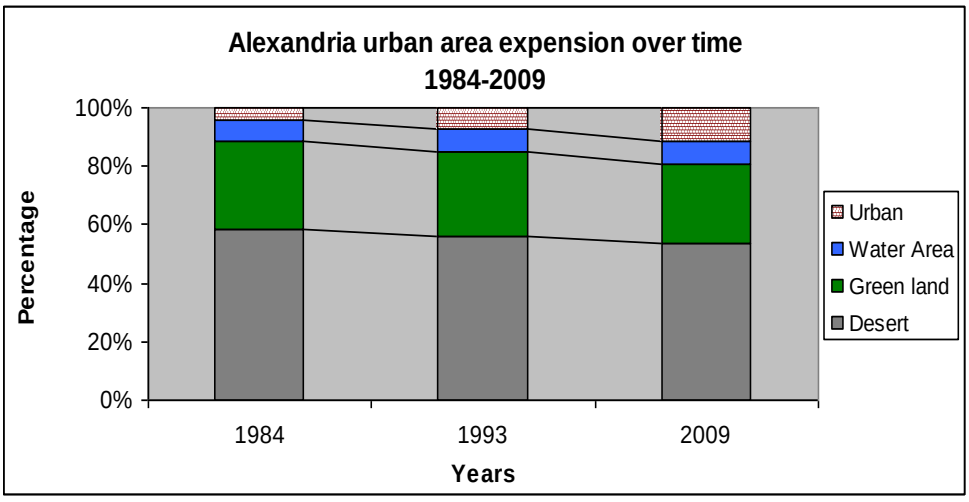
Figure 4-1: Spatial Changes Occurred in Alexandria in the last one Century



Source: **Azaz (2008)**

The centre of Alexandria also witnessed changes in its existing feature due to new developments. In the eastern part of Alexandria valuable agriculture became a victim of urban development. The observation from 1984 till 1993 shows 23.79% of green land loss, with an annual rate of 0.67 % (Azaz, 2008). The graph 4.1 below shows how the land distribution changed over time.

Graph4-1 Alexandria Land Distributions



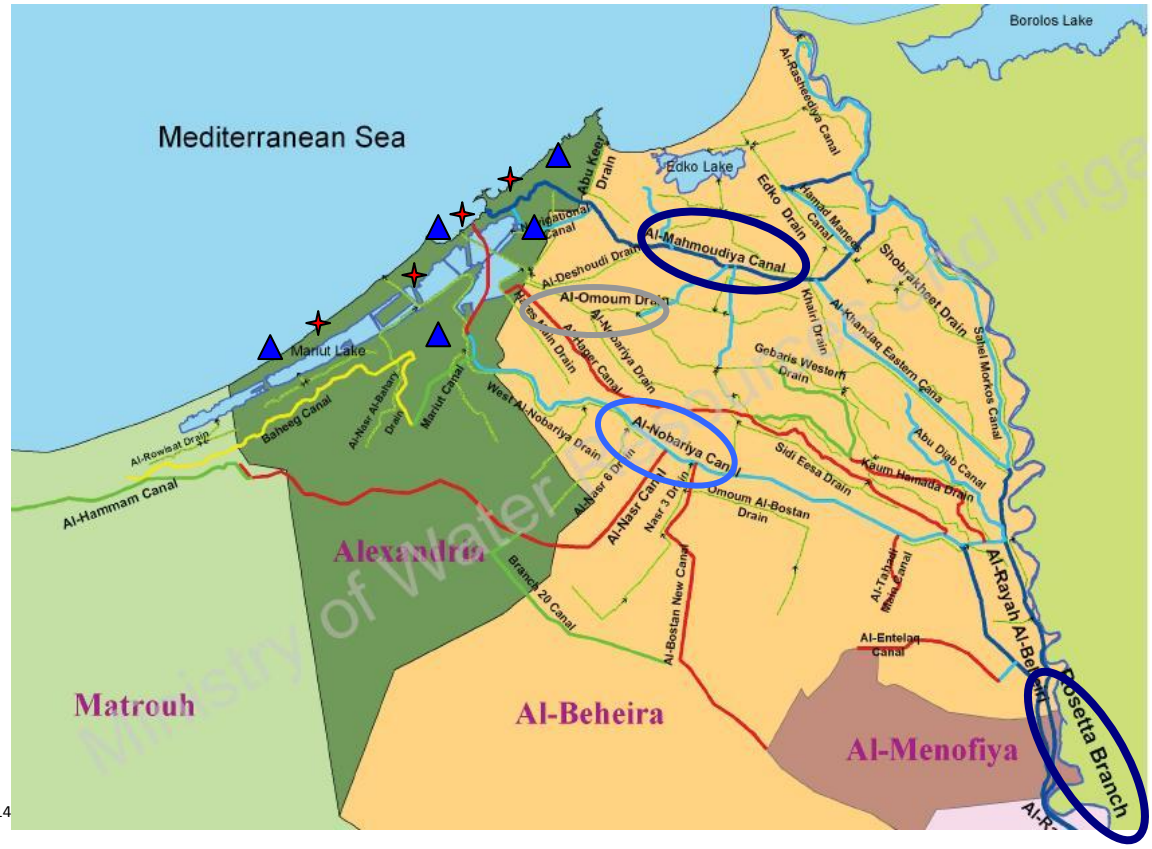
Currently in Alexandria desert area is about 1,230 square kilometres which represents about 53 percent of total area; this is lesser compare to 56% and 58% in year 1993 and 1984 respectively. Agriculture and green land area shrink to about 730 square kilometres that is 27 % compare of the total area; this is also lesser compare to 29% and 30% in year 1993 and 1984 respectively. The urban built up area expended to 310 square kilometres which is about 12% of the total area; this is greater compare to 7% and 4% in year 1993 and 1984 respectively. The graph clearly

represents the expansion of built up areas in Alexandria. During the field visit to Alexandria, it was noticed during the interviews that the current expansion is only possible in the west of Alexandria, like Borg-ul-Arab and New Borg-ul-Arab are the examples. Water area is represents 8% that is about 210 square kilometres. Many parts of the water area changed into built up areas but at the same time many artificial fishing farms were established too, which nullifies the overall land cover change, but still the pressure on fresh water resources is obvious.

4.3 Freshwater Stress

Alexandria is receiving freshwater mainly from the sub branch of River Nile i-e Rosetta Branch, which enters to Alexandra through encircled Tarat-ul-Mahmoudia and Nobariya Canal.

Figure 4-2: Map of Alexandria and Important Water Resources



Source: **Ministry of Water Resources & Irrigation**

In figure 4.2 the dark blue encircled canals reflects the freshwater sources entering Alexandria, sky-blue coloured canals show little polluted agriculture drains while gray colour encircled canal are polluted agriculture drain water. Mahmoudia Canal before entering to Alexandria irrigates about 55,020 hectors of crop land in Al-Beheira governorate (see Map 4.2). The available water resources in Alexandria are shown in the table below.

14

✦ Estimated location of major wastewater treatment plants in figure 4.2

▲ Estimated location of major water supply plants in figure 4.2

Table 4-2: Available Water Resources in Alexandria

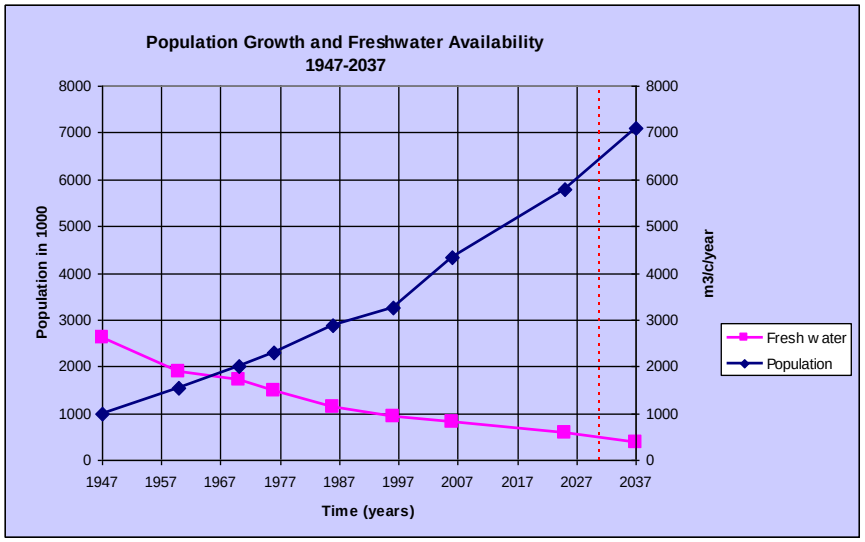
Sources	Quantity (M.M3/Day)
Nile	10.40
Drainage Water Reuse	1.10
Wastewater reuse	0.50
Total	**12.00**

Source: Hillaly & Kassem (2009)

As shown in the Table 4.2, the available water resources are 12 million m3 per day while the literature review of Kassem & Hillaly (2009) reveals that water consumption is exceeding with about 0.90 million m3/day. There may be other rational reasons for this difference, but I assume it is because of the high quantity of bottle water consumption particularly by the huge tourism industry. Figure 4.2 highlights the main water sources, water supply plants and water treatment plants in Alexandria.

There are enough evidences available that shows the gradual decline of freshwater availability with the population growth in Alexandria. In support of first proposition relation of freshwater availability and population growth is shown in graph 4-2.

Graph4-2 Freshwater Availability and Population Growth in Alexandria



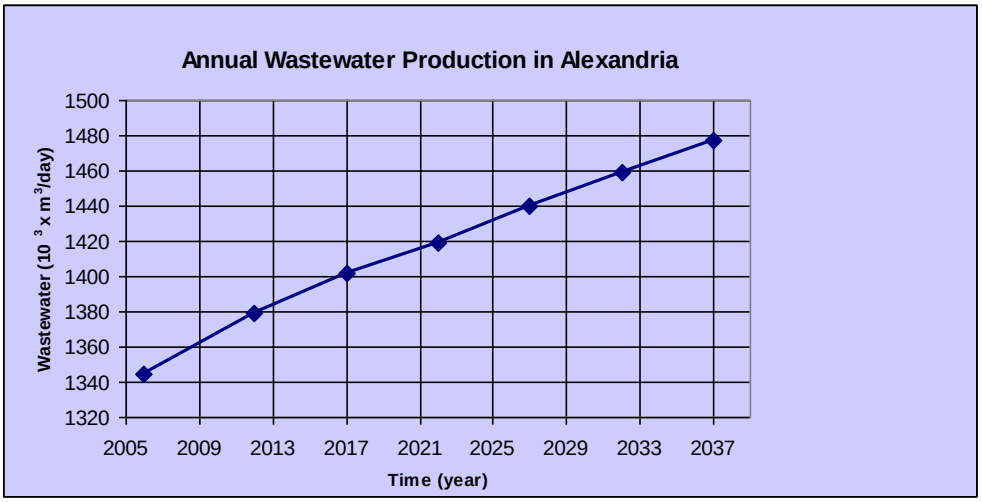
Graph 4.2 clearly indicates that with increasing population freshwater availability per capita is declining. The graph also show that from 1947 till early nineties the freshwater availability was above 1000 m3/year, but if the population trend remains the same then in 1930s it is expected that the freshwater availability for Alexandria will decline below 500m3/year, which will turn it into a water deficit governorate. Equally important challenge is to cope with increasing wastewater production and the inflow of agriculture drain water into Alexandria.

4.4 Wastewater Production

Alexandria receive agriculture drain water mainly via Nubariya canal and Omoum drain canal (see map 4-2), beside this Industries produces about 308,000 m3 per day of which about 48,000 m3

ends in the Lake Maryout (Explained in Box 1) directly. Graph 4.3 below shows the current and future projected maximum wastewater production in Alexandria

Graph4-3 Annual Wastewater Productions (Max) in Alexandria



Data Source: GIS Department ASDCO[15]

Graph 4.3 shows the increasing wastewater production in Alexandria. About 95% of this wastewater currently passes through only primary treatment, resulted in pollution of environment, increases further water freshwater stress and raises many health related concerns. Additionally this leads to water scarcity and increases water competition among various water users, like agriculture, industrial and domestic water users. To cope with increasing demands and to reduce water competition, government is looking for various new water sources and also managing the existing freshwater common pool resource i-e Tarat-ul Mahmoudia canal.

4.4.1 Wastewater a challenge and Resource for Alexandria

Though broadly wastewater is considered a challenge in Alexandria and it is mainly because of the current wastewater disposal point i-e Lake Maryout, which is a livelihood source for many poor people. Wastewater in Alexandria is also considered challenge, because Alexandria is the most downstream city in Egypt and pumping out wastewater for any reuse will have high economic cost. On the other hand the consequence of increasing wastewater is pushing the authorities to turn wastewater into a resource so that help in reducing water competition, environmental protection and will create potential for freshwater swaps. But the current measure taken by the government is not enough to encourage the users to reuse wastewater. To change the challenge of wastewater into opportunity requires funding and resources, therefore government has to act promptly before the negative consequences of wastewater further deteriorate the environment of Lake Maryout.

4.4.2 Government Response

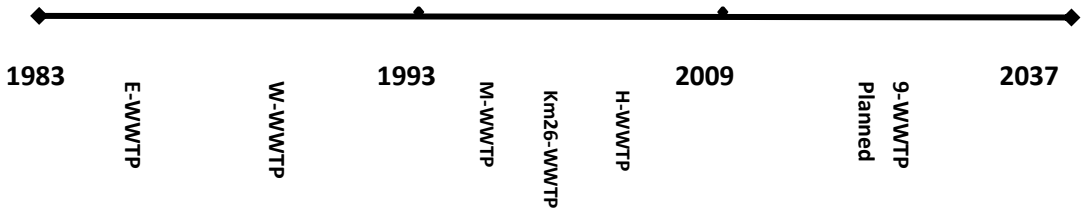
[15] The data considered for this graph is based on the business as usual projection, though the maximum wastewater flow is considered. Also the annual average values are considered, Alexandria being a tourist city receives about 2 million of tourist each summer, which increases the wastewater production up to 40%.

Realizing water scarcity and deteriorating situation of existing water resources, many legal actions which are briefed in the Background chapter, are taken to protect freshwater sources. Poor enforcement of legislations failed to completely cope with the situation (Di-Luciano, 1995; Showers, 2002) and many factories and household excreta still end into the freshwater sources.

Figure 4-3: View of a Tarat ul Mahmoudia, a Freshwater Source for Alexandria

Source: Hamdard(Dec, 2009)

In terms of infrastructure the first two primary wastewater treatment plants were built in 1993. Later on from 1993 till now three more secondary treatment plants start operational and about nine more with advance secondary treatment are planned.



This clearly indicates that not only number of treatment plants is increasing with increase in urban wastewater due to growing population but also the treatment quality of wastewater plants is improving. This would mean high potential of wastewater reuse in future. But the wastewater reuse is limited to small scale timber tree, there is very small area of about 0.34 square kilometres timber trees which is irrigated with diluted wastewater as a pilot project near Borg-el-Arab. Egypt climate is not friendly to natural forests; only 0.01% of the area represents forests and is importing about 900 million USD of furniture wood each year. During the interviews it also appeared that the only potential of wastewater reuse seems to be for non-fruit trees, only if the wastewater comply the national standards for reuse. Additions research to assess the varieties of trees that tolerate soil and water salinity, pests and disease, keep high economic value and suites the Egyptian conditions is required.

4.4.3 Wastewater Quality Compliance Failure

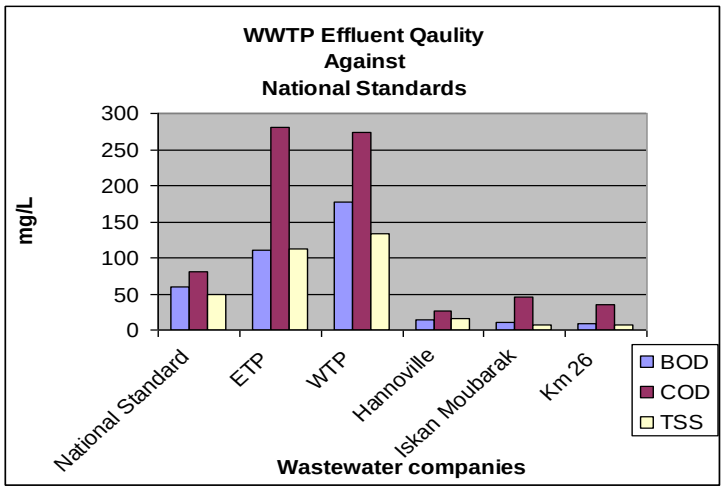
One prominent reason that discourages users to reuse wastewater is the failure of the wastewater companies to treat their effluent that comply the National Wastewater Quality Standards (NWQS) as prescribed in Decree 44/2000 of Law 93/1962 for wastewater reuse. Table 4-3 gives a glance of few but important quality parameters like BOD, COD and TSS of both influent and effluent of the operational wastewater treatment companies.

Table4-3: Effluent Quality of Major Wastewater Treatment Plants

WWTP	Quantity (m3/day)		Quality					
	Designed	Actual	BOD(mg/L)		COD(mg/L)		TSS(mg/L)	
			Inflow	Outflow	Inflow	Outflow	Inflow	Outflow
ETP	607,000	600,955	155	111	327	280	244	112
WTP	462,000	368,000	487	177.4	995	273	910	133
Hannovile	50,000	50,000	307	14	386	27	305	15
Iskan Moubarak	15,000	15,000	109	10	377.7	46	114	7
Km 26	4,000	4,000	91	8	>80	<80	120.2	7.41

Decree 44/2000 only allows wastewater to enter surface water if and only if the BOD, COD and TSS are equal or lesser than 60 mg/l, 80mg/l and 50mg/l respectively. While the table above shows that the East and West wastewater treatment plants which almost treat 95% of Alexandria's wastewater does not comply the National Standard (Annex II) standards. The comparison of the effluent of wastewater effluent against the national standards is show in the graph below.

Graph4-4 Comparing National Standards and WWTP Effluent



The review of Decree 44/2000 that describes the degree of treatment, kind of plant & soil, and method of irrigation (Annex I) reveal that even the effluent of East and West Treatment plants can be used for timber tree. The main reason given for low effluent quality was the financial constraint; this appeared during the interviews with the officials of the wastewater treatment company. The secondary treated wastewater of three other treatment plants has high potential of reuse from the quality perspective. But still this wastewater has not been utilized to extend that the authorities in Alexandria should have. This reflects that quality of wastewater is not the only issue in promoting wastewater reuse in Alexandria.

4.4.4 Financial Constraints

Alexandria follows a combine billing system for both water supply and sanitation. Although the costs of wastewater treatment are higher than the water supply but still 50% goes to water supply and 50% to wastewater companies. Also upgrading of urban wastewater treatment quality to a level of reuse requires heavy financing and efficient cost recovery system. Additionally the conveyance costs to take wastewater to the spot where it could be reused are higher, a cost-benefit study conducted by the World Bank for El Hammam Extension (West of Alexandria, see map 4-2) has estimated 393.6 million US dollars for the conveyance system and additionally 40.2 million US dollars as annual operation and maintenance cost (Kassem & Hillaly, 2009). During the interviews conducted, six out of eight water supplies and sanitation companies' employee mention financial constraints in upgrading the wastewater effluent quality. The solo source of cost recovery is the bimonthly fee collected from the connection holders for water supply and sanitation services. On the other hand the operation and maintenance costs are going up with the extension of connection to outskirts of the urban areas. The table below shows the revenue generated and expenditure for the nine months.

Table4-4: Revenue and Expenditures of Water Supply and Sanitation Companies (Nine Months Data)

Duration	Months	Revenue Generated (Exchange rate as per 14 Dec, 2009)	O&M Expenditures (Exchange rate as per 14 Dec, 2009)	Subsidy from Holding Company
1/7/2008-31/3/2009	9	71,326,558 LE 8,994,522 €	96,943,915 LE 12,224,958 €	25617357 LE 3,230,436 €

Source: (Kassem & Hillaly, 2009)

Looking at table 4-4 it is clearly visible that expenditures are higher than the revenue generated, to overcome this problem the water supply and Sanitation Company receives subsidies from the Water supply and Sanitation Holding Company in Cairo.

4.4.5 Role of Informal Institutions

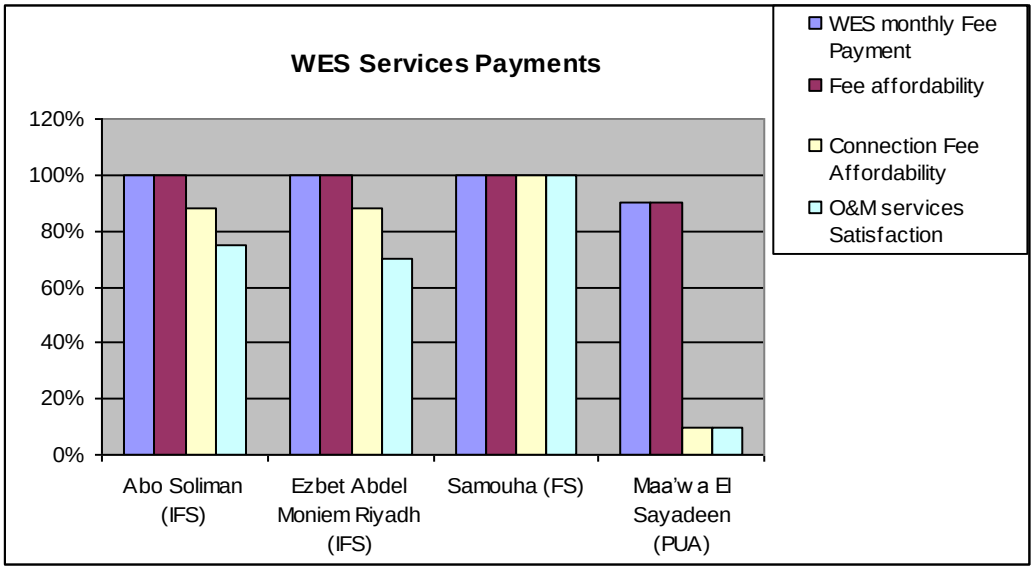
Religiously in Alexandria water is considers as God's (*Allah's*) Gift (Allen, 2002), which gives a perception of infinity to users; people prefer to be in contact with clean water and utilize more water in cleaning their bodies and washing household stuff. On the other hand traditionally it is believed that water is the right of former and duty of government. This gives formers a free hand

to use water as much as they can. Though during some interviews, it appeared that some farmers are illegally using wastewater for irrigating their crops but it lack religious and legal support. The informal tradition irrigation systems which is leaded by *Rais El Munawaba* (the leader of irrigation organizational unit) has changed in to Water Users Associations, which are legal entities governed by law 213 of 1994. Due to centralized water management rules and regulation, where government is getting more responsibility with fewer resources available in hands, it is far insufficient for a district engineer to manage 40,000 to 50,000 farmers (Abdul-Aziz, 2003). In this case where government role is weak, existing informal institution are dominant, and those are not really in favour of wastewater reuse.

4.4.6 Low Fiscal Accountability

One possible reasons of low revenue generation as assumed in proposition from the water supply and sanitation users. During the interviews conducted it appeared that residents are paying on average 15-18 Egyptian ponds per month, which are nearly equal to 2 Euros(as per 14 Dec, 2009 exchange rate). Then this fee is half divided between water supply and Sanitation Company. Some of the result about payments for water supply and sanitation services and its affordability is shown in the graph below.

Graph 4-5: Water supply and Sanitation Services Survey



4.4.7 Payments for Water Supply and Sanitation Services

The graph above shows the only in Peri-urban areas in comparison with an urban areas(Samouha) , In fact in Peri-urban areas everyone had access to water supply but some houses were sharing one meter. The graph also show that the inhabitants of Peri-urban areas are paying same as that of other areas, though the fact is that lack sanitation facilities. Since Alexandria has one billing system for both water supply and sanitation. This could be interpreted that inhabitants of Peri-urban areas are paying for sanitation services as well though they are not benefiting from the sanitation services.

4.4.8 Water Supply and Sanitation Fee Affordability

People living in Maw'wa el Sayadeen are usually poor fisherman, car mechanics or carpenters. There are retired fishermen who are only getting less than 10 Euros (75 Egyptian Ponds) per month from the government. The water fee ranges from 10 to 20 Egyptian ponds per month or even lesser, which was affordable to all. But the connection fee which is double for the inhabitants of Peri-urban areas is double as that of other settlement was not affordable to many who were interviewed. The possible reason of high connection fee might be higher conveyance cost of connection for Peri-urban areas.

4.4.9 Operation and Maintenance Services

Almost all the people interviewed in Peri-urban areas as well as in informal settlements were not satisfied from the operation and maintenance services, particularly from the sanitation services. During the interviews it appeared that during the rainy season the street are full of sewage water and the sewage line usually blocks. This makes it difficult for the people to pass in the streets. During the interviews it also revealed that in informal settlement and Peri-urban area they have to make their own arrangement, in case if any problem occurs with water supply and sanitation system, many complained that even if someone comes from the company for maintenance the resident have to pay him, which the water company personal explain as a tip for the services.

Figure 4-4: Ezbet Abdel Moniem

Source: Ezbet Abdel Moniem Riyadh- dated: 13 December, 2009 by Hamdard)

4.4.10 Coordination Gap and Legislations Issues

There are about six ministries and about four research centres involved in water and wastewater management in Alexandria. Although MWRI is responsible of water resources planning and management but still coordination with other stakeholders are not strong enough to eliminate

conflicts (Attia, 2004) During the interviews conducted it appeared that in Peri-urban area no one knew whom to complain in case of any water supply problem. On the other hand the lack of coordination among Water Supply Company and Sanitation Company was clearly visible. The main holes build by Water Supply Company were used by Sanitation Company too for their on going project. The people were concern if any problem occurs with water supply system then no one is willing to help in maintaining the water supply system. An environment of mistrust among the community and government was observed during the interviews. All this may be because of the vacuum of responsible authorities due to its administrative status.

A possible reason for poor services in Peri-urban and informal areas might be fear of authorities regarding property right. In Egypt water supply meters play an important role in property right, the water meter gives the right of the property to its owner. So the government fear might be if those settlements receive water meters which will ultimately give them the property right and that may hamper the urban planning programme. In an interview with Water supply company staff it appeared that to cope with the water theft challenge, the water company is going to install temporary meters after consultation with the Alexandria governorate.

So from the discussions it appears that poor people living in Peri-urban areas are paying more for water supply and sanitation services compare to other settlements as opposed to the proposition.

It was also observed during the Egyptians are sceptical about wastewater reuse but also the national standards set for wastewater reuse are not encouraging. Article 12 of Law No. 48 of 1982 concerning pollution protection of the River Nile and the Water channels clear states that "It is not allowed to reuse the water channels directly or mixed with fresh water for any purpose, unless it is proved valid for use". The decree is not only limited to certain quality parameters but also highlights the soil type to which wastewater will be used, the irrigation type, the crop or tree types it. This makes the application of wastewater more complex and less encouraging for uneducated formers.

4.5 Public Perception about Wastewater Reuse

The perception of community plays an important role in reusing wastewater. Diluted wastewater has being used for decades in Egypt as a source of crop nutrients, but over the years it become less popular with awareness of environmental and health issues and with improvement in treatment technologies. People in general feel uncomfortable to reuse the excreta of their toilet ignoring that it passes through a treatment plant (Drechsel et al., 2010). However many formers still believe wastewater a valuable resource, In Pakistan farmers are paying for buy wastewater for irrigating their crops. Also in Jordon the Peri-urban community contributes 90% of capital and operation and maintenance costs of wastewater reuse projects. The interviews conducted revealed that most people in Egypt are in favour of diluted reuse of wastewater but only for limited purposes. It was also observed that some formers believe the national standards for wastewater reuse as constraint. In general community looks at results rather than knowing about the chemical and biological parameters of wastewater. The deteriorating situation in Lake Maryout (Box 4.1) which has badly affected the aquaculture, has built a negative perception in the community about the urban wastewater.

The analysis of the perception of the community about wastewater reuse is shown in the table below.

Table4-5: Perception of Wastewater Reuse

Income (Egyptian Pond LE/Month)	Willingness to Reuse Wastewater						
	No		Yes				
	Quality Reason	Any other	Recreational gardens Irrigation	Agriculture (Only non-fruit trees)			
				Diluted		Direct	
				Primary Treatment	Secondary Treatment	Primary	Secondary
<1000	50%	No Idea	30%	40%	60%	0%	30%
>1000	50%	20%	20%	20%	80%	20%	40%

The assessment of urban wastewater reuse was done based on the income of the people. The target groups were from different backgrounds like the government officials, NGO representatives, farmers, fishermen, representatives of Water Supply Company and Sanitation Company. Table 4.5 is a short summary of the interviews results. It was observed that only 30 % of the people interviews were against the reuse of wastewater, this is mainly due to the quality and cultural or religious reasons. Supporting this one person mentioned “Half of our faith is based cleanliness, how can we use wastewater, why don’t the government explore new resources, like ground water, even water from the sea”.

Other who were in favour of the wastewater reuse were only limited to non-fruit trees and for recreational gardens. Majority of the people were in favour of secondary treatment plus dilution with fresh water before reuse. This was mainly because of recent health accidents due to eating some vegetables grown with application of wastewater. Another interesting fact that discourages users from the wastewater reuse was the deteriorating environment of Lake Maryout, because almost 95% of the Alexandria’s wastewater after passing through primary treatment discharges into Lake Maryout. This has resulted in a negative perception in the community’s mind about the wastewater effluent quality.

BOX 1 Wastewater effects on Lake Maryout:

Lake Maryout is an important wastewater disposal sink and income source for many inhabitants of Alexandria. The lake has five basins, those are;

a. Main basin with an area of 21km2 and average depth of 1.2 meters

b. Northwest basin with an area of 10.5km2 and average depth of 1.25 meters

c. Fishery basin with an area of 4.2km2 and average depth of 1.35 meters

d. Southwest basin with an area of 21km2 and average depth of 0.5 meters

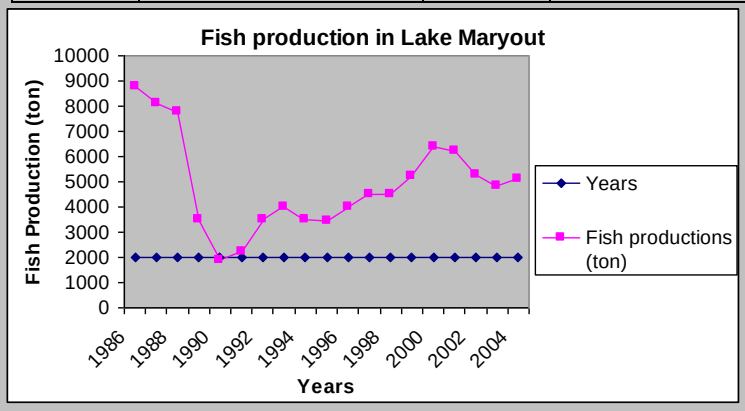
e. West basin with an area of 8.4 km2 and average depth of 0.6 meters

Lake Maryout receives water mainly from El- Ommum agriculture drain, El- Qala drain which has mixed wastewater, from rainfall, direct sewage, industrial wastewater and domestic wastewater after partial treatment. In eighties when the local authorities in support of promoting tourism, decided to divert wastewater to Lake Maryout which was before entering directly to the Mediterranean, the lake got polluted with direct discharge of industrial chemical and domestic wastewater without any sort of treatment. Later on in 1990s two primary treatment plants East and West treatment plants were built to decrease the load of pollutant in the lake (IESIA, 2006). Lake Maryout basically receives wastewater from three main sources, the agriculture drain water, domestic and industrial wastewater.

The lake now receives about 900,000 m3/day of primary treated effluent from East wastewater treatment plant and West Wastewater treatment plant. In the effluent the numbers of coliform are above the levels as specified in the Egyptian Government regulations. The lake also receives about 48,000 m3 of direct industrial wastewater daily (Kassem & Hillaly).

Due to continuous contaminated inflow into the lake, the lake's environment is subjected to deterioration. This has affected the livelihoods of many who are relying on fish catch and other economic activities related to the lake. The table below shows how the fish catch decreased over time due to pollution.

Year	Fish Production(ton)	Year	Fish Production(ton)
1986	8,800	1995	3,466
1987	8,100	1996	3,976
1988	7,770	1997	4,489
1989	3,500	1998	4,521
1990	1,900	1999	5,235
1991	2,200	2000	6,378
1992	3,500	2001	6,200
1993	3,990	2002	5,303
1994	3,516	2003	4,861
		2004	5,100

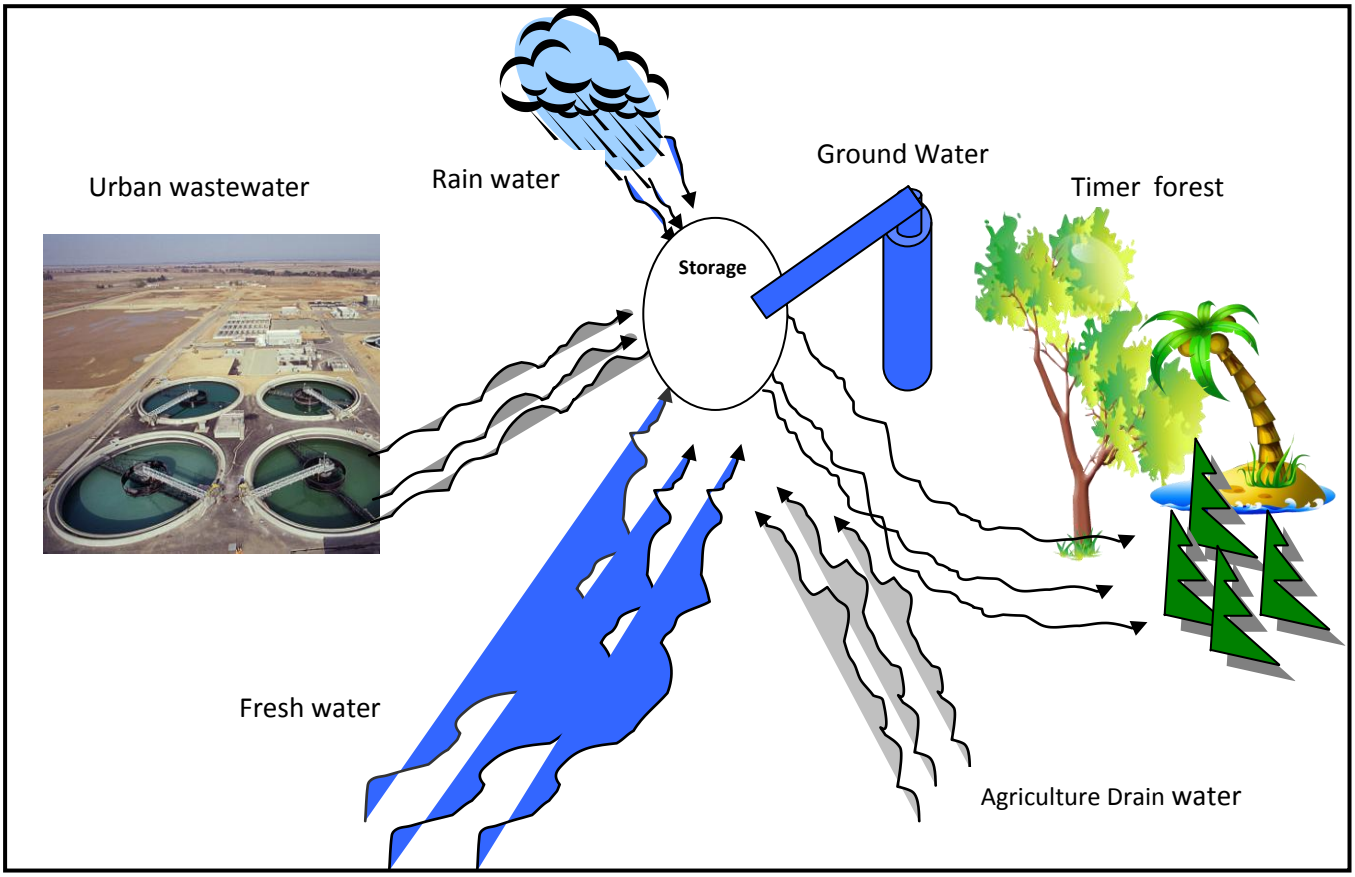


The wastewater discharge since 1988 substantially decreased the fish production in the lake. During the field trip interviews the fishermen said that during late eighties the less pollution tolerant high valued fish started disappearing. The graph clearly indicates that till 1990s the number of fish is declining rapidly but then after installment of East and West wastewater treatment plants and installment of decentralized wastewater treatment plant by the industries the lake's environment is improving and so does the number of fish.

4.6 Conjunctive Water Management

The analysis of data reveals that conjunctive water management could be a possible solution to utilize urban wastewater for timber trees, either Alexandria or neighbouring Matrouh governorate. Conjunctive water management concept could be incorporated in an already existing planned project of Al-Hammam Extension. Usually conjunctive water use is the combination of ground water and surface water but in Alexandria the groundwater salinity is higher due to sea water intrusion. A mixture of partially urban treated water, freshwater, drain water, rainwater and ground water could be an option.

Figure 4.5 Conceptual design of Conjunctive water use system



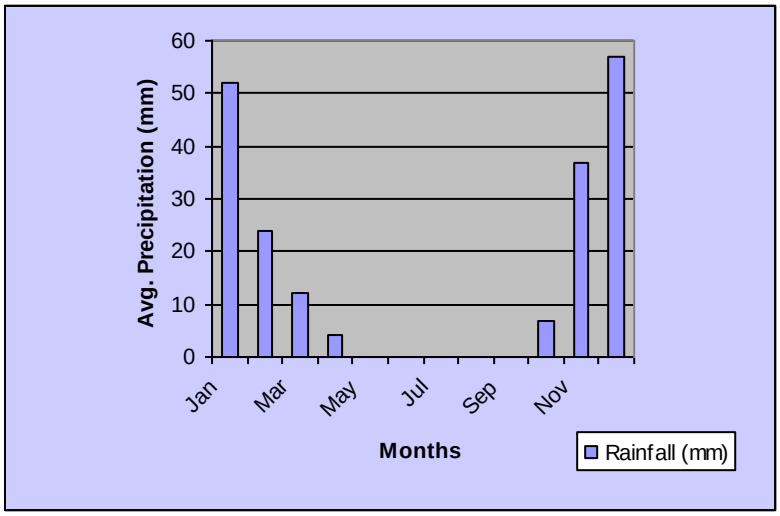
4.6.1 Agriculture Drain Water

Alexandria receives high quantity of agriculture drain water from Al-Baheira governorate (Shown in map 4.2) mainly via Omoum drain and Al Nobariya canal. This water either goes to Mediterranean or to the lake Maryout without any reuse. In the West of Alexandria the El-Hammam extension is proposed and feasibility study has already been conducted with financial support of European Investment Bank, the conjunctive water management can fit in as a component of that plan.

4.6.2 Annual Rainfall and Groundwater

Alexandria is receiving about 200mm of annual rainfall; the graph below shows the seasonal precipitation in Alexandria.

Graph4-6: Average Annual Rainfalls in Alexandria, Egypt



Source: BBC Weather (2010)

Looking at the graph it appears that annual rainwater is low therefore rainwater harvesting will not be a good choice; instead the storm water can be direct in to sewage network and then to the storage point. On the other hand ground water is rarely used in Alexandria due it high salinity. The table below shows the groundwater table and salinity in various locations of Alexandria.

Table 4-6: Water Table and Salinity in Ground water of Alexandria

No.	Areas	Groundwater	Groundwater Salinity
1	El Hammam	4-11	1100-2800
2	Al Agami	3-14	650-1700
3	Mallahat Mariuit	10.5-13	800-3700
4	Km 40-Km 60- Northern	5-14	700-1500
5	Burg El Arab	8-17	960-5000
6	Bahig	4-5	3900-5000
7	Km. 190- Desert Road	1.5-3	2500-3500
8	Industrial Zone	2.5- 7	2100-3500
9	Bangar El Sukr	1.5-18	1100-4000

Source: SWITCH (2009)

Further Studies are required to assess if it is economically feasible to use ground water as a part of conjunctive water management or not.

4.6.3 Urban Wastewater:

Instead of investing more on upgrading wastewater quality from the two main wastewater treatment plants i-e East and West wastewater treatment plants, it is possible to bring wastewater as a part of the conjunctive water use scheme and dilute it with freshwater at a certain ratio.

4.6.4 Vegetation Type

The vegetation type can be selected based on the qualities of water. The type of plants that are tolerant to salinity and wastewater shall be cultivated. Also further research is required to assess the type of plants which can flourish in the Egyptian environment and the soil type in which it can grow needs to be assessed.

4.6.5 Merits of Conjunctive water Use

Some of the benefits of conjunctive water use are given below:

i. Reducing wastewater

ii. Expanding green area

iii. Reducing furniture wood import

iv. Protecting environment from wastewater and enhancing long term environmental sustainability particularly the environment of Lake Maryout

v. Saving fertilizer costs

vi. Employments and income etc

But alongside the benefits many cost like the costs of rainfall storage, conveyance costs etc are also attached. Addition to all this more research is required to assess a proper ratio of freshwater, rainwater, ground water, drain water and urban wastewater. Also the research is required to asses the type of plants that are tolerant to salinity and can grow in Egyptian environment.

4.6.6 Roles and Responsibilities

The whole idea of proposing conjunctive water management is to reduce water competition, increase freshwater availability and protect environment. Ministry of Agriculture and Land Reclamation (MALR) can take lead to back this approach. MALR has the constitutional support under Law 12/1984 for issuing licences of any development related to agriculture. But Article 12 of this law quotes “Reuse of Drains water shall not be allowed either directly or by mixing with fresh water for any purpose unless it is proven usable for that purpose”. This means that Ministry of Health has to be consulted. The Soil Water Environment Research Institution of MALR along with Drainage Research Institute of Ministry of Water and Irrigation, Environmental Health Department of Ministry of Public Health and Egyptian Environmental Affairs Agency could be the responsible organizations in conjunctive water management.

Information dissemination to all stake holders about environmental risks, standards, best practices etc is crucial. Beside all this separate guidelines and institutional arrangements are required to incorporate conjunctive water management with national water resource

management planning. On the other hand user should be fostered through incentives to voluntarily adopt conjunctive water management and provide markets support for selling woods and subsidized input items.

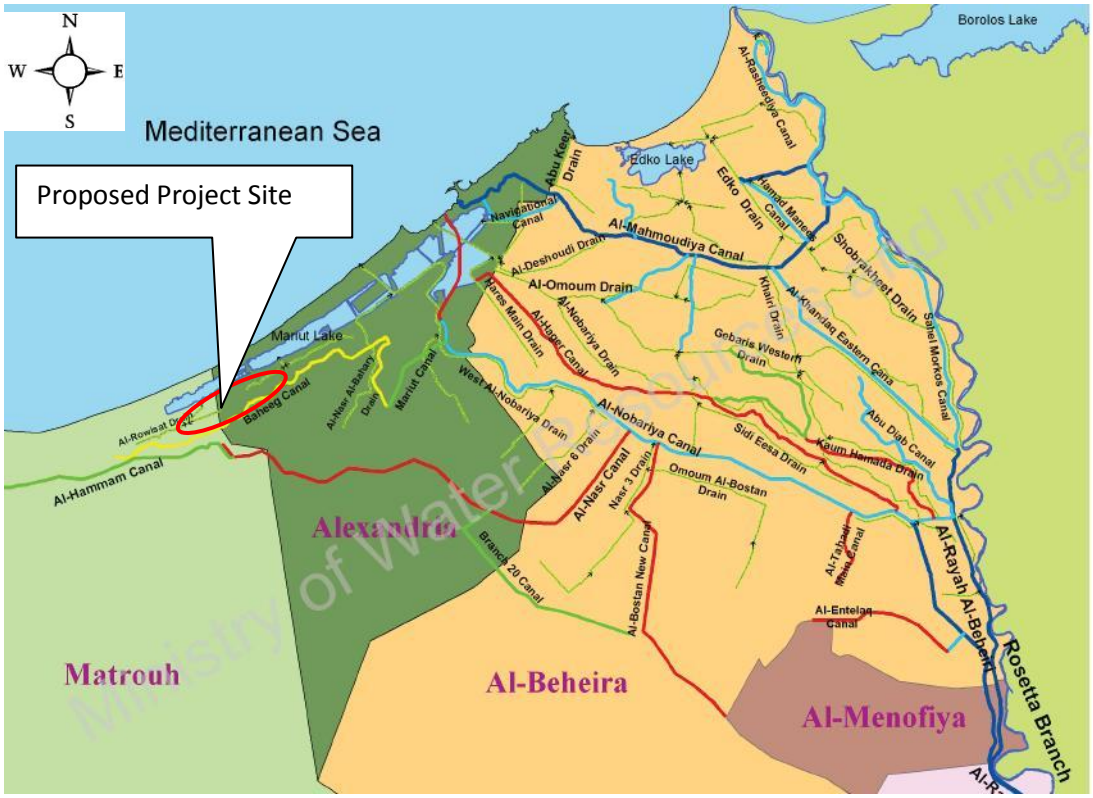
4.6.7 Funding

The conjunctive water management approach can be placed in horizontal land expansion program of the Government of Egypt. Therefore central government could be a source of funding, Also donor like USAID, the World Bank, European Commission and European Investment Bank who are already involved in Alexandria water management projects can be potential sources of loans or even grants.

A study conducted by European Investment Bank estimated about 438 million US$ for extension of 57 km El Hammam canal. This includes water conveyance to the project site and annual operation and maintenance costs. There are various irrigation technologies available but the predominantly used trickle and sprinkler irrigation technologies could be an option. Trickle irrigation particularly with sub-surface drippers will help in protecting the farmer and consumers exposure to wastewater (Qadir et al., 2008). But this would require pre-treatment to avoid clogging. Both proposed irrigation technologies are expensive and has high maintenance costs because of availability of suspended solid materials in the wastewater. Furrow irrigation could be a cheap alternative but may result in bad health consequences.

Immediate cost recovery could not be possible, as in Egypt irrigation water is free of any cost but in the long run it will result in decline furniture wood import, creating more jobs and environmental sustainability.

Figure 4.6 Proposed Project Site



5 Conclusions

Alexandria is facing freshwater stress from two dimensions, one is the increasing freshwater use for agriculture practices in the upstream of Tarat-ul-Mahmoudia, letting less freshwater to enter Alexandria, and another is to meet the internal growing demand of water supply for increasing population. This put Alexandria in water competition with upstream agriculture activities. Currently there is no reuse of wastewater in a larger scale in Alexandria, though the potential for wastewater reuse exists but due to poor wastewater management, non-compliance of national standards for reuse, financial constraints and less legal support to encourage users for reusing wastewater . There is a general negative public perception about the wastewater reuse. The financial constraints in upgrading wastewater treatment are mainly due to the overall low rate of tariffs as oppose to my propositions of low cost recovery in Peri-urban areas.

Some of the conclusions made from this study are:

i) Increasing water demand and competition for water in Alexandria is inevitable

ii) The wastewater reuse related legislations does not encourage users to use wastewater

iii) Scope for freshwater swaps exists but requires high investments, which requires external financial support.

iv) Freshwater swaps are more cost effective when agriculture activities are at downstream instead at the upstream.

v) Large size and mobile nature of resource system (canal) lessen the coordination among the upstream downstream users.

vi) Combine billing system for water supply and sanitation services does not work effectively if the services are provided by separate companies.

vii) In combine billing system for water supply and sanitation services poor, of the Peri-urban areas pay more for fewer services

viii) Water users are in favour of diluted wastewater reused rather than direct reuse of the effluent of wastewater companies.

ix) Conjunctive water management could be a possible solution to deal with urban wastewater, environmental protection, reducing freshwater competition and increasing availability of freshwater.

This study adds to the policy and management response to wastewater in Alexandria. The study suggests the policy makers to bring more flexibility in wastewater reuse guidelines with more flexible quality standards and information dissemination at local scale. Further more the Governorate of Alexandria can play vital role in providing incentives to encourage wastewater reuse. The current tariff system needs to be revised as the annual revenue generated even does

not cover the operation and maintenance costs. Combine billing system needs to be revised, because first the water supply and sanitation coverage is not equal and secondly the wastewater treatment costs are higher in water supply.

The only contribution of this study to theory is that the management of resource systems are more likely when there are two productive resource systems and one is affecting the other. Like in case of Alexandria, there are two productive resource systems one is Tarat-ul-Mahmoudia and another is Lake Maryout. So actually the impact on the Lake Maryout tends to the management of both resource systems.

References

Abdel-Aziz Y (2003) Decentralisation and Water User Participation, the Case of Egypt. Water Demand Management Forum, Decentralisation and Participatory Irrigation Management, Ministry of Water Resources and Irrigation

Abdou-Azaz L K (2008) Analysis and Assessment of Land Use Change in Alexandria, Egypt Using Satellite Images, GIS, and Modelling Techniques. Egypt. J. Remote Sensing & Space Science. V.11, PP, 17-26

Abdou-Azaz L K (2001) Monitoring Urban Growth in Alexandria-Egypt Using Satellite Image, Postgraduate Research, APL, The Second Symposium Remote Sensing of Urban Areas, Regensburg (Germany)

AbuZeid M K, Elrawady M H (2007) Institutional Mapping and Water Governance Analysis in the City of Alexandria, Water Resources Research Centre for Environment and Development for the Arab Region and Europe (CEDARE)

Alexandria General Organization for Sanitary Drainage(AGOSD) (2000) Alexandria Effluent and Sludge Reuse System, Feasibility Study and Outline Design for Effluent Reuse system

Allen A (2003) Environmental planning and management of the Peri-urban interface: perspectives on an emerging field. Environmental Planning and Management 15 (1), pp 135-148

Allen A, Davila J, Hoffman P (2006) Governance of water and sanitation services for the Peri-urban poor: A framework for understanding and action in metropolitan regions. Development Planning Unit, London: University College London

Aquastat-Food and Agriculture Organization (2003) Available at:http://www.fao.org/nr/water/

Attia B B (2004) Water as a basic human right in Egypt, Water as a human right: The understanding of water in the Arab countries of the Middle East – A four country analysis. Published by the Heinrich Boll Foundation

Bardhan P (1989) The New Institutional Economics and Development Theory: A Brief Critical Assessment- World Development, Vol.17, No. 9, pp.1389-1395, University of California Berkeley

British Broadcast Centre Weather (2010), site visited on 19 March, 2010. http://www.bbc.co.uk/weather/world/city_guides/results.shtml?tt=TT000160

Central Agency for Public Mobilisation and statistics Egypt (1996) Statistic Year Book 1996

Central Agency for Public Mobilisation and statistics Egypt (2006) Statistic Year Book 2006

Dietz T (2009) Climate-based risks in Cities: Climate Variability and Urban Sanitation. UNESCO-IHE Online Module on Urban Water and Sanitation Services

DiLuciano D (1995) Egypt's Water Reforms Spell Big Business. Available at http://www.awo.net/newspub/ubs/tradelin/950908b.asp

Drechsel P, Scott CA, Sally LR, Redwood M, Bahri A (2010) Wastewater Irrigation and Health: Assessing and Mitigating Risk in Low-Income Countries International Development Research Centre, and the International Water Management Institution in United Kingdom pp-5

Dudley T, Fulton A (2006) Conjunctive Water Management: What is It? Why Consider It? What are the Challenges?

Egyptian Environmental Affairs Agency (2009) Egypt State of the Environment Report 2008, Ministry of State for Environment Affairs, Arab Republic of Egypt

El-Din A H, Taha H, El-Megeed, Riad N (2009) Water Demand Management Study

El-Shorbagy E W (2000) Impact Assessment of an Irrigation Improvement Project in Egypt, Water Resources Management 14: p 229-246.

Ensink J.H.J, van der Hoek W., Matsuno Y., Munir S. , & Aslam R.M (2002). Use of untreated wastewater in Peri-urban agriculture in Pakistan: Risks and opportunities, (Research report - 67). International Water Management Institute, Colombo, Srilanka.

Faguet J.P (2002) Does decentralization increase government responsiveness to local needs? Evidence from Bolivia, Journal of Public Economics 88(2004) 867-893

Ground Water Study (2009) Alexandria Strategic Planning Progress Report No. 1, SWITCH Project

Harriss J, Hunter J, Lewis C. M (1995) Development and significance of New Institutional Economics-The New Institutional Economics and Third World Development

Helally H, Kassem A (2009) New Strategies for Wastewater Management and Reuse in Alexandria in 2037

Ian Gordon, Janet Lewis and Ken Young (1977) Perspective on Policy Analysis, Public Administration Bulletin, 25, 1977, pp, 26-30

Integrated Environmental and Social Impact Assessment (IESIA) (2006) Alexandria Governorate, E1437 v. 2, prepared by North South Consultants Exchange for the Word Bank

Integrated visioning RIDA and DSS activities in Alexandria, 2nd SWITCH Scientific Meeting Dan Panorama Hotel, Tel-Aviv, Israel, 25-29 November 2007

Kaiser R, Nikiforova E (2006), Borderland spaces of identification and dislocation: multiscalar narratives and enactments of Seto identity and place in the Estonian-Russian borderlands. Ethnic and Racial Studies 29 (5), pp 928-958

Karyabwite R D (2000) Water Sharing in the Nile River Valley

Keremane G.B (2007) Urban Wastewater Reuse for Agriculture: governance paradigms and institutional arrangements in Australia and India, PhD Thesis, University of South Australia

Keshk A M (1999) Land and Water in Egypt, Usage and Management of Water Resources in Egyptian Agriculture Cultivation, pp 151

Kurain M (2010) Institutional and Economic Development: A Framework for Understanding Water Service, Page 23

Kurian M, Reddy R, Van Dijk MR, Dietz T, Brdjanovic D (2009) Climate Variability and Peri-Urban Wastewater- A Framework for Assessing Impact and Evaluating Adaptative Options, Urban Research Forum, The World Bank, Marseille, June 28-30, 2009

Livingston D, Stenekes N, Colebatch H.K, Ashbolt N.J, Waite T.D (2004) Water Recycling and Decentralized Management: The Policy and Organisational Challenges for Innovative Approaches, in Daniell T (Eds.). Proceedings of the international conference on Water Sensitive Urban Design: Cities as Catchments, Adelaide, 21-25 November, 2004: 581-592

MacDonald D.H, Dyack B (2004) Exploring the institutional Impediments to conservation and water reuse - National issues, CSIRO Land and Water Client Report

Mahgoub M. E-S.M (2007) Prioritizing Actions in Alexandria's Urban Water System Based on Life Cycle Approach, MSc Thesis ES 07.24, UNESCO-IHE Institute for Water Education

Masuda R.J, Garvin T (2008) Whose Heartland? The politics of place in a rural-urban interface, University of Alberta, Edmonton, AB., Canada, published in Journal of Rural Studies 24 pages 112-123

Mehanaham, G. (1998). Policy Paradigms, policy networks and water policy in Israel, Journal of public Policy, 18(3), 283-310

Ministry of Water Resources and Irrigation (MWRI) (2005) Water for the Future, National Water Resources Plan 2017

Myint H (1964), the Economics of Developing Countries. Hutchinson, London

Nile Basin Initiatives (NBI, 2009) to achieve sustainable socio-economic development through the equitable utilization of, and Benefits from The Common Nile Basin Water Resources, site visited 16 Feb. 2010. http://www.nilebasin.org/index.php?option=com_content&task=blogcategory&id=59&Itemid=123

North D. C (1991) Institutions, Journal of Economic Perspectives, 5(1), 97-112.

North D. C (1990) Institutions, institutional change and economic performance, Cambridge University Press

Ostrom E, et al. (2009), A General Framework for Analyzing Sustainability of Social-Ecological Systems. Science 325, 419 (2009);

Ostrom E (1990) an institutional approach to the study of self-organization and self-governance in CPR situations, Governing the Commons, The Evolution of Institutions for Collective Action pp 29-57, pp 194

Patton M.Q (1990) Qualitative evaluation and research methods (2nd edition) Newbury Park, CA: Saga Publications

Qadir M, Wichelns D, Rachid-Sally L, McCornik P. G, Drechsel P, Bahri A, Minhas P.S (2008) The Challenges of Wastewater Irrigation in Developing Countries , AGWAT-2715; Page no.5

Rijsberman F (2004) the water challenges. The Copenhagen Consensus Challenge Paper

Rogers P, Hall A (2003) Effective Water Governance, Global Water partnership, TEC Background Papers no. 7 (page12)

Rondinelli D (1979) Applied policy analysis for integrated regional development planning in the Philippines, Third World Planning Review, vol 1 (2): 151-178

Salome A.A (2010) Wastewater Management under the Dutch Water Boards: Any Lessons for Developing Countries? UNESCO-IHE lecture note: Peri-Urban Water and Sanitation Services: Policy, Planning and Methods (P 128)

Shah A (1998) Balance, Accountability and Responsiveness: Lessons about Decentralization, World Bank, Washington DC Policy research working paper 2021

Shalaby A, Tateishi R (2007) Remote Sensing and GIS for Mapping and Monitoring Land Cover and Land-Use Changes in the Northwestern Coastal Zone of Egypt, Applied Geography 27 (2007) pp 28-41

Sharp J.S, Smith M.B (2002) Social capital and farming at the rural-urban interface: the importance of non-farmer and farmer relations, The Ohio State University, Agriculture Systems 76 (2003) pp 913-927

Showers B.K (2002) Water Scarcity and Urban Africa: An Overview of Urban- Rural Water Linkages, World Development Vol. 30, No 4, Pp 5

Slaymaker T (2006) Aiding Water Governance, Efforts to improve Coherence

Swart R, Roginson J, Cohen S (2003) Climate Change and sustainable development: expanding the options. Climate Policy

The Human Development Report (2006)

Trochim W.M (2006) the Research Methods Knowledge Base (2nd Edition)

United Nations Demographic Yearbook (1988), Egypt statistic for year 1986

United Nations Development Programme (2004), Water Governance for Poverty Reduction, Key Issues and the UNDP Response to Millennium Development Goals, Chapter 1: Water- A key to Meeting the Millennium Development Goals. Pp 03

United Nations Environment Programme (2008) Africa: Atlas of our changing environment, pp 06

Woods M (2006), Redefining the 'rural question': the new 'politics of the rural' and social policy. Social Policy and Administration 40 (6), pp 579-595

Yin R.K (1994) Case Study Research: Design and Methods. (2nd Edition, Applied Social Research Methods Series, Vol.5). Sage Publications, California

Yin R.K (1994) Discovering the Future of the Case Study: Methods in Evaluation Research. Evaluation Practice, vol. 15, No. 3, pp. 283-290

Zenger T.R, Lazzarini S.E, Poppo L (2001) Informal and formal organisation in New Institutional Economics

Annexes

Annex I

Decree 44/2000: Reusing Treated Wastewater in Agriculture; Degree of Treatment, Kind of Plant & Soil, and Method of Irrigation

Proposed Kind of Soils	Suitable Irrigation Methods	Environmental & Health Precautions	Plants	Degree of Treatment	Group
Light texture authorized for use in desert land 5 km away from dwelling communities while complying with periodical assessment of the environment	Furrow	Fencing farms No direct contact with water and entrance of farm workers only Prohibit from entering farms Take health measures required for the protection from infection with pathogenic organisms and treatments	Trees for Timber	Primary	First
Light medium texture	Furrow & sprinkling	Cattle not yielding milk, and producing met could be used Food should be cooked prior to eating	Palm trees, cotton, flax, linen, jute Fodder crops & dried cereals Husky fruits & crops Cooking vegetables Heat processed fruits Flower nurseries Raw edible plants Husky plants	Secondary	Second
All kinds for soil	All methods except spraying	None	All kinds of horticulture crops Fodder & green grasses	Advanced	Third

Annex II

Maximum Standards Permitted for Reusing Treated Sanitary Drainage Water & Degree of Treatment

Ser.	Description	Unit	First Group Preliminary Treated Water	Second Group Secondary Treated Water	Third Group Advanced Treated Water
1	B.O.Ds	Part per million	300	40	20
2	C.O.D. Dichoromate	Part per million	600	80	40
3	T.S.S.	Part per million	350	40	20
5	Number of Enteric Nematode Cells or eggs	Number/litre	5	1	1
6	Number of Fecal Coliform Cells	For every 200/m2	undetermined	1000	100

Annex III

Table 1-16. Decree 44/2000 :Egyptian Microbiological Quality Standards for Treated Wastewater Use in Agriculture

Category	Re-use Conditions	Exposed Group	Intestinal nematodesb)arithmetic mean no. of eggs/litrec(	Faecal coliforms geometric mean no./100 mlc	Wastewater treatment expected to achieve required microbiological quality
A "Unrestricted"	Irrigation of crops likely to be eaten uncooked, sports fields, public parksd	Workers , consumers and public	<1	<1000d	A series of stabilization ponds designed to achieve the microbiological quality indicated, or similar treatment

B	Irrigation of cereal crops, industrial crops, fodder crops ,pasture and trees	Workers	<1	<1000	Retention in stabilization ponds for 10-8days or equivalent helminth and faecal coliform removal
C	Localised irrigation of crops in category B if exposure of workers and the public does not occur	None	Not applicable	Not applicable	Pretreatment as required by the irrigation technology , but not less than primary sedimentation