WATER RESOURCES MANAGEMENT IN TOURISM DEPENDENT COASTAL REGIONS; THE CASE OF BAFRA, NORTH CYPRUS

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ABSTRACT

Potable water requirements of tourism sector in the TRNC are examined by means of a questionnaire. Fluctuating demand rises in parallel with increasing occupancy rates for the summers months is observed. Linearly correlated data for the hotels investigated gave 590 l /day/tourist consumption; a value 50% higher than its counterparts like Benidorm, Spain.

Projected water requirements for Bafra tourism area gave a minimum requirement of 15,000 m^3/day for 20,000 bed capacity. In addition to an existing reverse osmosis plant, a new pipeline construction from Dörtyol to Bafra is recommended. With this pipeline unit water prices are expected to be less than 1 $/$m^3$ as compared with 1.5 $/$m^3$ for reverse osmosis. Furthermore marine pollution of reverse osmosis is observed to be a major disadvantageous factor.

A computer software in excel is prepared to guide the hotel managers in water purchasing and contracting requirements. Details for cost savings as well as optimal water purchase and minimal water consumption are introduced.

Keywords: Potable Water, Tourism occupancy, Water Resources, Reverse Osmosis, Contract Agreement.

ÖZ

Anket yöntemi ile KKTC turzim sektörünün su kullanım eğilimleri analiz edilmiştir. Yaz aylarında doluluk oranlarına bağlı olarak değişken su tüketim miktarları tespit edilmiştir Analiz edilen oteller için günlük korelasyon değerleri, turist bazında 590 litre olarak tespit edilmiştir. Bu değer benzer turizm kullanımının % 50 üzerindedir.

Bafra turzim yöresi için hedef gereksinimin günlük 15000 ton olduğu saptanmıştır. Mevcut geri ozmos tesisine ilave olarak, Lefkoşa-Mağusa hattı üzeri Dörtyol noktasından Bafra'ya yeni bir ishale hattının yapılması tavsiye edilmektedir. Bu boru hattı ile su birim fiyatlarının 1$/ton olması beklenmektedir. Geri ozmosta bu rakam 1.5 $/tondur. Geri ozmosta deniz kirliliği etkilerininde ciddi bir dezavantaj olduğu unutulmamalıdır.

Excell programı kullanılarak su alım ve planlamalarında otel müdürlerine yardımcı olmak için bir program geliştirilmiştir Asgari su kullanımı, uygun kaynaklardan su alımı ve optimal su alım sözleşme planlaması geliştirimiştir.

Anahtar Kelimeler: Kullanım, suyu, Turizm Doluluk, Su Kaynakları, Geri Ozmos, Su alım Sözleşme.

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Dedicated with love to my parents, my brothers and my sister who have been always with me …..

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LIST OF SYMBOLS

w_T: Daily potable water consumption per occupant

S_{VN}: Co-variance

S_{NN}: Variance

r : Correlation coefficient

S: Peak correction factor of water demand

f: Moody friction factor

g: Acceleration due to gravity

P_{in}: Pump Power input

P_{out}: Pump Power output

ρ: Density of water

η: Efficiency of pump

t: Time in hour

u_{ep}: Unit electricity price kw/h

u_{wp}: Unit water price

Φ : Diameter size

$(\mathbf{Vmax})_i$: Demand requirements for a given month

$\boldsymbol{i}$: Given month

$\mathbf{P_{1i}}$: Unit price of purchased water from source 1 at given moth

$\boldsymbol{c_i}$: Cost of buying water at a given month

$\boldsymbol{P_{2i}}$: Unit price of purchased water from source 2 at given moth

$\boldsymbol{V_{2i}}$: Demand can be supplied from second source at given month

$\boldsymbol{V_{3i}}$: Demand can be supplied from third source at given month

$\boldsymbol{P_{3i}}$: Unit price of purchased water from source 3 at given moth

$\boldsymbol{V_{ni}}$: Demand can be supplied from source $\mathbf{n}$ at given month

$\boldsymbol{P_{ni}}$: Unit price of purchased water from source $\boldsymbol{n}$ at given moth

$\boldsymbol{p_1}$, $\boldsymbol{p_2}$: Pressure at position one and position two respectively.

$\boldsymbol{z_1}, \boldsymbol{z_2}$: Elevation at position and position two respectively.

$\boldsymbol{h_L}$: Head losses through pipe line .

$\boldsymbol{H_p}$: Head of pump.

List of Abbreviations

IWRM: Integrated Water Resources Management

RO: Reverse Osmosis

WDM: Water Demand Management

IDA: International Desalination Association

V: Volume of water

N: Number of tourists

T: Time of year

D_{peak}: Projection of peak potable water Demand by tourism

H_p: pump Head

L: Length of pipeline

Q: Flow rate

D: Diameter of pipeline

A: Cross section area of pipeline

C: Cost

MSF: Multi-Stage Flash evaporation

ME: Multiple Effect Evaporation

VC: Vapor Compression

NF: Nan Filtration

SWRO: Sea Water Reverse Osmosis

GWI: Geographical Information System

OECD: Organization for Economic Co-operation Development

WTO: Word Trade Organization

EEA: European Environment Agency

CHAPTER 1

1. INTRODUCTION

The Mediterranean is the main tourist destination in the world, every year millions of people flock to the Mediterranean costs. One of the most beautiful destinations is Cyprus, the third largest island in the region. The Turkish Republic of Northern Cyprus (TRNC) occupies the northern part of Cyprus covering an area of 3355 square kilometers; TRNC has long coastlines to north and east of the country with easy accesses to the sea. It is situated at the cross –roads of east –west and north –south navigational routes, is only 70 kilometers of south Turkey and 385 kilometers north of Egypt. North Cyprus has a Mediterranean type of climate that can be defined as a transition zone between the arid and the temperature region climate. The winters are mild and invigorating. On the plains and on the coastal belt the air temperature rarely fall below freezing point but the southern mountains, Troodos Mountains are usually snow covered in winter months. The summers are hot and dry. The mean monthly temperatures of July and August range between 35˚ C and 40˚ C. over the plains the maximum daily temperatures exceed 40 C˚ in certain days of the summer associated with very low relative humidity (RH). The coastal regions can be more humid compared to inland but the temperatures are relatively lower; the maximum recorded daily summertime temperatures illustrate that this difference between the inland and coastal regions can be as high as 8 ˚C or 9˚C, through the small distance between the regions. This situation occurs due to the difference in the specific heat capacities of water and land, and the mountainous region surrounding the plains, preventing efficient ventilation between sea and land and exacerbating the temperature differences. Briefly the climate of North Cyprus is warm and dry summers from mid May to mid October and fairly dry cold winters and from December to February.

Generally tourist areas suffer from significant fluctuations in the number of local dwellers that have to be supplied with freshwater and consumption peaks normally occur in the dry season. As mentioned by Lamei A. (2009) the coastlines are characterized by high population density, intense economic activity and tourism, so the increasing number of residents and visitors exert a strong pressure over water resources producing over extraction and lowering of the ground water table in aquifers resulting in heavy seasonal demand. The impacts of tourism on freshwater sources would be exacerbated in the arid and semi-arid climate regions, like Cyprus which has limited water sources depend almost entirely on rainfall and the of average rainfall in North Cyprus, as reported by Gökçekuş H. *et, al.,* (1997) is 413 mm/y, also the recorded of rainfall continues declining and as a result of this there is currently a serious water shortage affecting most parts of the island. The recent droughts have considerably increased the concern about water scarcity on the island and the island always suffered from water shortage during drought seasons even when its population was small and agriculture land under irrigation was minimal. With increasing population, the agriculture land under irrigation has expanded twice during the last decades. Therefore, water shortage has become a considerable problem.

North Cyprus is a country with long solar duration and high solar radiation. High rate of evaporation reduces the contribution of the rainfall to the groundwater. Already due to over pumping, levels of water in the aquifers have significantly decreased, the aquifers affected by sea water intrusion resulting in high levels of salinity. According to Plan Bleu (1999), aquifer overexploitation is considerable in many Mediterranean countries, for example in Cyprus it is 13 %. As rewarded by El Kiran G., and Turkman, A. (2011) the Magosa aquifer, which located in the East of the country with an area of 45 km² of which 20 km² is located in the North, which was one of the main aquifer supplying water to the country in 1960's, is completely salinated by seawater due to over-pumping. The aquifer is completely damaged, but it can be used for other purposes now.

Nowadays the main problem forcing the North Cyprus is salination of aquifers in all coastal lines which also extends to others aquifer far from coasts, because of excess withdrawal. North Cyprus suffers from water shortage and one of the possible solutions is adopting integrated water resources management (IWRM).

1.1 Integrated Water Resources Management (IWRM)

IWRM is a systematic process for the sustainable development, allocation and monitoring of water resources use in the context of social, economic and environmental objectives.

Uses of water resources are considered together, water allocations and management decisions consider the effects of each use on the others.

As described by Savenije and Van der Zaag, (2008); IWRM takes into account the following four dimensions:

- Water resources including stocks and flows as well as water quantity and quality. It critically assesses supply options, including developing alternative water resources, e.g. desalination (removal of dissolved minerals including salts) and reclaimed wastewater. It also seeks to increase the management efficiency of conventional resources and schemes and will also consider demand management options.
- Water users, considering all sectoral interests and stakeholders, including the environment and future generations.
- Spatial dimension, including the spatial distribution of water resources, and the various spatial scales at which water is being managed.
- Temporal dimension, considering the temporal variability in availability of and demand for water resources and the physical structures that have been built to even out fluctuations and to better match supply with demand.

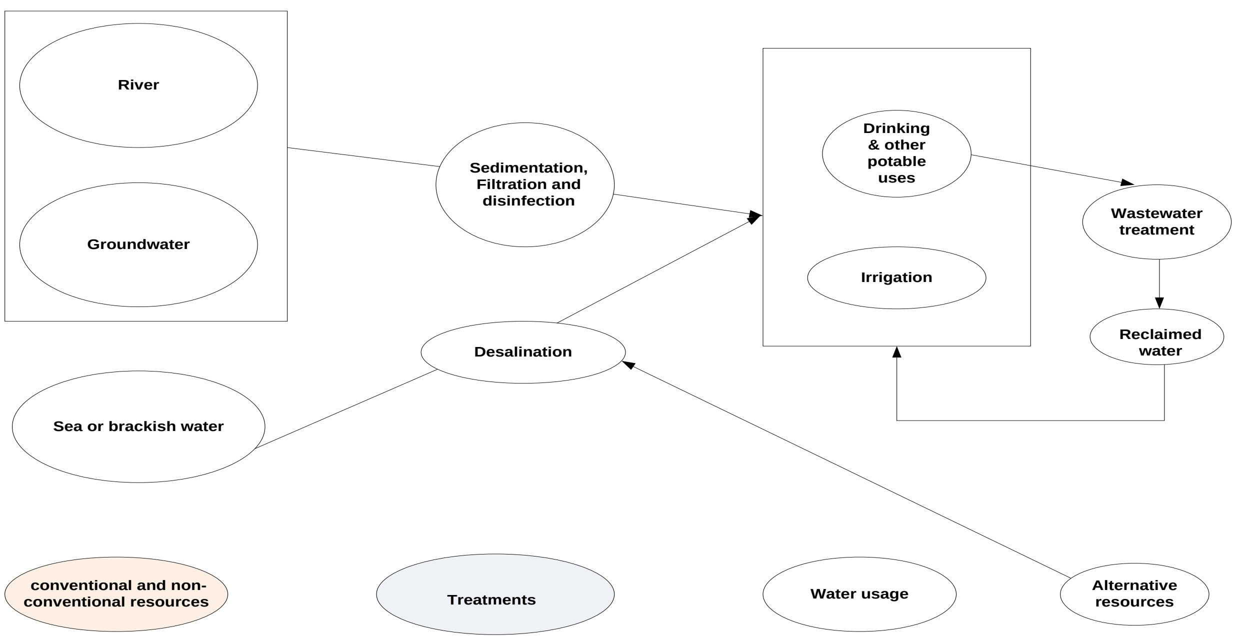


Fig 1.1 Integrated water resources management approach (adapted from Thomas and Durham, (2003)).

Figure 1.1 explains the concept of Integrated Water Resources Management (IWRM) as offering the solutions to the water crisis in linking water to other vital resources and viewing the whole water cycle together with human interventions as the basis for sustainable water management.

1.2 Literature Survey on IWRM

Tourism is directly or indirectly dependent on water, whether it is winter tourism, agro tourism, wildlife tourism or 'sun and sand' tourism. As mentioned by Charambous K. *et al.,* (2012) Cyprus attracts a large number of tourists in the summer season due to good weather and beaches. So tourism is an economic activity like other sectors which affects water demand, available water suppliers, wastewater and treatment.

1.2.1 Water Demand

Water demand in coastal areas is increasing because of population growth, industry, agriculture, and tourism development in this limited portion of emerged lands. When translating all these activates in terms of water demand, we notice a concentration in time and space, in most cases the demand increases extremely during summer times and within a fringe of a few kilometers from the sea toward mainland as described by Salgot M. *et al.*, (2004).

1.2.2 Water Supply

As described by Salgot and Tapias, (2004). Conventional water supplies are surface and ground water. However, in many cases conventional sources are either limited or not evenly distributed where it is needed. Non conventional sources include seawater and brackish water desalination and reclaimed wastewater. Other possibilities could include transportation of water by pipeline, trucks, railways or ships. For the study area of North Cyprus, conventional water supplies are limited and suffering from water shortage. One of possible solutions is to transport water from Turkey to North Cyprus by pipeline. Already Bafra village is supplied by non conventional water sources (reverse osmosis plant). In this study Water supply options for the case of Bafra village are investigated in terms of availability, energy demand, cost and impact on environment.

1.2.3 Water Resources in Arid Coastal Regions

The city of Sharm in Egypt is a typical example of a tourist city located in an extremely arid environment with a haphazard approach to water resources management. As described by Lamei A.(2009) water supply to Sharm is mainly from reverse osmosis (RO) desalination complemented by groundwater from Al Tor which is transported by tanker or long-distance pipelines as well as from treated domestic wastewater (for landscape irrigation).Desalinated water is provided by two government-owned RO plants two centralized privately-owned RO plants and by about 50 decentralized small RO plants . Government-owned RO plants are selling water at a very low subsidized price to the local residents while the two centralized private RO plants (owned by two different private companies) could control the market and raise prices considerably especially in periods of high water demand. As mentioned by Djebedjian B. et al,(2005), the average cost of desalination of one cubic meter of seawater ranges between 0.5 to 1.5 US$, so that the selling price ranges from 1.6 to 2.5 US$/m3). All of these RO plants cause environmental problems due to high energy consumption per cubic meter of water produced and the impact of uncontrolled brine disposal on the environment.

Both reverse osmosis (RO) desalination and long-distance piping options are meant to provide water of potable quality. Unit production costs of RO plants in Egypt are comparable to plants of similar capacity (above 600 m^3/d) in the International Desalination Association (IDA) report (2006). The observation that RO desalination costs in Egypt are higher than international trends as mentioned by Hafez and El Manharawy (2000) is not valid as plant capacities were not taken into consideration (Egyptian RO plants being generally smaller than 5,000 m^3/d). However, it should be noted that current standard industry unit production costs are much lower (about 0.5 to 1 US$/$m^3$. In North Cyprus private RO plants are currently operation in Gazimagusa with total capacity 3500 m^3/day. The Bafra village is supplied by water from a nearby private RO plant. The unit cost of production of one cubic meter is 1US$, selling price for hotels is 1.5 US$/$m^3$ as described in section 3.3.1.

1.2.4 Water Supply by Transported Water

One of estimates of water transport has been provided by Guren, G. (2000), transporting water from Turkey to North Cyprus by 78 km pipeline with capacity of 75 Mm^3/year to be at 25-34 ¢/m^3 as mentioned by Zhou . Y and S.J.Tol. R. (2004).

As described by Abou Rayan M. *et al.*,(2003) and Djebedjian B. *et al.*,(2005).The transported water from Nile to the Red Sea Governorate, the pipeline supplies all the cities that lie on the Red Sea coast. There are two main lines, the first with a total length of 180 km. There are three parallel lines with different diameters: 200mm, 300mm and 400mm, supported by 13 pumping stations distributed on the route, the total capacities of the lines are 17,000 m^3/d distributed on three cities.

The second pipeline of diameters 1000 mm and 600 mm, with a total capacity 28,000 m^3/d distributes to cities. There are seven pumping stations on the pipeline. The total cost of the pipeline is 194 million US$ and unit cost 0.62 US$/$m^3$.

1.2.5 Tourism Development in Coastlines

Coastal areas are transitional areas between the land and sea characterized by a very high biodiversity and they include some of the richest and most fragile ecosystems on earth, like mangroves and coral reefs. At the same time, coasts are under very high population pressure due to rapid urbanization processes. Today’s more than half of world population live in coastal areas (within 60 km from the sea) and this number is on the rise.

Additionally, among all different parts of the planet, coastal areas are those which are most visited by tourists and in many coastal areas tourism presents the most important economic activity. In the Mediterranean region for example, tourism is the first economic activity for islands like North Cyprus, Malta,the Balearic Island and Sicily, as well as further education in tourism . Others coastlines in Mediterranean region facing rapid development are as follow:

Spain is the second world tourists’ destination (51,748 million tourists in 2002, World Trade Organization: WTO) and annual income from tourist industry in 2002 was 33,809 million USD$.

Seasonal peaks in water demand by tourism are extreme and their increase over the last few decades has been spectacular, as mentioned by Plan Bleu (1999) points of that the population of 27 municipalities on Costa Brava (Spain) swells from 150,000 in winter to 1.1 million in mid-August. The EEA (2000) reports that water consumption during the peak tourism month in 1999 in the Balearic Islands was equivalent to 20% of the used by local population in whole year. Tourist water consumption has increased by about 80% since 1994. Murcia plans to double its tourist potential in the next ten years, to reach nearly one million hotel places and 100,000 new residents. This increase puts pressure on fresh water resources during summer when the population in the southeast in four times as big as during winter.

Turkey, with around 12 million visitors each year, according to the OECD income from international tourism account for approximately 15% of total export incomes. A WWF analysis pointed out that in 2005 Turkey was experience massive surge of new tourism development. And by 2020, it will be a leading tourist destination in the Mediterranean together with Greece and Croatia. In Turkey tourism is concentrated mainly along the Aegean and Mediterranean coasts (in 1997 about 70% of tourism bed capacity was located in these areas).Along the Aegean and Mediterranean coasts lines are many small and medium sized municipalities located very close to each other and their resident population doubles or even triples during the tourism seasons.

The present study is focused on Bafra village. It has been designated an area for tourist expansion by the North Cyprus government, and it is certainly expanding rapidly. Since the development of two five star hotels, other planed hotels in future are to increase the bed capacity by an additional 20,000 beds.

1.2.6 Water Resources Management

In arid and semi-arid coastal regions, water resources are limited, so that water resources management in these regions ranges from water demand management, to the development of alternative water resources and their integration into the water resources system.

1.2.6.1 Water demand management

As described by Van der Merwe B. (1999) WDM is defined as a management approach that aims to decrease water demand by promoting efficient water use through economic, educational and technological. An example of a water demand management (WDM) projects was mentioned by Lamei A. (2009) is addressing the tourism in several resorts in arid Namibia. As pointed out by Schachtschneider K.(2000), WDM project includes awareness programs for visitors and staff. For a one-year preliminary survey of water use in twelve tourist camps was conducted by the Department of Water Affairs. It found that visitors only use a fraction of the water, while most is used by staff, on gardens or is lost due to leaks. It recommended that to increase water use efficiency at tourist facilities, water demand management should be implemented at all levels. The preliminary studies have shown that efficient water use can be achieved if the facility management is in control of the daily water use and is interested in water demand management approaches. Tight maintenance schedules, water pricing for visitors and staff members, landscaping of gardens and retrofitting water outlets with water efficient devices.

1.2.6.2 Integrated water resources management

A way of analyzing the change in demand and operation of water institutions that evaluates a variety of supply-side and demand-side management measures to determine the optimal way of providing water services. Some examples are presented in this section for IWRM projects. In the Canary Islands, wastewater reuse has increased significantly. The treated wastewater is used for Agricultural irrigation reducing demand on potable water. As a result of reducing groundwater availability, seawater desalination and reuse has grown dramatically to satisfy demand for important tourist industry.

Another IWRM was implemented in Hawaii, is one of the largest and most innovative new wastewater projects for the production of unrestricted reuse water for irrigation and distribution networks. Majorca need additional potable water to satisfy the growing tourist industry, the source of energy for desalination of seawater using the waste heat from power stations, at competitive costs.

1.2.7 Modeling of Integrated Water Resources Management

Mathematical models have been developed to address integrated water resources management in arid and semi-arid regions. As developed by Xu et al., (2003b) an integrated technical economic modeling framework to help planning and managing of water resources in a Mediterranean tourist area, in France and Spain is given four types of models were established and coupled: hydrological model, water demand and/or need model, reclaimed water storage model, and a technical economic model. In addition, a multi-criteria analysis was utilized for the evaluation of scenarios. The target of their model was to integrate the reuse of treated wastewater for irrigation reducing demand on potable water. The authors focused on developing a modeling tool to facilitate the implementation of water reuse in water resources management. Beside the integrated model developed by Xu et al., (2003a) other models were designed for integrating wastewater reuse.

The technical-economic modeling tool developed in this work will follow an integrated approach for sources of potable water supply, optimization of contracted-for water supply. This model focuses on the economic side for water consumption in the tourism sector in guiding the planers to take right decision for management of water consumptions in hotels .

The modeling tool is developed by Excel Worksheets, which handles sources available during the year in arid and semi arid regions, and related prices to optimization of total cost with achieving water demand, it also considers other alternatives for supplying non- conventional sources like desalinated water and wastewater treatment plant in future alternative plans for study area.

1.3 Water Resources for TRNC.

As observed by Turan F. (1997), the water resources for North Cyprus are as following:

- Rivers; most of them rise from Torodos Mountains which are in the Greek region. There are 40 main rivers in the Cyprus Island. A few of them have continuous flow measurement, 70% of them are out of the North Cyprus area.
- Springs , a few springs rise, Girne mountains side which has little water.

- Existing dams; more than 40 dams were built in North Cyprus. The purposes of dams were to supply water, recharge the aquifer and irrigation.
- Groundwater; main water resources is groundwater in North Cyprus. Like GaziMagosa aquifer and the main aquifer in North Cyprus is Guzelyurt aquifer.
- Recently, new water source supplying of North Cyprus by water, is by conveying dam water (75 MCM per year) from Turkey through a 78 km pipeline. The project is due to reach completion in 2014.
- Other sources, have limited utilization in North Cyprus (desalination plants and treated waste water).

1.4 Water Supply Methods Used in Study Area

There is mixture of water supply methods on Girne's coastlines for hotels; some depend on their reverse osmosis desalination plants for desalinated sea water with no need for buying water from other sources. During the summers, demand reaches the peak point of water consumption due to intensive activities from tourism, so the tourism sector is forced to meet the demand by buying water from other expensive sources like transported water by tankers.

Reverse osmosis is not available in some hotels, so the main source is groundwater (mainly brackish water). As we know some of coastal aquifers suffer from salinity, so care must be exercised in monitoring withdrawal quantities. The second source is supplying of water by pipelines from municipality. The reliability of this source is low. Because of discontinuous supply of water during summer times, water supplied by tankers is the last choice for hotels.

Water sources in Bafra area include a private desalination plant currently 3500 m^3/day capacity which could be extended in future. There are plans to increase the number of hotels to receive additional 20000 tourists in the future. We need to meet the increasing water demand by searching for other alternatives, regardless of the sources as conventional or non conventional. One of these sources is sea water. As reported by Romanel *et al*., (1998) for the Mediterranean Sea contains about 35,000 milligrams of dissolved solids per liter, it is generally considered that the maximum salt content for water to be potable water the contents of dissolved solid should not be more than 800 milligrams per liter, a value of 500 milligrams per liter would be better as target to reach this percentage of dissolved solids. A lot of processes are needed for desalination, which requires excessive energy to separate the salt from sea water. One of desalination methods is reverse osmosis, and it consists basically of pumping sea water up to a very high pressure and allowing it to percolate through semi-permeable filters. This would seem to be similar to filtration but, in fact, it is not the case. Also we could desalinate groundwater which is divided into two kinds: brackish and low salinity. Recently reverse osmosis technology which is one of the newest desalinated membrane technologies has been applied to a wide range of separation process.

The second alternative is by way of pumping water by pipeline from the nearest point which is far from Bafra about 35 km. The source of water is Gecitkoy dam near Girne , which will be supplied by water from Alakopru Reservoir in Turkey's southern province of Mersin through underwater pipeline. The pumping costs are expected to be high. It is important to note that desalinated water is a water resources added to the national water supply. A variety of desalinating technologies has been developed over the years, including primarily thermal and membrane process. The costs of water produced by desalinations have dropped considerably over the years as a result of reductions in the price of the equipment. Reduction in power consumption and advances in system and operating experiences, as the conventional water supply tends to more expensive due to exploitation of aquifers and increasing contaminated water resources, desalted water has became alternative water source. The unit cost of desalted water is expected to decline in the future as the technology progresses. Other alternative sources like water transported by tankers are generally no longer considered to be the practical solution.

Dealing with existing sources in region by adopting IWRM projects should be sustainable and fulfill the public interest. Sustainability should be considered from the following perspectives as mentioned by Lamei A. (2009):

- Maintenance of environmental quality (including water quality)
- Financial sustainability (cost recovery)
- Good governance (effective management mechanism)
- Institutional capacities (capacity building, human resources, and appropriate policy and legal framework).
- Social equity (equal right of people to water resources).

In some hotels there is no adopted strategy for buying water from suppliers. If they adopt contractual agreement, they will save more money especially in cases of high occupancy rates.

Supply of freshwater requires energy and both of them are inseparable and essential commodities for sustaining human life on earth, but unfortunately many countries in the world that lack freshwater sources are also deficient in energy sources. Up to 30% of desalination cost is due to the energy requirements for the production of fresh water, and most large desalination plants around the world are driven by fossil fuels. This is a limited source for energy and prices are continuously increasing. Also transportation and pumping consume energy that lead to contribution to acid rain and climate change by releasing green house gases as well as . The alternate energy sources are becoming crucial for energy security and future sustainable development and are in many cases compared with conventional sources are more economic.

Solar energy is renewable and available source of energy, so we can depend on this source for producing energy in process of desalination water by using photovoltaic (PV) solar energy, however, PV is appropriate for TRNC as it is more applicable to smaller RO plant size. Solar energy is not cost competitive at the moment but advances in the technology will continue to drive the prices down, whilst penalties on usage of fossil fuel will increase electricity costs from conventional non-renewable sources.

All of these RO plants cause environmental problems due to high energy consumption per m^3 of water produced and the impact of uncontrolled brine disposal on the environmental. In reverse osmosis technology, fifty percent of the feed water will be potable water and the other will be the discharge brine. Environmental impacts associated with concentrated discharge have historically been considered as a major environmental concern to marine life with desalination plants.

1.5 Scope and Objectives

The objectives of this work as follow:

- To show temporal variation of water demand for tourism sector in the study area.
- Reliability of water resources in meeting the demand.
- Application of technical – economic modeling on the study area and to find possible solutions.
- The strategy in water purchasing to be followed by the hotels.

- To compare the case of contract agreement between hotels and suppliers.
- To investigate the availability of adapting new sources like desalination plants and transported water through pipe line to the Bafra region.

1.6 Thesis Outlines

Chapter 2 presents information on the water usage of tourism sector. This chapter deals with data collection and its analysis, shows some characteristics of surveyed hotels and potable water consumption as periodic with fluctuating peaks occurring in summer months. This is followed by a description of the relation between potable water consumption and number of occupants. Function of potable water consumption for the case study gives average potable water consumption per occupants for comparison purpose.

Chapter 3 presents the projected water demand calculation for the case study region. The quantity of water that will be demanded by additional 20000 occupants is 15000 m^3/day and comparing the capacity of current sources in the region cost comparison for two options to supply potable water to meet the additional demand. Option 1 (pipe line route), or option 2 (Desalination with reverse osmosis technology) for the case study of Bafra.

Chapter 4 presents optimization of supply sources in order to formulate the cost relationship of supply from n sources to fulfill the demand required for a given month and the cumulative cost C incurred over time summation for one year. For optimization of total cost of buying water from different suppliers is introduced. After optimization of total cost we could formulate and write contract agreements between two parties or more for better unit price. This chapter describes the methodology of working the model and contract agreement.

In chapter 5 a discussion of the theoretical and practical implications of the thesis research is given.

CHAPTER 2

WATER USAGE of TOURISM SECTORS

2.1 Introduction

The water demand in arid and semi-arid regions by hotels and related services is a major problem in many coastal regions. The usual way to meet demand is through conventional surface and ground water, but in semi-arid regions like North Cyprus water resources are limited. The main problem is shortage of water so a shift is taking place towards non-conventional sources such as desalination or transported water and further development of new sources.

The characteristic of demand is time – variant. A peak value in summer coincides with the time when water availability is at its lowest due to of intensive activities from tourism. As mentioned by Chartzoulakis et al., (2001) and Gonzalez et al., (2005), tourism industry requires huge amounts of water (between 300 and 850 L/day/tourist) much more than a local inhabitant requires and tourists are normally not prepared to encounter water scarcity.

Water usage by the tourism sector is not well documented by statistics in North Cyprus and at present it was difficult to assess the impact it has on water resources. Therefore a comprehensive survey of water usage by the tourism sector was a necessity. Surveying depends on the collection of data and the development of detailed statistics. This chapter deals with data collection and its analysis. The various questions raised to explore the use of water and to identify the relationship between tourism and water consumption in North Cyprus is described in section 2.2. In this study we focused specifically on the tourism sector. The breakdown for different types of resources and supply prices were investigated. The occupancy rates, water consumption per tourist per day, variation in water consumption at different months of the year are investigated. The details of the questionnaire as well as analysis of data are presented shortly. The determination of water usage per occupant and the future prediction of the quantity of water that will be demanded by the tourism sector in Bafra region of North Cyprus form the main themes of this study.

2.2 Methodology for Case Studies.

In this study six hotels were selected and surveyed for a period of three-weeks. A typical survey form used is given in Table 2.2. The data collected covers the period January 2010 to December 2011. In this questionnaire, the parts addressed are:

- Potable water consumption (m^3/month).
- Occupancy rate.
- Bed capacity.
- Irrigation water (m^3/month).
- Water suppliers and price per m^3.

The technical managers from hotels provided us the data from their data records after having explained the main purpose of this work for the study area of North Cyprus. Altogether, data was collected from 5 hotels . Two of them are located in the Bafra tourism area. The other hotels are located on Girne's coasts. The sources are a mixture of water desalination plants, municipality pipeline supplying groundwater and water supplied from local wells by tankers in deficiency cases. Figure 2.1 shows coastlines hotels investigated in North Cyprus. Consumption of potable water is expected to depend on the occupancy rate, which depends on the time of the year (for the surveyed hotels the average occupancy varies from 26% to 86%). In summer times in some hotels occupancy rates reach 100%.

Table 2.1 shows some characteristics of the surveyed hotels. The average occupancy for Hotels 3and 5 are fairly low. They are located in the Bafra region. However this area is under development for the tourism sector with the main aim of becoming the tourism center for North Cyprus. The planned increase in bed capacity for this area is 20,000. This study and analysis of data is expected to aid projections on future water demand for the Bafra tourism area.

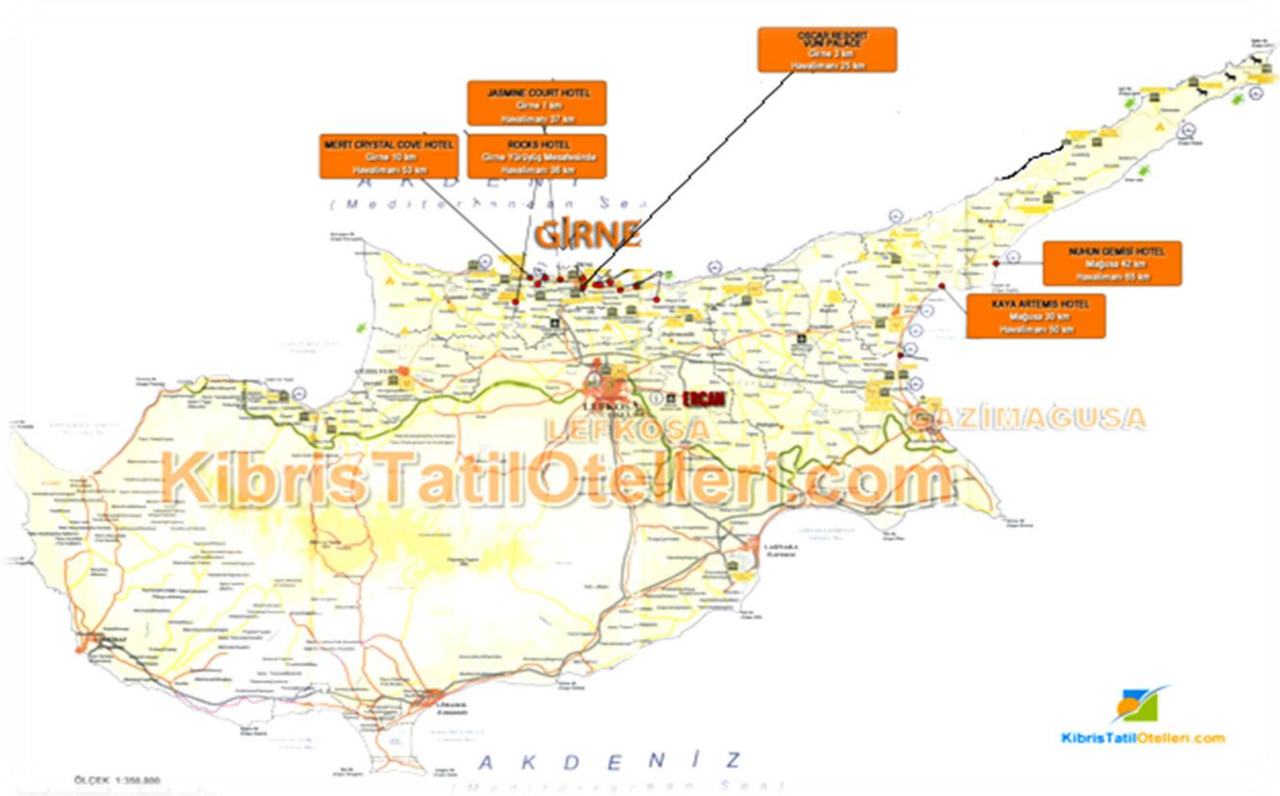


Fig 2.1 Surveyed Hotels in TRNC. (http://www.kibristatilotelleri.com/girne-otelleri.php April/2012).

Table 2.1 Some Characteristics of surveyed Hotels.

	Hotel 1	Hotel 2	Hotel 3	Hotel 4	Hotel 5
Source of water	Own R.O	R.O, Tanker, Groundwater	Municipality, Groundwater	Municipality, Tanker , Ground water	Municipality Groundwater
No. of Rooms	350	427	1800	312	1530
Avg. Occupancy	76%	86%	30%	57%	26%

Hotel number: 1			Hotel type: 5 star									year :2010
Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)							
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)	
					m^3	TL	m^3	TL	m^3	TL	m^3	TL
Jan	51	350	4600		–	–	–	–	4600	2.5	–	–
Feb	54	350	4850		–	–	–	–	4850	2.5	–	–
Mar	57	350	5100		–	–	–	–	5100	2.5	–	–
Apr	63	350	5600		–	–	–	–	5600	2.5	–	–
May	71	350	6250		–	–	–	–	6250	2.5	–	–
Jun	98	350	8700		–	–	–	–	8700	2.5	–	–
Jul	99	350	8800		–	–	–	–	8800	2.5	–	–
Aug	100	350	9000		–	–	–	–	9000	2.5	–	–
Sep	99	350	8850		–	–	–	–	8850	2.5	–	–
Oct	86	350	7500		–	–	–	–	7500	2.5	–	–
Nov	71	350	6400		–	–	–	–	6400	2.5	–	–
Dec	57	350	6000		–	–	–	–	6000	2.5	–	–

Diğer bilgi:

Other information: hotel own reverse osmosis with maximum capacity 1200 m^3/day

Table 2.2 Hotel 1 (2010)

2.3 Data Analysis.

2.3.1 The case study of Hotel 1

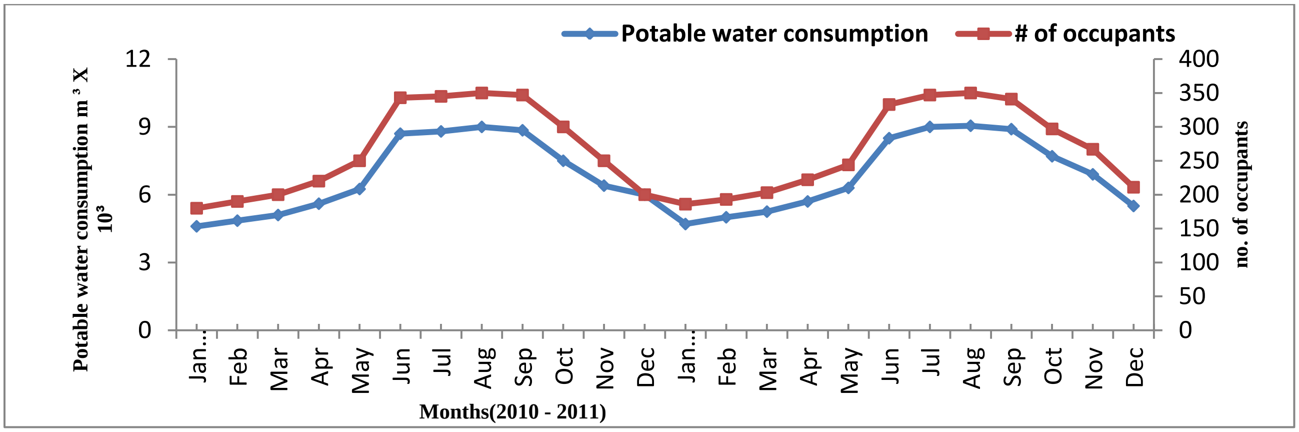


Fig 2.2 Potable water consumption pattern for Hotel 1.

Figure 2.2 shows a periodic fluctuating pattern of potable water consumption for hotel 1with peaks occurring in summer months as expected. The correlation between occupancy number and water consumption is clearly observable form the same phase relationship between consumption and occupancy. This point is further analyzed in section 2.3.2. An important feature of this figure is that typically the ratio of peak demand to lowest demand is approximately 2:1. This highlights a sharp demand rise for summer months. In this respect a hotel depending on its own reverse osmosis would have to double its capacity for the summer months, other times the system would only operate with no more than 50% capacity.

For a given hotel it is expected that water consumption per tourist per day will depend on the time of the year. For example in summer months tourists tend to take more showers, more water is used for swimming pools and for green areas irrigation. Our expectation is

$$V = f_n(N, T) \tag{2.1}$$

Where V is water consumption,N stands for the number of tourists and T is the time of the year.

For summer month since N rises, we expect the data to show a steeper pattern as sketched in Figure 2.3.

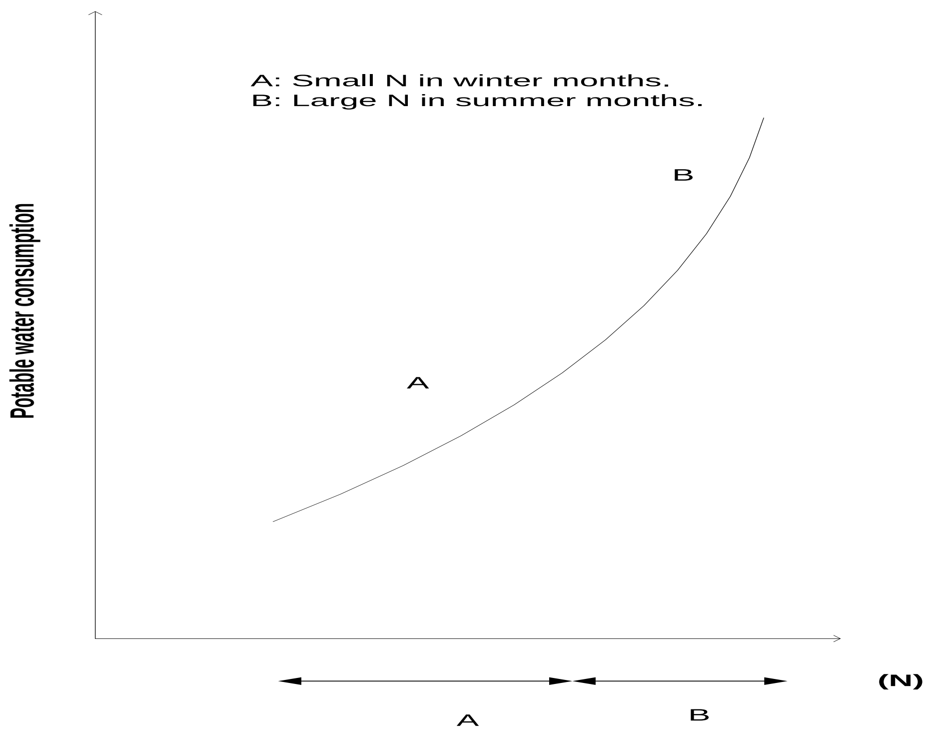


Fig 2.3 Expectation of potable consumption against the number of occupants.

In Figure 2.4 the functional relationship is plotted from the available data. We observe an almost straight line with a correlation coefficient of 0.99. The data supplied by hotels cover monthly consumption. The expected sharp increase for summer months is not observed in fig 2.4. The reasons for this are that the consumed quantities given by the hotels consist of green areas irrigation as well as potable water. If this data could separately be obtained, the current data would be expected to show a trend as in Figure 2.3.

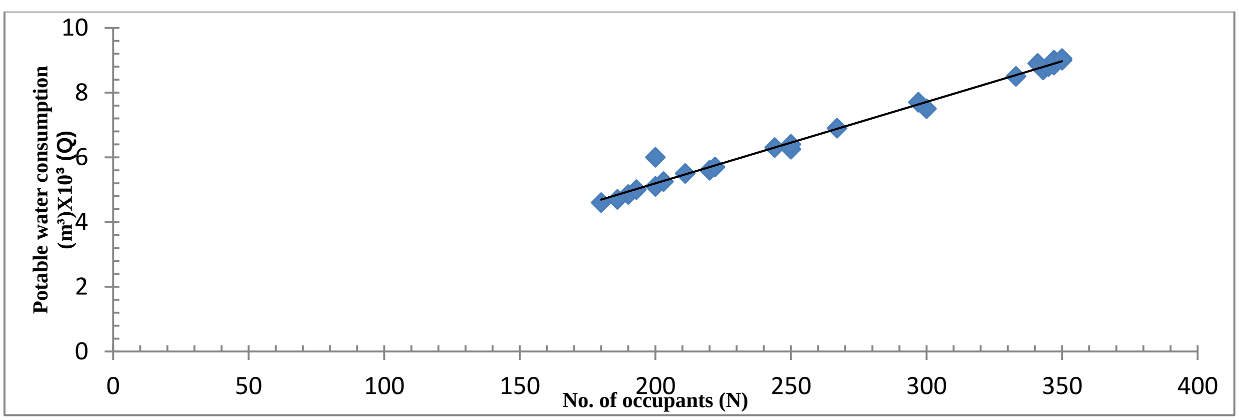


Fig 2.4 The variation of potable water consumption against the number of occupants for hotel 1.

2.3.2 Function of Potable Water Consumption for Hotel 1.

As clearly seen in figure 2.4 there is a strong linear correlation between the amount of water required and the number of occupants. The data for correlation coefficient calculation is given in Table 2.3. From this correlated data the equation of the regression line is.

$$V = a + W_T\, N \tag{2.2}$$

Where $W_T = \frac{S_{VN}}{S_{NN}}$ and $a = \bar{V} - W_T \bar{N}$. The co-variance S_{VN} and the variance S_{NN} are tabulated in the Table 2.3. where the product moment of correlation is defined as.

$$r = \frac{S_{VN}}{\sqrt{S_{NN} S_{VV}}} \tag{2.3}$$

The product moment of correlation gives a measure of how closely the data are linearly related. In this case the value of r=0.99 is a very strong correlation with the gradient W_T, representing mean amount consumed per day per occupant. For this study the mean demand, W_T was found to 0.840 m^3/day/occupant. For the summer months the availability of data per occupant was only global monthly data. In order to observe the effect of increasing temperatures on finer scale, data based on daily weather conditions and fine scale daily consumption measurements are required . Due to only the availability of monthly data, further refined work on this can only be as additional work of study.

Table 2.3 Calculation of correlation coefficient for Hotel 1

Month	n. of occupants(N)	Daily water consumption(V) m^3	N^2	V^2	N*V
Jan(2010)	180	153	32400	23511	27600
Feb	190	162	36100	26136	30717
Mar	200	170	40000	28900	34000
Apr	220	187	48400	34844	41067
May	250	208	62500	43403	52083
June	343	290	117649	84100	99470
July	345	293	119025	86044	101200
Aug	350	300	122500	90000	105000
Sep	347	295	120409	87025	102365
Oct	300	250	90000	62500	75000
Nov	250	213	62500	45511	53333
Dec	200	200	40000	40000	40000
Jan(2011)	186	157	34596	24544	29140
Feb	193	167	37249	27778	32167
Mar	203	175	41209	30625	35525
Apr	222	190	49284	36100	42180
May	244	210	59536	44100	51240
Jun	333	283	110889	80278	94350
Jul	347	300	120409	90000	104100
Aug	350	302	122500	91003	105583
Sep	341	297	116281	88011	101163
Oct	297	257	88209	65878	76230
Nov	267	230	71289	52900	61410
Dec	211	183	44521	33611	38683
n=24	**6369**	5472	**1787455**	**1316803**	**1533607**
$\bar{V} = 228$	$\bar{N} = 265.4$				
S_{NN}	S_{VV}	S_{NV}	**r_{NV} (Cc)**	w_T	**A**
97282	69339	81563	**0.99**	0.84	5

$S_{NN} = \sum N^2 - \frac{(\sum N)^2}{n}$, $S_{VV} = \sum V^2 - \frac{(\sum V)^2}{n}$, $S_{NV} = \sum NV - \frac{\sum N \sum V}{n}$

$V = a + w_T N$ yield daily potable water consumption for hotel 1: $V = 5 + 0.84\ N$ (m^3/day)

2.3.3 The Case Study of Other Hotels

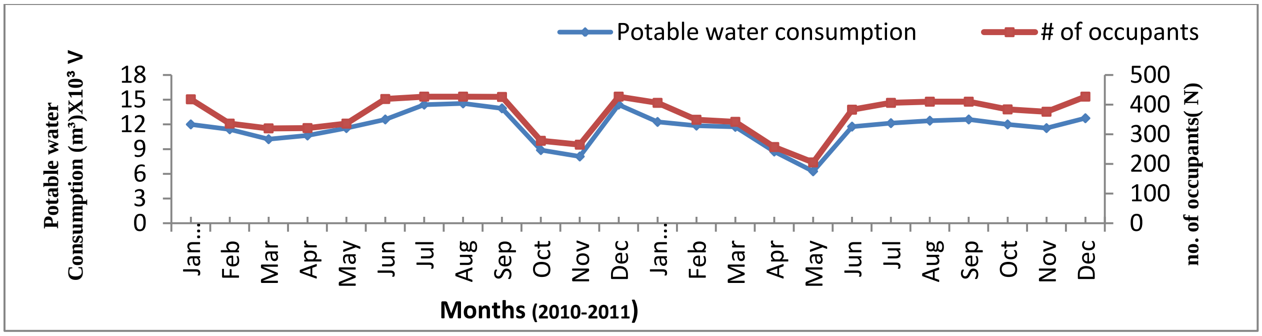
Figure 2.5 shows the variation of water consumption and occupancy for all the hotels investigated during a 2 year period. As in Figure 2.2, Hotels 2 and 3 exhibits a periodic variation with the number of occupants hence consumption increases in summer months. The data for hotel4 exhibits a slightly different trend as compared with the others. This hotel has almost uniform occupancy throughout the year.

For all of hotels 2-5 the consumption against occupancy is shown in Figure 2.6. The trends of increasing consumption with increasing numbers of occupants are still observable with some scatter about the fitted straight line.

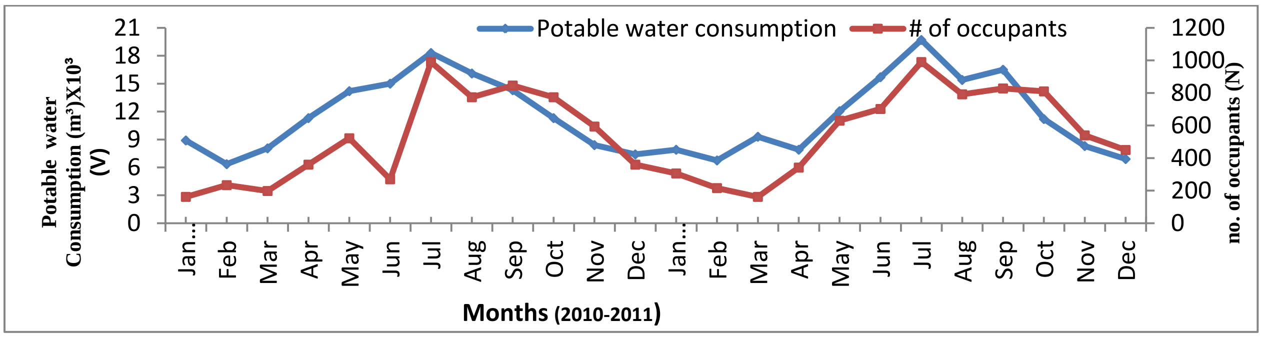
Table 2.4 The mean demand values W_T and correlation coefficients for Hotel 1-5.

	Hotel 1	**Hotel 2**	**Hotel 3**	**Hotel 4**	**Hotel 5**
W_T **(m³/tourist/day)**	0.84	1	0.38	1.04	0.82
R (correlation coefficient)	0.99	0.95	0.77	0.81	0.76

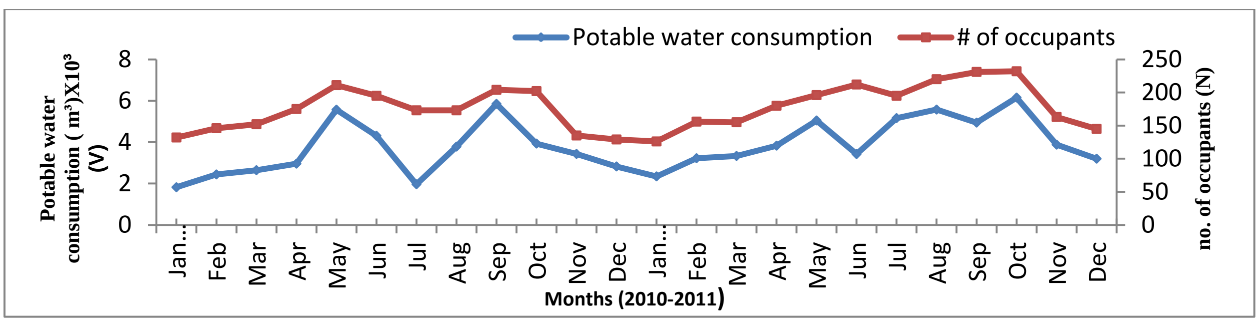
As can be seen from Table 2.4 the value of W_T(consumption / tourist /day) varies significantly from one hotel to other. The main reason for this is the fact that data supplied for hotel 2 and 4 also includes irrigation consumption. To get realistic mean value for all the hotels, all the available data are plotted together as in figure 2.7



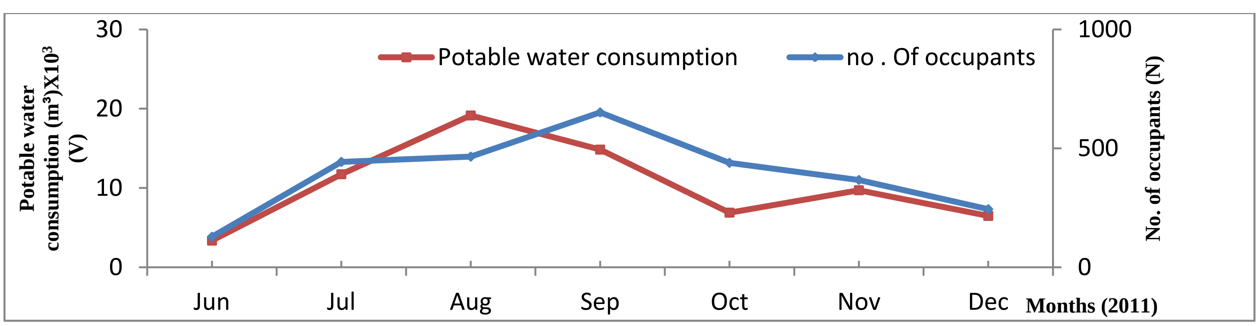
(a) Hotel 2



(b) Hotel 3

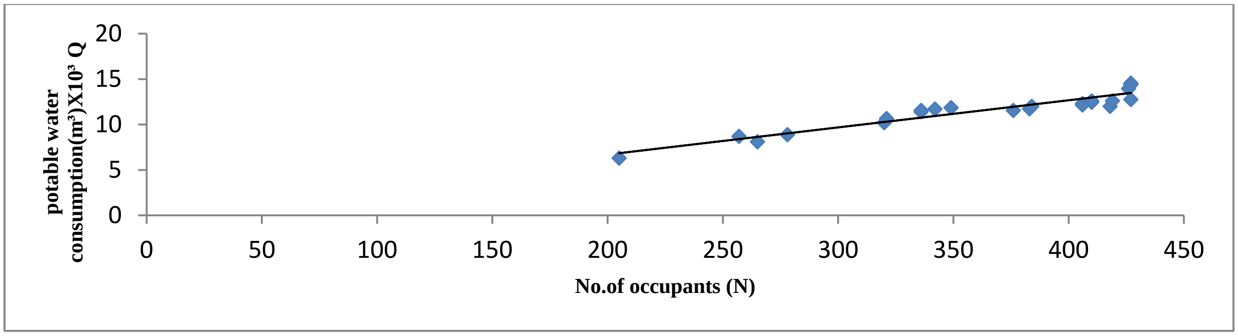


(c) Hotel 4

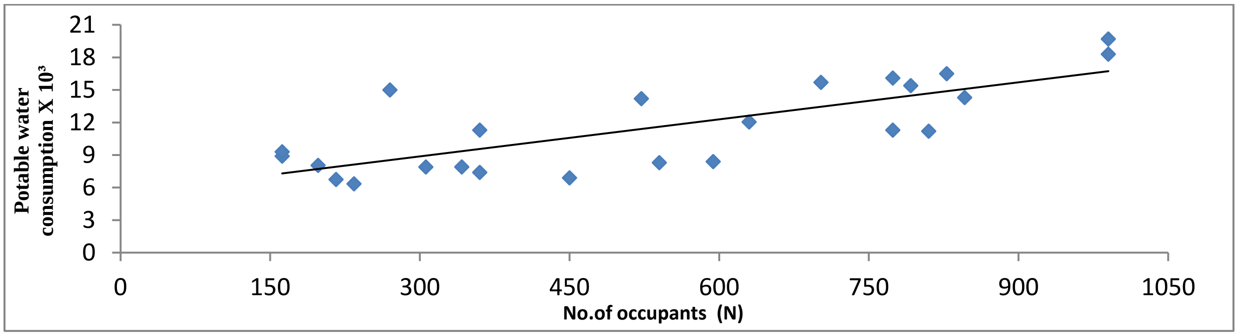


(d) Hotel 5

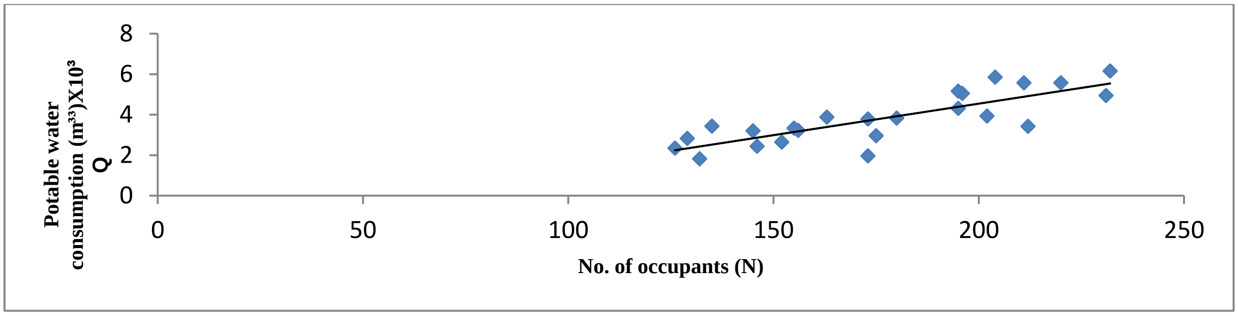
Fig 2.5 Potable water consumption patterns for hotel (2 - 5).



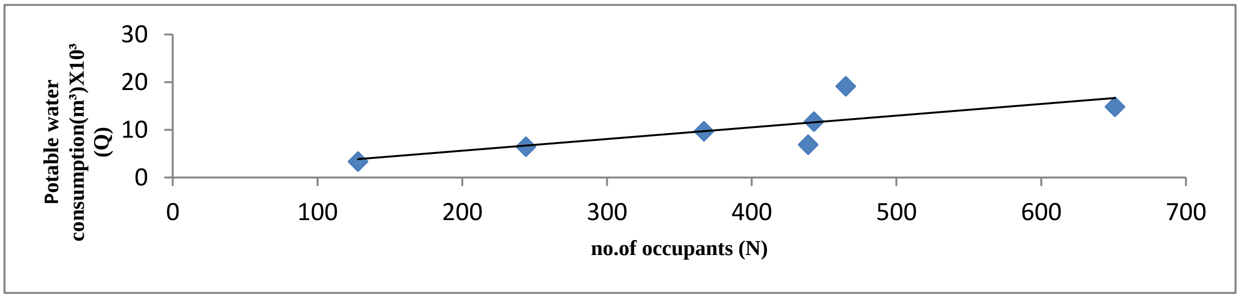
(a) Hotel 2



(b) Hotel 3



(c)Hotel 4



(d)Hotel 5

Fig 2.6 The variation of potable water consumption against number of occupants for Hotels 2- 5.

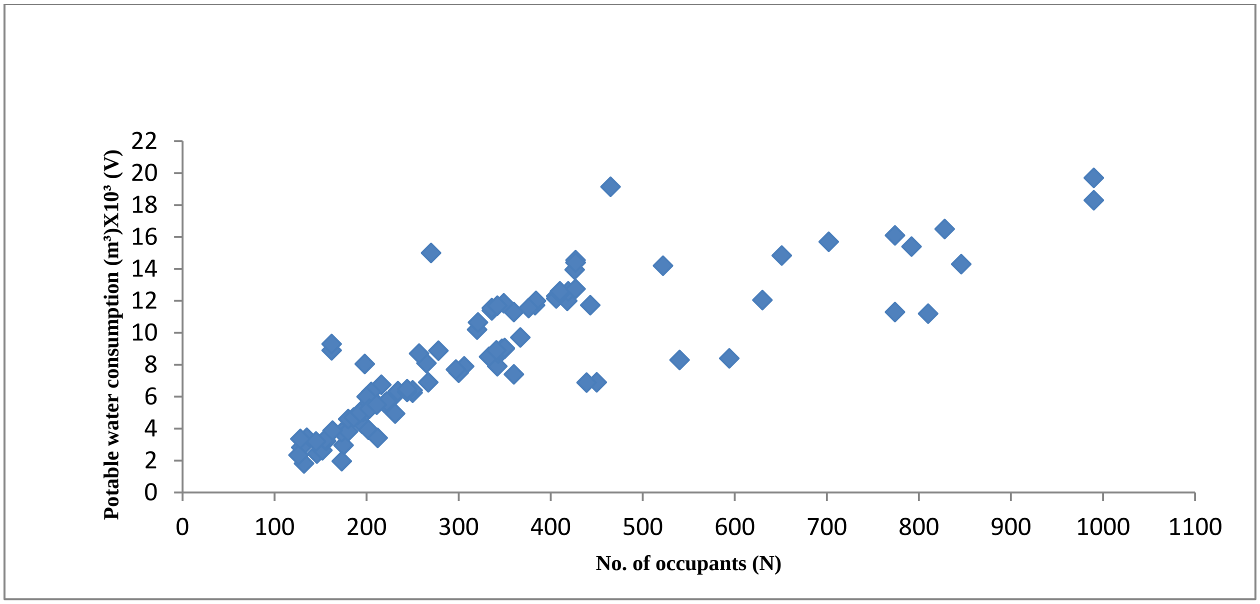


Fig 2.7 The variation of potable water consumptions for all the hotels against number of occupants.

For this combined data, the value of W_T is calculated as 590 L /day. This value represents the average daily consumption per tourist per day for North Cyprus. This value is used for future demand projections as given in section 3.1.

In table 2.5 the data of Charalambous *et, al. (2012)* and that of present findings are compared. The average consumption for North Cyprus is relativity higher than other areas like Sharm El Sheik in Egypt and Benidorm in Spain.

Site	Water consumption (L /tourist/day)
Sharm El sheik , Egypt	400
Benidorm ,Spain	380
Zanzibar , Tanzania	920
North Cyprus (this work)	590

Table 2.5 Comparisons of tourism average potable water consumption in coastal regions.

As can be seen in Table 2.5 the mean consumption as 590 L /day is almost 50% higher than its counterparts Benidorm and Sharm in Egypt . The data of this study certainly includes some water used for irrigation purposes. However a main difference between Benidrom and North Cyprus is that in North Cyprus the hotels are located next to the sea. A tourist feeling the hot is within walking distance from the hotel. During peak heat times the tourist can easily reach the hotel for rest, for extra showers etc. In Benidorm however, although some of the hotels are on the coastline , the majority are further inside . Also the younger tourist age group (20-30) affects the consumption as younger people trend to leave their hotel in the morning for sea and return late in the afternoon or early evening. Their majority of time is spent at sea or on the shore with less consumption of water during the day.

CHAPTER 3

PROJECTED WATER DEMAND CALCULATIONS

The area of Bafra is located on the north-eastern ‘panhandle’ of the North Cyprus coastline. An area which stretches from the ancient town of Famagusta to the northern-most tip of Cyprus. This substantial area is known locally simply as ‘Cyprus’ paradise’, and is widely recognized as being one of the most unspoiled places in the Mediterranean. Virtually undeveloped, the area is home to a diverse range of wildlife, flora and fauna; its coastline features some of the most beautiful, idyllic beaches and scenery in North Cyprus. A reasonable distance (around 1 hour by car) from the more touristic area of Girne – and a short 40 minute drive from Ercan airports – the Karpaz Peninsular is nonetheless busy in its own, quieter way, with the area around the village of Bafra being a particular point of investor interest.

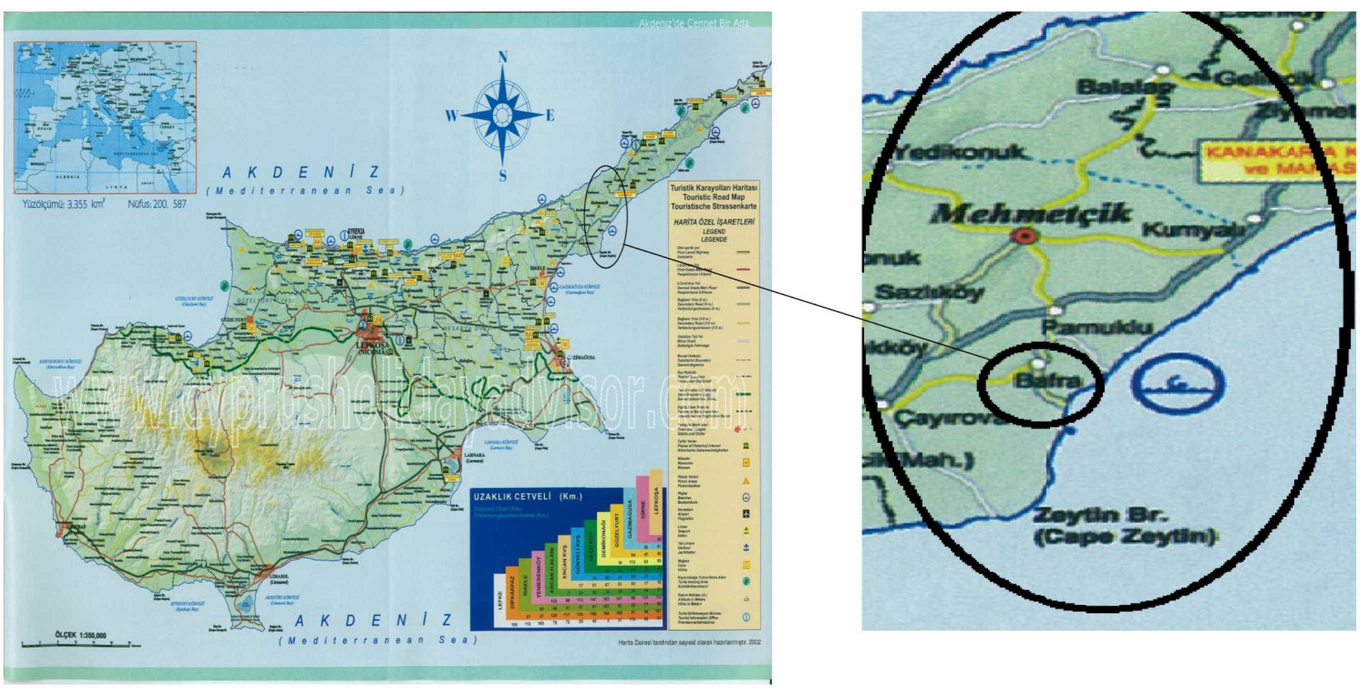


Fig 3.1 Location of Bafra in North Cyprus.

As mentioned by North Cyprus-Bafra Resot (2012), the Bafra region covers 1.5 km of beautiful sandy beaches, which has one of the cleanest seas in the world. In order to maintain the sustainability of tourism in North Cyprus, the Government of Turkey has pledged to establish a 300 million dollar investment project with the help of Turkish businessmen. A part of these investments include Bafra region, which facilitates the region with 14 quality hotels, comprising 11 five-star, 2 two-star, and one three-star, having an overall 20,000 bed capacity.

Two of the hotels already opened are hotel 3 and hotel 5 of this study. These two hotels are the biggest tourism investment directly made in North Cyprus. Hotel 3 is the largest hotel in the island in terms of room capacity of 1800 beds. With increasing bed capacity in this region, the water demand/supply situation will worsen. Unless measures are taken, this region will face growing water demand and shrinking water supply. The Bafra region will suffer from water shortage and this area is important for North Cyprus's economic growth. The only disadvantage for the development of this area is water; this is the driving force the scope of this work.

3.1 Projection Demand for Bafra Tourism Center

Tourist life cycle analysis for North Cyprus shows that there is a continuous increase of number of tourists visiting North Cyprus. For example Hotel 3 in Bafra has increased its occupancy by 3.2% from 2010 to 2011. The current bed capacity in Bafra region is 3300 beds. Based on the plans for expanding the hotels capacity by additional 20000 beds there will be extra water demand.

The quantity of water that will be demanded by additional 20000 tourists in Bafra region is calculated as.

$$D_{peak} = W_T * N * S \tag{3.1}$$

Where $D_{peak,}$ is the peak value of water demand by tourists. W_T is daily consumption of water per tourist per day (from section2.3.2 the Value for North Cyprus is *590* l/tourist/day). N is the number of tourists (*20,000* tourists). *S*, peak correction factor of water demand; a value of *1.25* was taken.

According to the above equation the peak demand for Bafra region is estimated at *15000* m³/day. Currently the only water supply in Bafra region is a reverse osmosis plant with capacity of 3500 m³/day.

Comparing the capacity of reverse osmosis with peak projection demand quantity, it will not be sufficient for meeting the demand for tourism in Bafra region. Therefore, investigating new sources to meet the peak demand is of significant importance possible expansion of existing RO in the region and the adoption of integrated water resources management for available resource in Bafra region is of importance. The options of transported water by pipeline and reverse osmosis are discussed in the following section.

3.2 Supply Alternatives

As seen in previous section 3.1 there will be shortfall between water demand and water availability in Bafra region, due to increasing in number of tourists and increasing hotel capacities. Since conventional surface and ground water resources are limited, water can be sourced by other alternatives. The potential alternative water source, options include:

1- Water transfers. Other nearby suppliers with surplus capacity may be able to provide sufficient water to offset ground water.(e.g. water transportation from Famagusta RO plant)
2- Developments of surface water sources, this option is not available in the Bafra region.
3- Increasing desalination capcity; Seawater can be treated to drinking water standards using well-established and widely used technology. Elsewhere, deep groundwater with high mineral content can sometimes be “de-salinated” at much lower cost and with much less waste than desalinated seawater.

In the evaluation process it is necessary to make evaluate the following information:

1. Service delivery area.
2. The nature of the existing water distribution infrastructure and current cost of operations.
3. The key decision makers who can or will decide which alternative is chosen.
4. The financial and environmental criteria that may affect that decision.
5. How tourists and water needs will change in the future.

In this work we examined two alternatives water sources for Bafra town as transported potable water from Dörtyöl by pipeline (alternative surface water pipeline routing) as figure 3.2 shows. The second one is expanding or construction of further reverse osmosis plant (RO) for desalination of seawater. Fixed and operating cost analysis for these two alternatives are given in comparison of both alternatives with consideration of financial criteria as construction and development costs of an alternative supply, operating costs and reliability of alternative sources to meet peak demand.

Fig 3.2 Location of Dörtyol and Bafra regions in North Cyprus.

3.3 Transported Water by Pipeline.

A route for transferring water by pipeline is by way of a possible new construction from the nearest main pipeline to Bafra region as seen in Figure 3.2. A possible lines starts from Dörtyol to Bafra (35 km).

For pipeline construction it is important to consider the cost parameters in order to synthesize water transporting system. The component sharing the capital costs are pumps, pipes of various commercially available size and materials, energy usage and operation and maintenance of the system component. The cost function of various component of water transporting system is described as section 3.3.1. The criteria of comparing between designs, its unit capital cost ($\$/m^3$) and the forecast of cost is expressed in terms of tourists served, the area covered and per tourist water demand.

3.3.1 Fixed Cost

The pipelines are normally buried underground with 1 meter of clear cover. Include the digging of a trench which is kept to 60 cm plus the pipe diameter. This criterion may vary based on the machinery used during the laying process and the local guidelines. The initial investment cost depends on the pipe material and the size of pipe. As the size of diameter increase the installation costs also increase. The installation cost includes all processes related to extension of pipelines, like digging, laying, welding and labors. The costs all of this processes addition to cost of pumps are called fixed cost for construction of water transported system. Table 3.1 shows variation of installation costs and pipe price per meter for different pipeline diameters. The cost data for this table is obtained from Ministry of Public Works in North Cyprus (2011).

Table 3.1 Capital cost details per meter of construction for different pipelines diameter.

Pipe diameter (mm)	Pipe cost $/m	Installation cost $/m
200	20	25
400	30	50
600	75	100

As observed form Table 3.1 the combination of pipe costs, installation costs and pump costs gives the fixed cost for water transported system. For the smaller pipe diameters, the fixed cost is lower but as shown in section 3.3.2 running costs are higher hence an optimum can only be found after comparing the total quantity of transported water.

3.3.2 Running cost

The running costs of transported water through pipelines by using pumps are the amount of capital that is spent on the energy costs like electricity. The annual cost of energy consumed in maintaining the flows depends on the flow rate and pumping head produced by the pump $H_{p.}$ According to Bernoulli equation the head of pump is given by.

$$\frac{p_1}{\gamma} + \frac{v_1^2}{2g} + z_1 + H_p = \frac{p_2}{\gamma} + \frac{v_2^2}{2g} + z_2 + h_L \tag{3.1}$$

So that,

$$H_p = h_L + \Delta z \tag{3.2}$$

Where ∇z is the difference in elevation between Dörtyol and Bafra village, and the value Δz of is 13 *m*.

From the figure 3.3 the head of pump is equal $234\,m$ and the head losses from difference in elevation represents 6% of head of pump, it is ignored with minor losses. So that head of pump equation is.

$$H_p = f\,\frac{LQ^2}{2gDA^2} \tag{3.3}$$

Pumps convert electrical power to useful work in moving water, so that the aim of careful pump selection and regular pump maintenance is to have the pump performance as efficiently as possible. Typical acceptable efficiencies for pumps are around 65%. From pump efficiency η we get

$$P_{in} = \frac{\boldsymbol{P_{out}}}{\boldsymbol{\eta}} \tag{3.4}$$

Where, $$P_{out} = \rho g\ Q\ H_p \tag{3.5}$$

The operation cost of a pump is given by equation (3.4).

$$Cost(C) = P_{in}\ \ t\ \ u_{ep} \tag{3.6}$$

Where P_{in} is power input (Kw), t is the time in hour and $u_{ep}$is unit electricity price 0.3 \$/$kw.hr$ in North Cyprus.

Over a given period of time for a given quantity of V of water transported total cost will be.

$$Total\ cost = Fixed\ Cost\ +\ Runinig\ Cost \tag{3.7}$$

And unit supply cost then becomes (u_{wp}).

$$u_{wp} = \frac{Total\ cost\ (\$)}{V(m^3)} \tag{3.8}$$

3.3.3 Life Cycle Cost (LCC)

Life cycle cost (LCC) analyses are used in the decision making to select an option from available alternatives to provide a specified service. The optimal system configuration is the one with least total cost over the period of service. The LCC analysis also provides the information to the decision maker about the trade-off between high fixed cost (construction) and lower running (operating and maintenance) cost of alternative systems. For the available sizes using equation 3.1 and 3.2 the head losses as well as power requirement values were calculated.

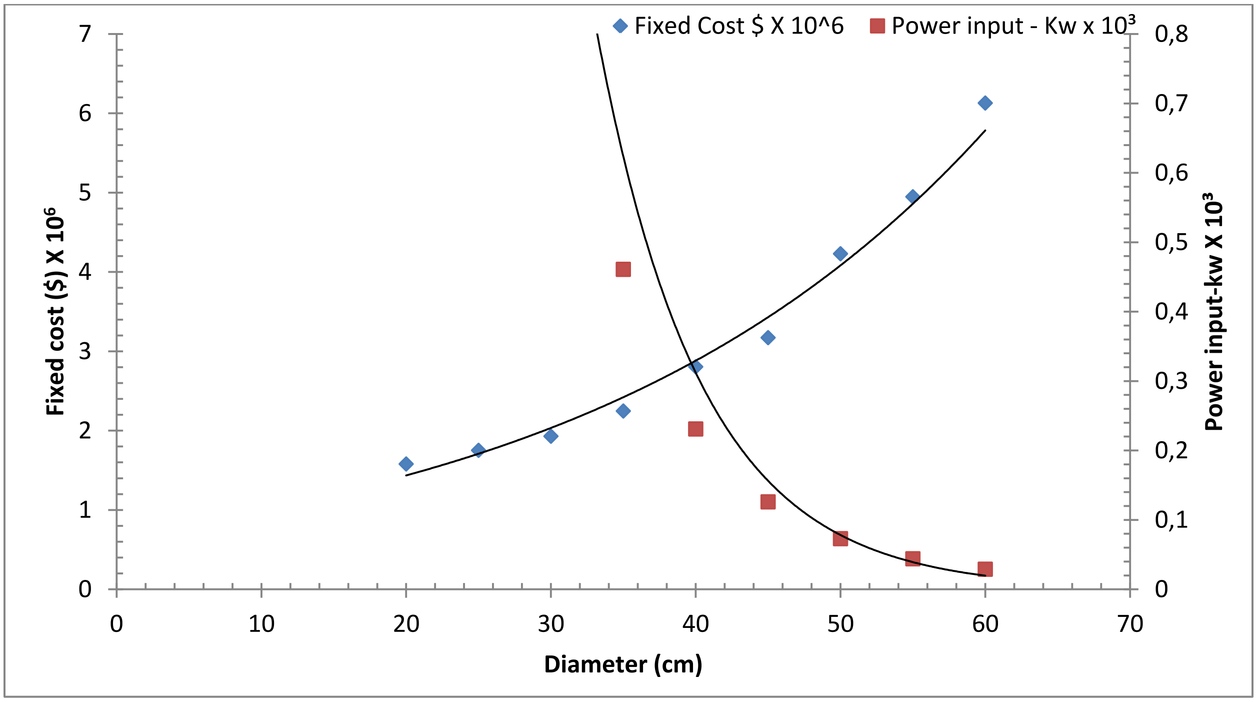


Fig 3.3 variation of fixed cost and power input for given diameter pipes.

As equation 3.5 shows the total cost is a combination of fixed cost and variable cost over the volume pumped or the time of operation, so that the total cost is a variable function of volume pumped.

Figure 3.3 shows the most critical constraints for construction of an optimum water system is pipe size. For small diameters, the fixed cost is relatively low due to lower pipe costs but the running costs are high because the head losses through small diameter are high and to overcome these losses the system need more power input for operation. On the contrary for big diameters, fixed cost is relatively high and running cost is low.

Figure 3.4 shows the variation of total cost incurred against the quantity of water pumped. For volume less than $32x10^6$ m^3, Φ 400 mm is preferable however due to steeper rise of Φ 400 mm characteristic line the cost of Φ 400 mm exceed that of Φ 600 mm. This is due to higher costs in pumping with a smaller diameter pipe.

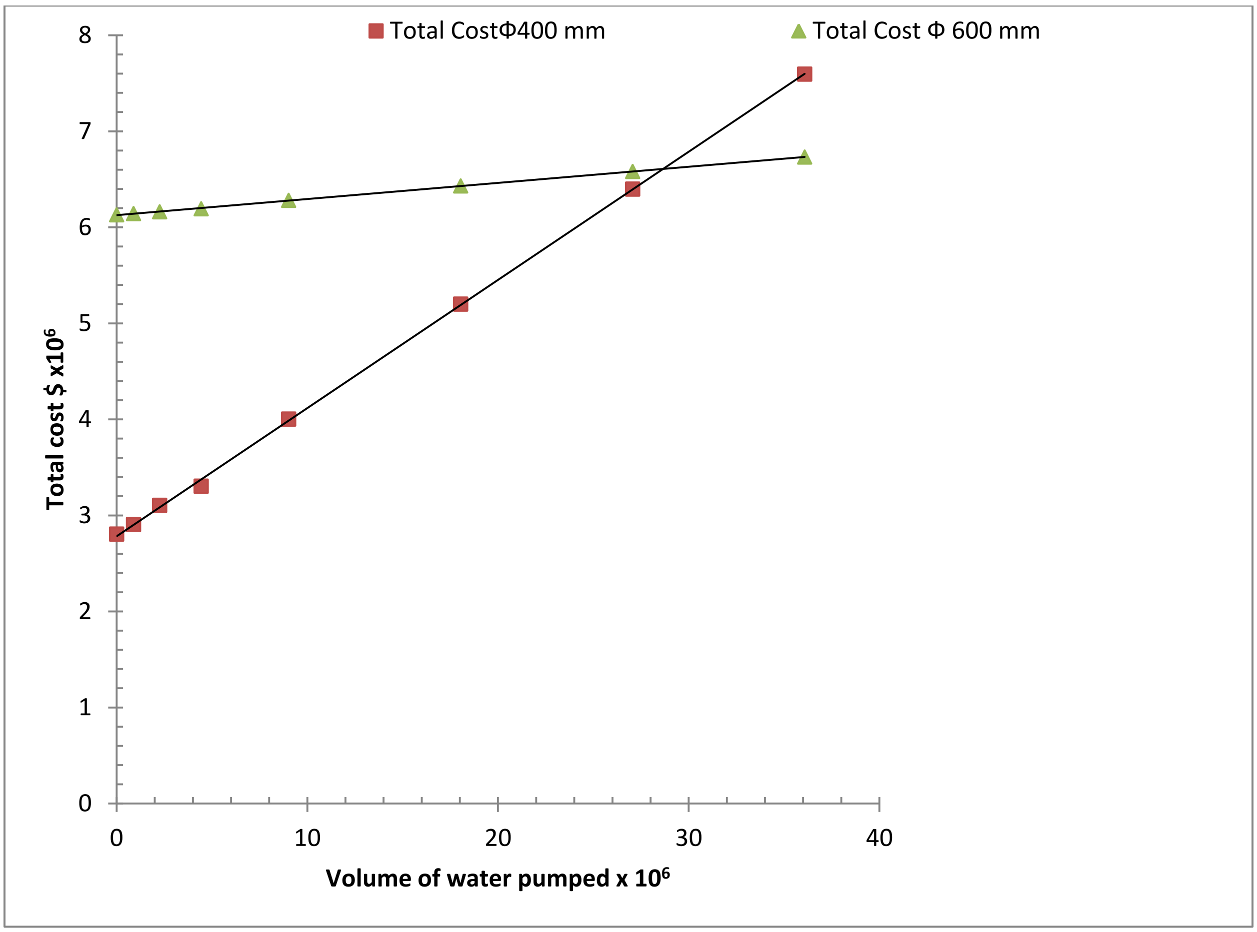


Fig 3.4 Variation of total cost with quantity of water for Φ400 & Φ600 mm.

3.3.4 Recovering the Costs

Another way of presenting the data is by way of unit cost u_{wc} against the volume pumped V. This is shown in Figure 3.5. As before for V greater than 32 x 10^6 m^3 the curve of Φ 600 falls below the curve for Φ 400. At this volume of flow pumped the unit price would fall to 0.2 $/$m^3$. For a selection with Φ 600 using volume 15x10^3 (equivalent to about 3 years of supply to Bafra) the unit cost would be around 0.5 $/$m^3$. The sale price of water from Turkey to North Cyprus is not known at present. However even if a unit cost 0.5 $/$m^3$ is added to our calculated costs, we should expect a price of around 1 $/$m^3$ at most.

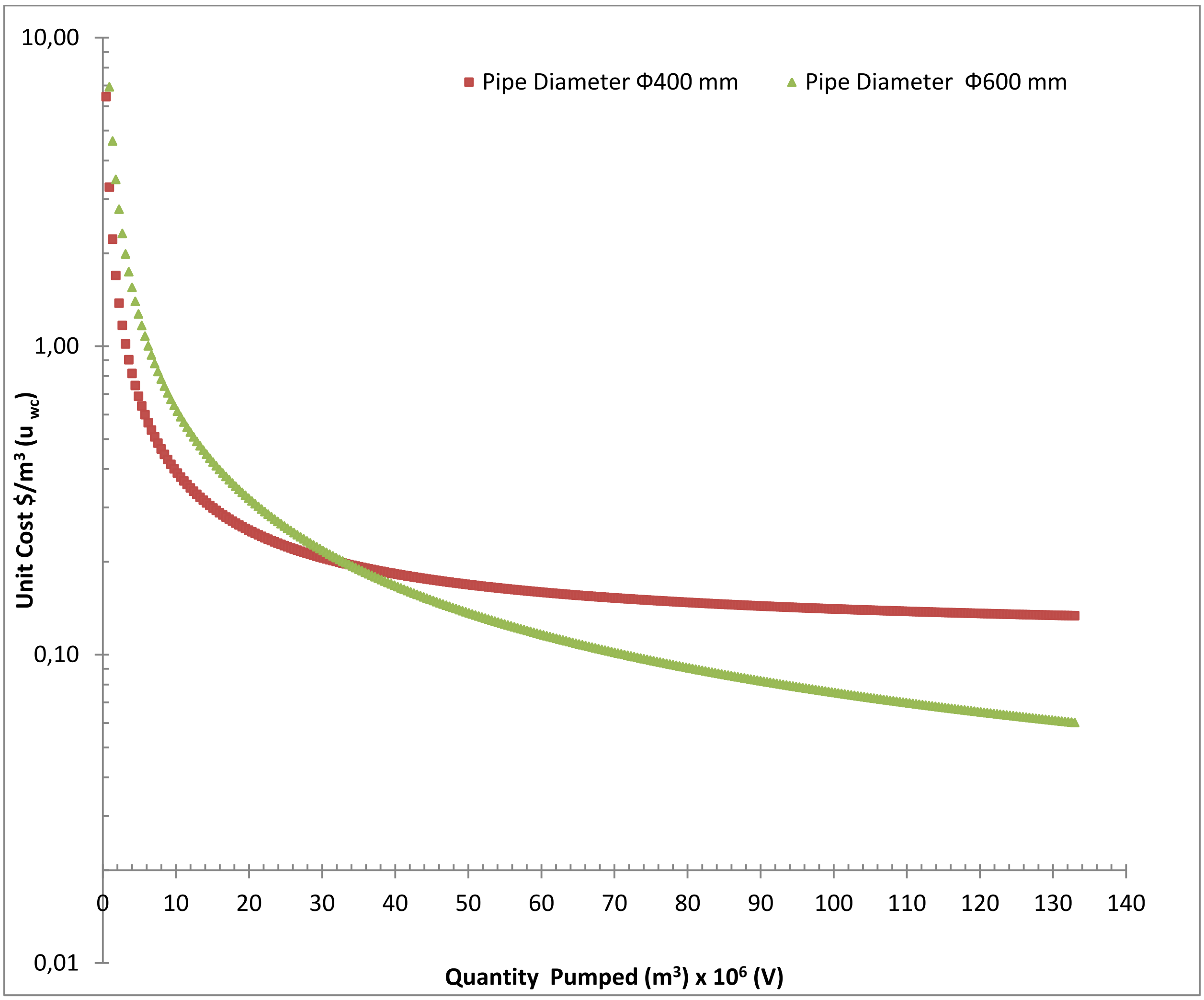


Fig 3.5 Changing of unit cost of water pumped through pipelines.

3.4 Desalination Plants

The second alternative that could be applicable to Bafra region is reverse osmosis. As mentioned by Zhou *et al.,* (2004) desalination of brackish and sea water has been expanding rapidly in recent decades, primarily to provide water for municipal and industrial uses in arid, semi-arid or water-short areas. Desalination involves several processes to remove the excess salt and other minerals from the water in order to get potable water for human usage. This sort of technology is very common in the Middle East and North Africa, and is growing fast in United States of America because of scarcity. Currently the hotels in Bafra region are supplied by water from a reverse osmosis (R.O) plant installed nearby. The plant currently is supplying 2000 m^3/day. But in future, the demand will be increased by the additional capacity. The current plant will not meet the future demand of 15000 m^3/day. Therefore it will be necessary to construct a new plant of bigger capacity. As mentioned by Danoun R. (2007) to build a desalination plant several criteria have to be addressed:

i. Establish the potential location of a desalination plant in an appropriate site where adequate land is available and the land is already zoned for industrial purposes
    a- Close proximity to the sea or the ocean so the pipeline length is not long and cost is minimized.
    b- Good quality seawater.
    c- To be in close proximity to power sources.

ii. An acceptable plan to deal with the issue of sustainable disposal and potential reuse of brine effluent from the desalination plant to minimize the possible impacts of high salinity and alkalinity from the brine discharge on marine life and to be environmentally compatible.

iii. Establish a suitable position for the inlet and outlet for feeding water and discharge brine to and from the desalination plant.

A variety of desalting technologies has been developed over the years, including primarily thermal and membrane processes. The main thermal processes include multi-stage flash evaporation (MSF), multiple effect evaporation (ME), and vapor compression (VC). The membrane processes contain reverse osmosis (RO), electro dialysis (ED) and nanofiltration (NF) as shows in the Table 3.2.

Table 3.2 Water purification technologies (Einav et al, (2002)).

Membrane technologies	Evaporation technologies
Electro Dialysis (ED/EDR) Electronic field is applied on the membrane between two electrodes	**Multi Stage Flash (MSF)** It is passed on an evaporation process by flowing hot water into a low pressure compartment
Reverse Osmosis (RO) The most popular technique worldwide and relies on the external pressure which is higher than osmotic one, high energy cost, seawater.	**Multi Effect Distillation (MED)** It is based on the cycle of potential heat to generate a steam of fresh water (combination with power station)
Nano filtration(NF) It is a relatively recent process and it is a cross-flow filtration technology which ranges somewhere between ultra filtration (UF) and reverse osmosis (RO), low energy cost, brackish water.	**Vapor Compression Distillation (VCD)** Basically is a method of using the heat pump of repeated cycles of condensation and evaporation

Essentially, a desalination plant is a system to separate saline water into streams. One with a acceptable concentration of dissolved materials (the fresh water stream, suitable for consumption by human begins) and the other containing the remaining dissolved salts (the concentrate stream or brine discharge).As described by Danoun R. (2007) the amount of flow discharge to waste as a brine discharge varies from 20 to 70 percent, depending on the technology that is used in plant. The most applicable technology for our case study is reverse osmosis (R.O). Membranes are more efficient, more durable, and much less expensive than other technologies.

By applying a pressure difference across the membrane the water contained in the feed is forced to permeate through the membrane. In order to overcome the feed side osmotic pressure, fairly high feed pressure is required in seawater desalination it commonly ranges from 55 to 68 bars as the figure 3.6 shows; this process needs huge quantities of energy. For Cyprus energy is expensive so that these technologies are expected to be expensive.

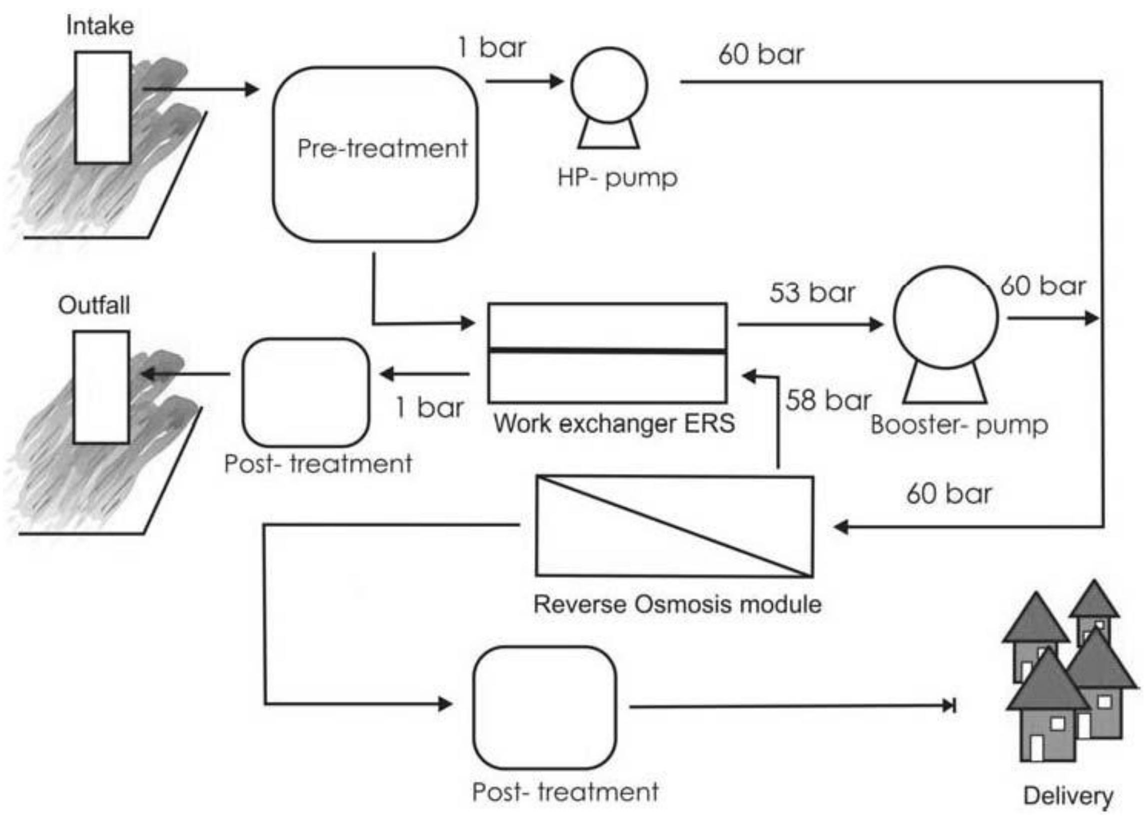


Fig 3.6 Simplified reverse osmosis scheme with energy system.(Fritzmann,et,al.2006)

3.4.1 Unit Production Cost of Reverse Osmosis

The primary element of desalination costs are capital cost and annual running cost. The capital cost includes the purchase cost of major equipment, auxiliary equipment, land, construction, management overheads, contingency costs etc. The capital costs for desalination plants have decreased over the years due to the ongoing development of process, components and materials. Annual running costs consist of costs for energy, labor, chemical, consumables and spare parts like membrane replacement costs. As mentioned by Zhou *et,al.* (2004). The energy cost plays dominant roles for desalination process especially in regions where the energy is fairly expensive.

Membrane modules, piping and pumping systems are standard plant equipment and can be easily scaled up. Membrane replacement cost depends on the rate membranes are damaged and irreversibly fouled. Fouling and membrane damage are minimized through efficient pre-treatment and cleaning. Membrane replacement cost generally accounts for about 5% of the overall life cycle cost of an sea water reverse osmosis (SWRO) desalination plant.

Chemicals are used in pre-treatment as well as cleaning operation and vary from plant to plant with the applied pre-treatment technique. Membrane pre-treatment generally requires less chemical addition than conventional pre-treatment Therefore; chemical's cost is reduced with the application of membrane treatment. Furthermore, chemical addition depends on raw water characteristics, membranes in use, regulations and operation parameters.

Maintenance of process equipment is necessary to guarantee stable and reliable operation throughout the lifetime of the desalination plant and accessories. In a study on desalination costing in Spain by Medina , maintenance costs for mechanical and electrical equipment are estimated to range from 2 to 2.5% of plant investment costs.

As reported by Lamei A. (2009) the unit cost of production falls with increasing capacity. Table 3.3 Presents SWRO desalination costs in the Mediterranean region and Saudi Arabia.

Table 3.3 shows a compilation of costs for 17 desalination plants in the Mediterranean region. These RO plants are the data base for the case study of Bafra in order to calculate the unit cost of producing water. The cost database demonstrated that current large-scale desalination plants are capable of producing water in the range of \$0.80–\$2.00/m^3.depending on the plant size. The unit cost of producing water for the data is represented as function of capacity in figure 3.3.

Table 3.3 RO desalination costs in the Mediterranean region. (Lamei A.,2009).

No of RO	Country	Capacity (m^3/d)	Investment (million US$)	Unit capital cost ($US\$/m^3/d$)	Annual cost of capital per unit($US\$/m^3$)	Unit production with O& M
1	Egypt	250	0.4	1659	0.74	3.21
2	Egypt	300	0.59	1961	0.89	1.82
3	Egypt	350	0.33	950	0.43	1.36
4	Egypt	500	0.54	1074	0.49	1.42
5	Egypt	500	0.77	1605	0.72	2.94
6	Egypt	2000	2.41	1313	0.58	1.25
7	Egypt	3500	4.27	1291	0.58	2.08
8	Egypt	4000	7.03	1756	0.8	2.02
9	Egypt	4800	4.23	1044	0.45	1.55
10	Egypt	5000	6.80	1360	0.58	1.54
11	Libya	7000	7.92	1131	0.51	1.21
12	Tunis	10000	9.62	962	0.44	1.18
13	Cyprus	40000	28.52	713	0.32	0.89
14	Cyprus	50000	33.35	667	0.3	0.86

Table 3.4 RO desalination costs in Saudi Arabia. (Lamei A., 2009).

No of RO	Capacity (m^3/d)	Investment (million US$)	Unit capital cost ($US\$/m^3/d$)	Annual cost of capital per unit($US\$/m^3$)	Unit production with O& M
1	15000	13.56	904	0.41	1.15
2	20000	16.64	832	0.38	1.04
3	30000	23.64	788	0.36	0.93

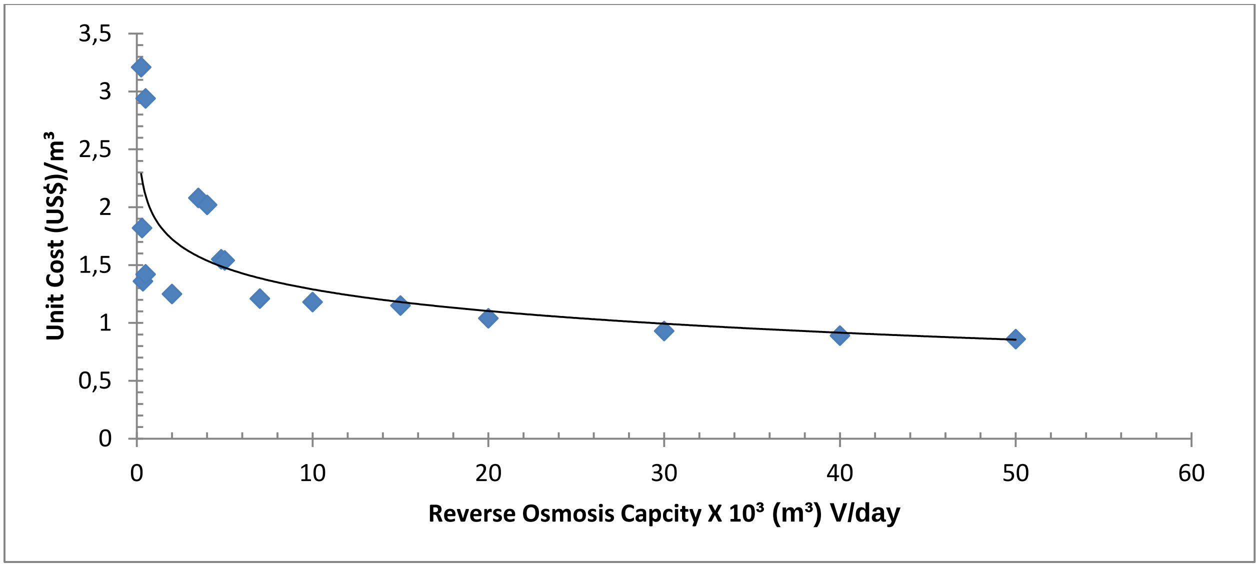


Fig 3.7 Unit cost versus plants capacity .

Figure 3.7 shows the variation of unit cost of desalination plants against the plant capacity. As the capacity increases the unit cost decreases. A curve fitting gives the unit cost of production .

$$u_{wp} = 1.781\ exp\text{-}2x10^{-5}\ \mathrm{V} \qquad (3.6)$$

The unit cost of reverse osmosis with capacity 15000 m^3/day for supplying Bafra region. It will be 1.32 US$/$m^3$. As we know RO plants are intensive power consumption. For North Cyprus Electricity power is very expensive. So unit costs are expected to be higher than 1.32 US$/$m^3$.

3.5 Comparison

As shown in section 3.3, transporting water through pipeline is expected to give unit cost of around 1 $ /m^3. With reverse osmosis costs will be higher than 1.5 $/ m^3. Also the environmental factors of R.O in particular the effect of discharge water affecting marine life needs to be considered. But on the other hand R.O makes countries independent. Even if a supply from the pipeline is cut (between Turkey and North Cyprus this doesn't seem possible) then RO has always that independence.

CHAPTER 4

OPTIMIZATION of SUPPLY SOURCES

4.1 Single Supplier

In this section an analysis is carried out to formulate the cost relationship of supply from n sources in order to fulfill the demand requirements $(\text{Vmax})i$ for a given month denoted by i $(i = 1 \rightarrow 12)$ and the cumulative cost C incurred over time summation for one year. Consider any given month i, with the supplied unit price of purchased water changing as function of the amount of demanded V.

As shown in fig 4.1 as the amount demanded V increases the unit price of this first source P_{1i} may remain constant or may increase to act as a deterrent to reduce water consumption.

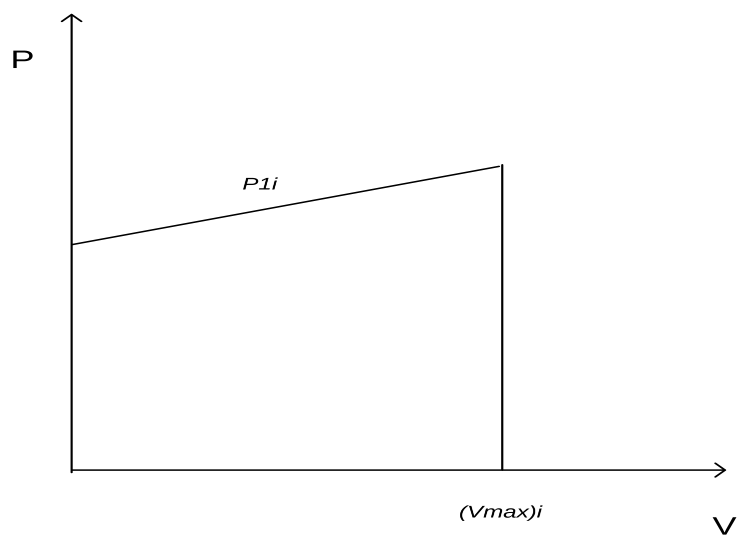


Fig 4.1 Unit price versus consumption.

With this single source only the ith time cost of demand is

$$C_i = \int_0^{(V_{max})i} P_{1i}\, dv \tag{4.1}$$

And the total cost over $i = 1\ to\ 12$ is.

$$C = \sum_{i=1}^{12} C_i = \int_{i=1}^{i=12} \left(\int_0^{(V_{max})_i} P_i\ dv \right) di \tag{4.2}$$

For simplicity, assuming price P_{1i} is independent of V , either because P_{1i} is actually constant or $P_{\ 1i}$ is the mean of prices over $(V_{max})_i$ range, we can write equation 4.2 as either discrete summation or in integral form as

$$C = \sum_{i=1}^{12} P_{1i}\ (V_{max})i \tag{4.3}$$

Or $$C = \int_{i=1}^{12} P_{1i}\, (V_{max}\ )_i\ \ di \tag{4.4}$$

Hence.

$$\frac{dC}{di} = P_{1i}(V_{max}\ )_i \tag{4.5}$$

i represents time variable.

To minimize C with only one source so far we require.

$$\frac{dc}{di} = 0 \tag{4.6}$$

And clearly from equation (4.5)

$$\frac{dc}{di} \neq 0$$

The only trivial solution is to set

$$(V_{max}\ )_i = 0 \tag{4.7}$$

i.e. demand must be zero for minimum cost. For any other values of demand there is a price to be paid and using one source only this may not give the minimum of all the possible options.

4.2 Introduction of a Second Supplier

For this second supplier, the supply unit price at a given $i\,th$ month is denoted by P_{2i} and the demand that can be supplied is V_{2i} .Again P_{2i} may depend on the volume supplied as well as time of year .

$$\text{i.e. } P_{2i} = f_n(V, i) \tag{4.8}$$

However for the time being, just as P_{1i} , P_{2i} will be treated as constant. With 2 sources the cumulative cost equation is

$$C = \sum_{i=1}^{12} (P_{1i}(V_{max} - V_{2i}) + P_{2i}V_{2i})$$

Or

$$C = \sum_{i=1}^{12} (P_{1i}V_{max} + V_{2i}(P_{2i} - P_{1i}) \tag{4.9}$$

A 3rd supplier would give

$$C = \sum_{i=1}^{12} ((P_{1i}V_{max} + V_{2i}(P_{2i} - P_{1i}) + V_{3i}(P_{3i} - P_{1i})$$

And n suppliers would give

$$C = \sum_{i=1}^{12} (P_{1i}V_{max} + V_{2i}(P_{2i} - P_{1i}) + V_{3i}(P_{3i} - P_{1i}) + \dots\dots\dots. + V_{ni}\,(P_{ni} - P_{1i}))$$

Or in shortened form .

$$C = \sum_{i=1}^{12} \left(\sum_{J=2}^{n} P_{1i}V_{max_i} + V_{Ji}(P_{Ji} - P_{1i}) \right) \tag{4.10}$$

Where J is the source number.

As in equation (4.5) with n suppliers equation (4.10) takes on the form

$$\frac{dC}{di} = \sum_{j=2}^{n}(P_{1i}V_{max} + V_{Ji}\left(P_{Ji} - P_{1i}\right)) \tag{4.11}$$

Equating equation (4.11) to zero would only give the ith month for which cost is minimized but would not give any information about the combination of V_{ji} for optimal conditions. For this, we proceed as follows: we consider 2 sources and we drop the i notation for simplicity of calculus we get

$$C = (V_{max}P_1 + V_2(P_2 - P_1)) \tag{4.12}$$

Since.

$$C = f\ (P_1, V_2, P_2) \tag{4.13}$$

$$\frac{dC}{dV_2} = \frac{\partial C}{\partial P_1}\frac{dp_1}{dV_2} + \frac{\partial C}{\partial V_2} + \frac{\partial C}{\partial P_2}\frac{dp_2}{dV_2} \tag{4.14}$$

P_1 is independent of V_2, and we assumed constant P_2 over V_2.

$$\therefore \frac{dP_1}{dV_2} = 0 \quad \text{and} \quad \frac{dP_2}{dV_2} = 0 \tag{4.15}$$

Equation (4.14) simplifies to

$$\frac{dC}{dV_2} = P_2 - P_1 \tag{4.16}$$

As we have introduced a new source V_2, we require the cost to fall; otherwise there would be no point of taking this action.

i.e. $\frac{dC}{dV_2} < 0$

or $P_2 - P_1 < 0$

$$\text{Giving } P_2 < P_1 \tag{4.17}$$

Equation (4.17) is a very trivial result which simply implies that "if the quantity to be bought is fixed and if this is divided between 2 sources, then the unit price of the second source must be smaller than the unit price of the first one, otherwise there was no point in selecting a 2^{nd} source in the first place.

4.3 Three or More Sources

With three sources

$$C = \sum(V_{max}P_1 + V_2(P_2 - P_1) + V_3(P_3 - P_1)) \tag{4.18}$$

i.e. $C = f\ (V_2, V_3, P_2, P_3)$

Hence,

$$dC = \frac{\partial C}{\partial V_2}dV_2 + \frac{\partial C}{\partial V_3}dV_3 + \frac{\partial C}{\partial P_2}dP_2 + \frac{\partial dC}{\partial P_3}dP_3$$

Or, dependence of cost on the third source.

$$\frac{dC}{dV_3} = (P_2 - P_1)\frac{dV_2}{dV_3} + (P_3 - P_1) + \frac{\partial C}{\partial p_2}\frac{dP_2}{dV_3} + \frac{\partial C}{\partial P_3}\frac{dP_3}{dV_3} \tag{4.19}$$

P_2 is independent of V_3 hence $\frac{dp_2}{dV_3} = 0$, and P_3 is constant across V_3 range so $\frac{dp_3}{dV_3} = 0$

As regards to $\frac{dV_2}{dV_3}$ we note that for a given volume ; as V_3 increases, V_2 decreases

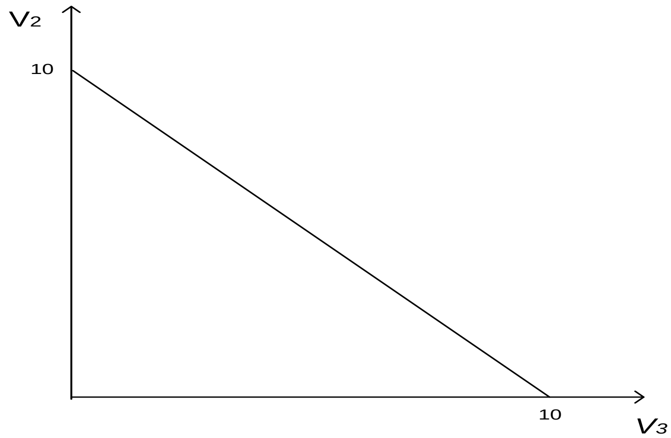


Fig 4.2 V_2 versus V_3

When V_2 is 10 units if V_3 is zero, when V_2 has fallen to zero, this volume is taken up by V_3 as 10 units .

Hence,

$$\frac{dV_2}{dV_3} = -1 \tag{4.20}$$

From (4.19) & (4.20)

$$\frac{dC}{dV_3} = (P_1 - P_2) + (P_3 - P_1)$$

$$\frac{dC}{dV_3} = P_3 - P_2 \tag{4.21}$$

We require $\frac{dC}{dV_3} < 0$ so that cost decreases with the introduction of a new sources V_3

Hence

$$P_3 - P_2 < 0 \quad \text{or} \quad P_3 < P_2 \tag{4.22}$$

Therefore with the introduction of source 2 and then source 3 requires the following inequality to be satisfied.

$$P_3 < P_2 < P_1 \tag{4.23}$$

If we now consider the splitting up of demand $(V \max)_i$ amongst three sources, the unit price volume histogram would be as in fig 2.3

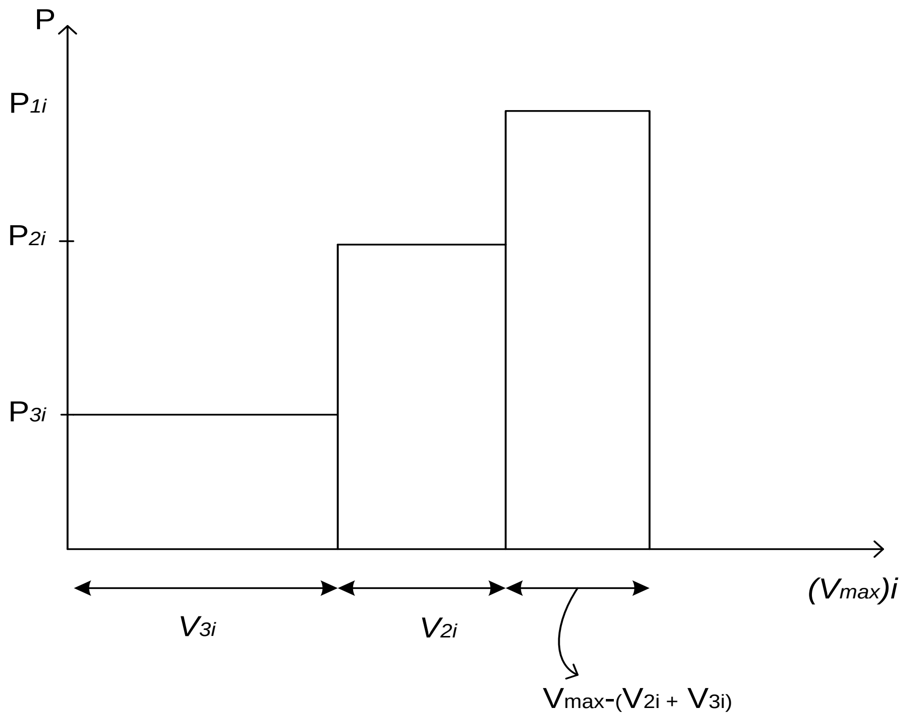


Fig 4.3 Unit price – Demand volume histogram.

4.4 Optimization Procedure

1- If $V_{3i} \geq (Vmax)_i$ then no other source is required. This volume bought at P_{3i}gives optimal cost .

2- If limitation on V_{3i} does not meet the total demand, then V_{2i} is introduced.

If $V_2 \geq V_{max} - V_3$ then in addition to available V_{3i} , rest of the demand is supplied form source 2.

3- As before, limitations on V_{2i} may lead to the utilization of source 1 as well. It follows that for any time variable i ,the procedure is to start with the lowest price source until its available amount is used up. Then progress is made to the next higher price level and the whole process is continued until the total demand $(V_{max})_i$is met. The cost obtained in this manners is the optimal cost $(C_i)_{opt}$ for the $i\ th$ month.

Finally total optimal cost is

$$(C_T)_{opt} = \sum_{i=1}^{12}(C_i)_{opt} \tag{4.24}$$

With general n sources, the sequence to be adhered to following the reasoning of equation (4.23) is

$$P_{ni} < P_{n-1} < \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots \; P_{3i} < P_{2i} < P_{1i} \tag{4.25}$$

With

$$V_{ni} > V_{(n-1)i} > \ldots\ldots\ldots\ldots\ldots\ldots\ldots V_{3i} > V_{2i} > V_{max} - \sum_{J=2}^{n} V_{Ji} \tag{4.26}$$

4.5 Constraints

4.5.1 Availability of Sources

We expect for any j , where j is the source number.

$$V_{Ji} = V_{Ji}(i) \tag{4.27}$$

For example, the local distribution network supplying a reasonable proportion of V_{max} in a winter month i=11, 12, 1, 2 (Nov, Dec, Jan, Feb), would only be supplying a smaller proportion in summer months due to increased consumption by the local residents in that particular area.

4.5.2 Unit Price of Sources

At most, unit prices may depend on time of year i and on the amount demanded V

$$P_{Ji} = P_{Ji}(i, V) \tag{4.28}$$

Generally prices do not depend on i, with the exception of tanker water carriage cases whereby in summer months the unit prices increase. However although RO supply has fixed unit prices per volume, local distribution system charges a fixed price up to a pre-determined volume, thereafter to deter excessive usage of water, unit prices increase by two fold – three fold as the local council sees fit to apply.

4.6 Excel Sheet Model

Following the theoretical aspects of optimization as described in sections 4.1-4, an Excel sheet model for optimization of total cost from different suppliers was developed. This model handles sources available during the year in arid and semi arid regions and related prices for the optimization of total cost. Table 4.1 shows the sources available in Bafra region and corresponding prices.

Table 4.1 Bafra region supply sources and unit prices.

Source	**V (m^3) / month**	**Price \$/m^3**
S 1 (RO)	3000	1.5
S 2 (local Wells)	9000	2
S 3 (Tanker)	8000	4

Each supplier has a maximum volume that could be supplied with a specific unit price. For example source 1 (S1) has 3000 m^3 monthly capacity with constant unit price of 1.5 \$. The methodology of this management is by choosing the cheapest unit price for buying water to meet demand. In case the first supplier couldn't meet the demand, the second cheapest supplier is selected as given by eq (4.25). The optimization of total cost enhances the idea of contract agreement between hotels and suppliers, so that this model could be used by technical managers in hotels to guide them to take the right decision of buying water from suppliers and contracting with them.

4.6.1 Instruction for Using the Excel Sheet Model

The CD for this excel model is given in Appendix B. As shown in Table 4.1 and 4.2 a sample excel sheet on optimization is given:

1) First, the available sources in the region and the monthly volume that can be supplied over the whole of the year and unit price are determined.

Table 4.2 The sources available for optimization total cost

	A	B	C	D	E	F	G	H	I	J	K	L	M	N	O	P	Q	R	S	T	U	V	W	X	Y
2	Source	Jan(1)		Feb(2)		March(3)		April(4)		May(5)		June(6)		July(7)		Agust(8)		Sept(9)		Octo (10)		Nove(11)		Dece(12)	
3		V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price	V (m3)	Price
4	S1	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5	3000	1.5
5	S2	9000	2	9000	2	9000	2	9000	2	9000	2	9000	2	9000	2	9000	2	9000	2	9000	2	9000	2	9000	2
6	S3	8000	4	8000	4	8000	4	8000	4	8000	4	8000	4	8000	4	8000	4	8000	4	8000	4	8000	4	8000	4

2) These sources are arranged in ascending unit price and each source is denoted as S1, S2, and S3 etc . The corresponding volumes and prices are inserted. For example for January, monthly values are entered in the cells B4, B5 and B6 and unit prices in cells C4, C5and C6.

3) Next we enter the monthly demand by the hotel in the column under title V need (m^3) for the whole of the year, as shown in Table 4.3. For January the volume demanded is entered in cell B14 and other months in cells B 15- B25. The calculated monthly costs and volumes used are given in columns H and G respectively.

Table 4.3 Excel sheet form for the model and outputs for hotel 3.

	A	B	C	D	E	F	G	H	I	J
12	Month	V-need (m^3)	sources used(m3)				Check (m^3)	cost $	case	V def(m^3)
13			S1	S2	S3					
14	1	7900	3000	4900	0		7900	14300	No more	0
15	2	6750	3000	3750	0		6750	12000	No more	0
16	3	9300	3000	6300	0		9300	17100	No more	0
17	4	7905	3000	4905	0		7905	14310	No more	0
18	5	12050	3000	9000	50		12050	22700	No more	0
19	6	15700	3000	9000	3700		15700	37300	No more	0
20	7	19700	3000	9000	7700		19700	53300	No more	0
21	8	15400	3000	9000	3400		15400	36100	No more	0
22	9	16500	3000	9000	4500		16500	40500	No more	0
23	10	11200	3000	8200	0		11200	20900	No more	0
24	11	8300	3000	5300	0		8300	15100	No more	0
25	12	6900	3000	3900	0		6900	12300	No more	0
26	Total	137605	36000	82255	19350		137605	295910		

4) As regards to contract agreements, from the previous year we find the maximum average occupancy rate. According to this occupancy rate we suppose that there is a decrease in occupancy, in order to find suitable volume to contract with supplier and thus saving money. The procedure is in Table 4.4.

Table 4.4 The procedure of contract agreement.

cost $	case	V def(m^3)
14300	No more	0
12000	No more	0
17100	No more	0
14310	No more	0
22700	No more	0
37300	No more	0
53300	No more	0
36100	No more	0
40500	No more	0
20900	No more	0
15100	No more	0
12300	No more	0
295910		

Factor	Bad Tourism		
90%	Month	V m^3	Cost
	1	7110	12720
	2	6075	10650
	3	8370	15240
	4	7114.5	12729
	5	10845	20190
	6	14130	31020
	7	17730	45420
	8	13860	29940
	9	14850	33900
	10	10080	18660
	11	7470	13440
	12	6210	10920
Total Cost		123845	254829

Contracting					
Avg price $	2.15	cost	for 2011	90% of 2011	80% of 2011
contrct price $	1.8	Case			
	Different Sources $		295910	254829	213848
	Contracting $		247689	247689	247689
	Saving money $		48221	7140	-33841

4.6.2 Sample of optimization total costs of water demand in Hotel 3

Table 4.3 shows the variation of monthly quantity needed by hotel 3 during the whole of year. Using equation 4.9 the cost analysis is performed form

$$C = \sum_{i=1}^{12}(P_{1i}V_{max} + V_{2i}(P_{2i} - P_{1i})$$

The cost for month 1 is $C_1 = P_{1\,1}Vtmax_1 + V_{2\,1}(P_{2\,1} - P_{1\,1})$

$$C_1 = 14300 \text{ US\$}.$$

Same procedure gives other costs for other months.

The volume-price histogram for month 1 is shown in Fig 4.4 and for month 7 (3 sources) is shown in Fig 4.5.

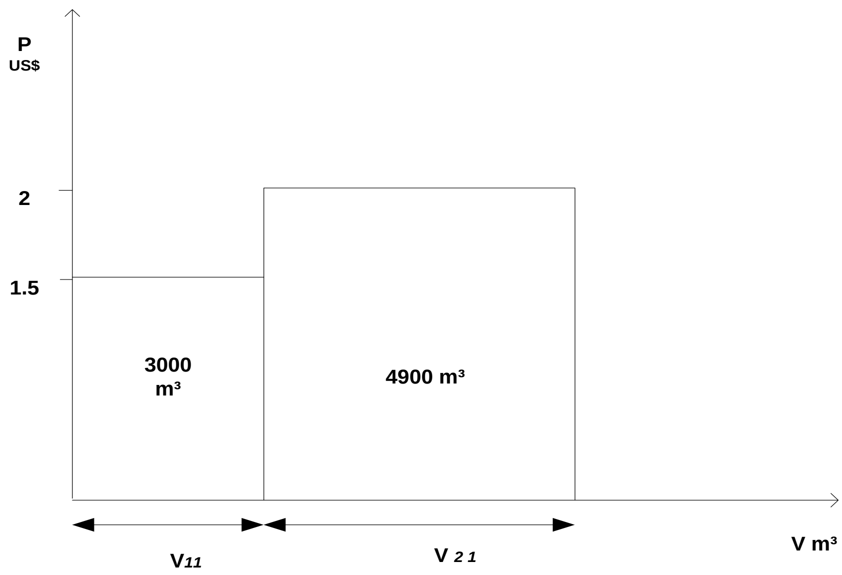


Fig 4.4 volume - prices histogram (month 1).

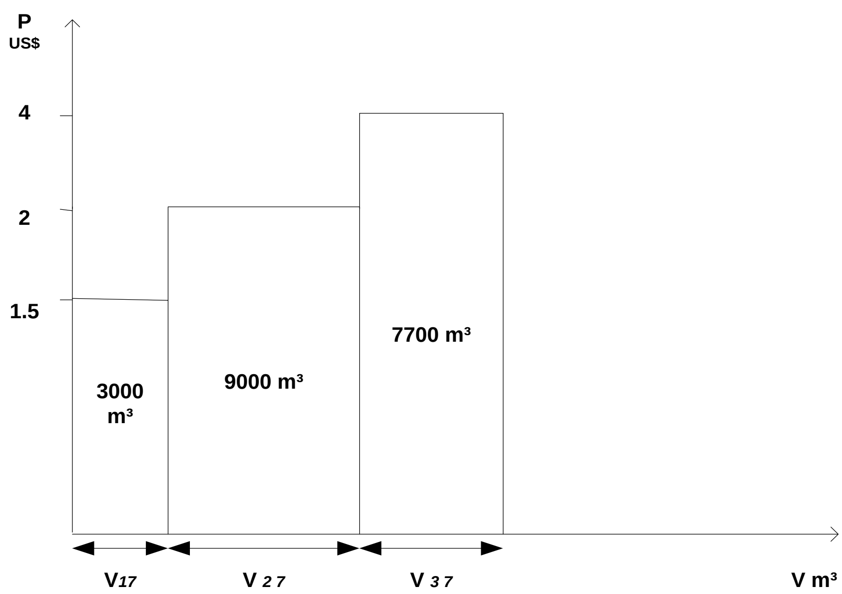


Fig 4.5 Volume - prices histogram (month 7)

4.6.3 Contracting for Supply.

For some hotels in the study area there are no contract agreements of water supplying for them from private suppliers like, RO plants and tankers. They just buy monthly as required from suppliers with different prices. After optimization of total costs in section 4.6.2, we could formulate and write a contract agreement between two parties or more for better unit prices. To do this in the excel program first we calculate the unit cost as before from different sources. For example for 2011, this is given in U19 Table 4.3 as 295910 US$ ($u_{wp} = 2.15\ \$/m^3$). If contracting was done at 1.8 $\$/m^3$, with full hotel capacity the saving would be 488221 US$ (U21). However, if in the following year there was a 10% drop in occupancy, normal sources would give 254829 US$ (V19), with contracting there is still savings of 7140 US$. As Table 4.4 shows if the tourism season was bad with 20% fall in occupancy, contracting would not be preferable. So when contracting is to be carried out one needs to consider the maximum anticipated fall in tourism and act accordingly. Contracting can be carried out with caution.

Table 4.5 Contracting agreement with full occupancy and bad tourism with reduced occupancy by 10% & 20%.

Methodology of Contracting					
Avg. of prices from different suppliers($)	2.15	Case / Cost	For 2011	90% of 2011	80% of 2011
Contracting price ($)	1.8	**Different Sources cost $**	**295910**	**254829**	**213848**
		Contracting cost $	247689	247689	247689
		Saving money $	**48221**	**7140**	**-33841**

CHAPTER 5

RESULTS AND DISSICUSIONS

5.1 Tourism and North Cyprus Water Problems

The Mediterranean is the main tourist destination in the world, every year millions of people flock to the Mediterranean costs. One of the most beautiful destinations is Cyprus, the third largest island in the region. TRNC has long coastlines to north and east of the country with easy accesses to the sea. Generally tourist areas suffer from significant fluctuations in the number of local dwellers that have to be supplied with freshwater and consumption peaks normally occur in the dry season. North Cyprus always suffered from water shortage during drought seasons even when its population was small and agriculture land under irrigation was minimal. With increasing population, the agriculture land under irrigation has expanded twice during the last decades. Therefore, water shortage has become a considerable problem.

Nowadays the main problem forcing the TRNC is salination of aquifers in all coastal lines. One of the possible solutions is adapting Integrated Water Resources Management (IWRM).

Tourism is an economic activity, and like other sectors it is affected on water demand. Water demand in coastal areas is increasing because of population growth, in most cases the demand increases extremely during summer times. So that water demand in coastlines is periodic depending on tourists and occupancy rates.

For the study area of North Cyprus, conventional suppliers’ solutions are limited and suffering from water shortage. One possible solution is transported water from Turkey to North Cyprus by pipeline and non-conventional sources like desalination plants.

5.2 The Case Study of Bafra

The present study is focused on Bafra region. It has become designated as an area for tourist expansion by the North Cyprus government. Increasing the bed capacity by an additional 20,000 beds. The determination of water usage per occupant and future prediction of the quantity of water that will be demanded by the tourism in Bafra region of North Cyprus is the theme of this study. So that we need surveying of water consumption by tourists in coastal regions of North Cyprus. In this study six hotels were selected and surveyed. Altogether data was collected from 5 hotels, two of them are located in the Bafra region. The other hotels are located on Girne's coasts.

Consumption of potable water by tourists is expected to depend on the occupancy rate, which depends on the time of the year. The characteristic of potable water consumption by tourism in North Cyprus is periodic fluctuating with peaks occurring in summer months as expected. The functional relationship between potable water consumption and the number of occupants is linear with good correlation coefficient. For the combined data for five hotels the value of potable water consumption per occupant (w_T) is calculated as 590 L / day. This value represents the average daily water consumption per tourist per day for North Cyprus.

The quantity of water that will be demanded by additional 20,000 tourists in Bafra region is 15000 m^3/day. Comparing the peak projection demand quantity with the RO supplier for tourism sector in Bafra region, shortages are unavoidable. Therefore, the investigation of new sources to meet demand is of importance.

5.3 Supply Alternatives

For pipeline construction it is important to consider the cost parameters in order to synthesize water transporting system. The component sharing the capital costs are pumps, pipes of various commercially available size, materials, energy usage, operation and maintenance of the system component. The installation costs include all process related to extension of pipelines like digging, laying, welding and labors. Running cost of transported water through pipelines by using pumps is the amount of capital that is spent on energy cost like electricity. Combination of fixed cost and running cost gives total cost.

The most critical constraints for construction an optimum transported water system is pipe size. For small diameters the fixed cost is relatively low due to lower pipe costs. But the running costs are high. For big diameters fixed cost is relatively high and running cost is low. The unit cost of transported water to Bafra is projected to be 0.5 $/m$^{3.}$ The sale price of water from Turkey is not known at present, however even if a unit cost 0.5 $/m^3 is added to our calculated costs, we should expect a price of around 1 $/m^3 at most.

The second alternative that could be applicable to Bafra region is reverse osmosis. Currently the hotels in Bafra region are supplied by water form a reverse osmosis (R O) plant installed nearby. The current plant will not meet future demand; therefore it will be necessary to construct a new plant of bigger capacity. The most applicable technology for our case study is reverse osmosis. The process of desalination of sea water needs huge quantities of energy. For Cyprus, energy is expensive, so that these technologies are expected to be expensive.

The plant size affects on unit cost of water production. As capacity increases the unit cost decreases. The unit cost of reverse osmosis with capacity 15000 m^3 /day for supplying Bafra region by fresh water will be at least 1.30 US$/m^3. As we knew R O plants are intensive power consumers, for North Cyprus electricity is expensive so that unit cost are expected to be higher than 1.30 $/m^3 .

5.4 Optimization of Supply Sources and Excel Sheet Model

For the optimization of supply sources, we formulated the cost relationship of supply from n sources in order to fulfill the demand requirements $(\text{Vmax})i$ for a given month denoted by i $(i = 1 \rightarrow 12)$ and the cumulative cost C incurred over time summation for one year. If the quantity to be bought is fixed and if this is divided between 2 sources, then the unit price of the second one must be smaller than the unit price of the first one, otherwise there was no point in selecting a 2nd source in the first place to optimization of supply sources. The similar rule applies for n sources. The procedure is to start with the lowest price source until its available amount is used up. Then progress is made to the next higher price level and the whole process is continued until the total demand $(V_{max})_i$is met. The cost obtained in this manner is the optimal cost $(C_i)_{opt}$ for the $i\ th$ month.

According to the theoretical aspects of optimization, we developed an Excel sheet modeling for optimizing the total cost of buying water from different suppliers. This model handles sources available during the year in arid and semi arid regions and related prices for the optimization of total cost. The methodology of this management is by choosing the cheapest unit price for buying water to meet demand. In case the first supplier couldn't meet the demand, the second cheapest supplier is selected as given by eqn (4.25). The optimization of total cost enhances the idea of contract agreement between hotels and suppliers. Contractors supply fixed quantities of potable water for a specific price. So that this model could be used by technical managers in hotels to guide them to take the right decision of buying water from suppliers and contractors.

5.5 General Discussions and Conclusions

Increasing the capacity of the tourism sector in Bafra region will unavoidably require significantly higher amounts. The demand shows periodic fluctuations with peaks occurring in summer moths as expected. The supply of water would have to double its capacity for the summer months, other times the system would only operate with no more than 50% capacity. The average potable water consumption per tourist in North Cyprus is 590 L/day. The projection future demand for Bafra region will be 15000 m^3/ day. The current sources in Bafra region will not meet demand, so that we need supply alternatives, transported water through pipeline and reverse osmosis (RO). Transporting water through pipeline is expected to give unit cost of around 1 $\$/m^3$. With reverse osmosis costs will be higher than 1.5 $\$/m^3$. Also the environmental factors of R O in particular the effect of discharge water affecting marine life needs to be considered. But on the other hand R.O makes countries independent. Even if a supply from the pipeline is cut (between Turkey and North Cyprus this doesn't seem possible) then RO has always that independence. However the environmental effects of RO must also be taken into account.

5.6 Future Works

Desalination plants are very intensive energy consumers. Furthermore, energy is very expensive in North Cyprus; therefore future works should concentrate on whether solar energy can be an alternative energy source for desalination plants for fresh water production.

Also investigations on whether treating waste water can be used for irrigation purposes at reasonable cost for green areas in hotels can be carried out.

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APPENDIX A: Surveys on hotels

Hotel number: 1 — Hotel type: 5 star — year :2011

Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)							
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)	
					m^3	TL	m^3	TL	m^3	TL	m^3	TL
Jan	50	350	4700		–	–	–	–	4700	2.5	–	–
Feb	55	350	5000		–	–	–	–	5000	2.5	–	–
Mar	58	350	5250		–	–	–	–	5250	2.5	–	–
Apr	63	350	5700		–	–	–	–	5700	2.5	–	–
May	70	350	6300		–	–	–	–	6300	2.5	–	–
Jun	95	350	8500		–	–	–	–	8500	2.5	–	–
Jul	99	350	9000		–	–	–	–	9000	2.5	–	–
Aug	100	350	9050		–	–	–	–	9050	2.5	–	–
Sep	97	350	8900		–	–	–	–	8900	2.5	–	–
Oct	85	350	7700		–	–	–	–	7700	2.5	–	–
Nov	76	350	6900		–	–	–	–	6900	2.5	–	–
De	60	350	5500		–	–	–	–	5500	2.5	–	–

Diğer bilgi:

Other information: hotel own reverse osmosis with maximum capacity 1200 m^3/day

Hotel 1 (2011)

Hotel number: 2			Hotel type: 5 star								year :2010		
Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)							
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)	
					m^3	TL	m^3	TL	m^3	TL	m^3	TL
Jan	95	427	12000		–	–	–	–	–	–	–	–
Feb	82	427	11400		–	–	–	–	–	–	–	–
Mar	80	427	10650		–	–	–	–	–	–	–	–
Apr	60	427	11560		–	–	–	–	–	–	–	–
May	48	427	12600		–	–	–	–	–	–	–	–
Jun	90	427	14400		–	–	–	–	–	–	–	–
Jul	95	427	14550		–	–	–	–	–	–	–	–
Aug	96	427	14550		–	–	–	–	–	–	–	–
Sep	96	427	13950		–	–	–	–	–	–	–	–
Oct	90	427	8880		–	–	–	–	–	–	–	–
Nov	88	427	8100		–	–	–	–	–	–	–	–
De	100	427	14400		–	–	–	–	–	–	–	–
Diğer bilgi: Other information:												

Hotel 2 (2010)

Hotel number: 2			Hotel type: 5 star							year :2011		
Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)							
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)	
					m^3	TL	m^3	TL	m^3	TL	m^3	TL
Jan	98	427	12300		–	–	–	–	–	–	–	–
Feb	79	427	11850		–	–	–	–	–	–	–	–
Mar	75	427	11700		–	–	–	–	–	–	–	–
Apr	75	427	8700		–	–	–	–	–	–	–	–
May	79	427	6300		–	–	–	–	–	–	–	–
Jun	98	427	11730		–	–	–	–	–	–	–	–
Jul	100	427	12150		–	–	–	–	–	–	–	–
Aug	100	427	12950		–	–	–	–	–	–	–	–
Sep	99	427	12600		–	–	–	–	–	–	–	–
Oct	65	427	1200		–	–	–	–	–	–	–	–
Nov	62	427	11550		–	–	–	–	–	–	–	–
Dec	100	427	12750		–	–	–	–	–	–	–	–
Diğer bilgi: Other information:												

Hotel 2 (2011)

Hotel number: 3			Hotel type: 5 star										year :2010
Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)								
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)		
					m^3	TL	m^3	TL	m^3	TL	m^3	TL	
Jan	9	1800	8900	–	8900	2.5	–	–	–	–	–	–	
Feb	13	1800	6350	215	6350	2.5	–	–	–	–	–	–	
Mar	11	1800	8050	305	8050	2.5	–	–	–	–	–	–	
Apr	20	1800	11300	655	11300	2.5	–	–	–	–	–	–	
May	29	1800	14200	2400	14200	2.5	–	–	–	–	–	–	
Jun	15	1800	15000	1300	15000	2.5	–	–	–	–	–	–	
Jul	55	1800	18300	810	18300	2.5	–	–	–	–	–	–	
Aug	43	1800	16100	1240	16100	2.5	–	–	–	–	–	–	
Sep	47	1800	14300	495	14300	2.5	–	–	–	–	–	–	
Oct	43	1800	11300	_	11300	2.5	–	–	–	–	–	–	
Nov	33	1800	8400	_	8400	2.5	–	–	–	–	–	–	
Dec	20	1800	7400	–	7400	2.5	–	–	–	–	–	–	

Diğer bilgi:

Other information: the main source is reverse osmosis

Hotel 3 (2010)

Hotel number: 3			Hotel type: 5 star								year :2011		
Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)								
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)		
					m^3	TL	m^3	TL	m^3	TL	m^3	TL	
Jan	17	1800	7900	–	7900	2.5	–	–	–	–	–	–	
Feb	12	1800	6750	200	6750	2.5	–	–	–	–	–	–	
Mar	9	1800	9300	255	9300	2.5	–	–	–	–	–	–	
Apr	19	1800	7905	700	7905	2.5	–	–	–	–	–	–	
May	35	1800	12050	2100	12050	2.5	–	–	–	–	–	–	
Jun	39	1800	15700	850	15700	2.5	–	–	–	–	–	–	
Jul	55	1800	19700	1245	19700	2.5	–	–	–	–	–	–	
Aug	44	1800	15400	470	15400	2.5	–	–	–	–	–	–	
Sep	46	1800	16500	_	16500	2.5	–	–	–	–	–	–	
Oct	45	1800	11200	_	11200	2.5	–	–	–	–	–	–	
Nov	30	1800	8300	_	8300	2.5	–	–	–	–	–	–	
Dec	25	1800	6900	–	6900	2.5	–	–	–	–	–	–	

Diğer bilgi:

Other information: the main source is reverse osmosis

Hotel 3 (2011)

Hotel number: 4 **Hotel type: 5 star** **year :2010**

Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)							
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)	
					m^3	TL	m^3	TL	m^3	TL	m^3	TL
Jan	42	156	1818	–	1818	3	–	–	–	–	–	–
Feb	47	156	2437	–	2437	3	–	–	–	–	–	–
Mar	49	156	2642	–	2642	3	–	–	–	–	–	–
Apr	56	156	2958	–	2958	3	–	–	–	–	–	–
May	68	156	5568	–	5568	3	–	–	–	–	–	–
Jun	62	156	4306	–	4306	3	–	–	–	–	–	–
Jul	55	156	1962	–	1962	3	–	–	–	–	–	–
Aug	65	156	3783	–	3783	3	–	–	–	–	–	–
Sep	65	156	5847	_	5847	3	–	–	–	–	–	–
Oct	65	156	3929	_	3929	3	–	–	–	–	–	–
Nov	43	156	3430	_	3430	3	–	–	–	–	–	–
Dec	41	156	2823	–	2823	3	–	–	–	–	–	–

Diğer bilgi:
Other information:

Hotel 4 (2010)

Hotel number: 4				Hotel type: 5 star							year :2011	
Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)							
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)	
					m^3	TL	m^3	TL	m^3	TL	m^3	TL
Jan	40	156	2343	–	0	3	344	4	–	–	1999	1.5
Feb	50	156	3221	–	0	3	–	4	–	–	3221	1.5
Mar	50	156	3331	–	0	3	62	4	–	–	3269	1.5
Apr	58	156	3828	–	12	3	632	4	–	–	3186	1.5
May	63	156	5046	–	352	3	2440	4	–	–	2254	1.5
Jun	68	156	3420	–	972	3	720	4	–	–	1728	1.5
Jul	63	156	5160	–	2199	3	1485	4	–	–	1476	1.5
Aug	70	156	5573	–	1573	3	1585	4	–	–	2415	1.5
Sep	74	156	4942	–	2866	3	1425	4	–	–	651	1.5
Oct	74	156	6153	–	2814	3	2860	4	–	–	479	1.5
Nov	52	156	3877	–	2287	3	1240	4	–	–	350	1.5
Dec	46	156	3198	–	2556	3	–	4	–	–	642	1.5

Diğer bilgi:
Other information: other (ground water)

Hotel 4 (2011)

Hotel number: 5 | Hotel type: 5 star | year :2011

Month (Ay)	Capacity (Doluluk %)	Bed Capacity Yatak Kapasitesi	Potable water(m^3) Kullanim Suyu (m^3)	Irrigation water(m^3) Sulama Suyu (m^3)	Water Suppliers and water price/m^3 (Su tedarikçileri Ve Ton Ücretleri)							
					Pipeline (Şebeke)		Tanker (Tanker)		Reverse Osmosis (Ozmos)		Other (Diger)	
					m^3	TL	m^3	TL	m^3	TL	m^3	TL
Jan	–	–	–	–	–	–	–	–	–	–	–	–
Feb	–	–	–	–	–	–	–	–	–	–	–	–
Mar	–	–	–	–	–	–	–	–	–	–	–	–
Apr	–	–	–	–	–	–	–	–	–	–	–	–
May	–	–	–	–	–	–	–	–	–	–	–	–
Jun	8	1500	3357	25200	3357	–	–	–	–	–	–	–
Jul	30	1500	11731	28100	11731	2.5	–	–	–	–	–	–
Aug	31	1500	19144	29450	19144	2.5	–	–	–	–	–	–
Sep	43	1500	14839	22130	14839	2.5	–	–	–	–	–	–
Oct	29	1500	6884	18154	6884	2.5	–	–	–	–	–	–
Nov	24	1500	9709	12186	9709	2.5	–	–	–	–	–	–
Dec	16	1500	6472	7456	6472	2.5	–	–	–	–	–	–

Diğer bilgi:

Other information: the main source is reverse osmosis

Hotel 5 (2011)

APPENDIX B: Software