FINANCIAL COMPARISON OF THE ALTERNATIVE WATER SUPPLY SYSTEMS IN WATER SCARCE COUNTRIES UNDER THE HIGHLIGHT OF MILLENNIUM DEVELOPMENT GOALS OF UNITED NATIONS – A CASE STUDY ON AVŞA ISLAND

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submitted by **İLKER BİLGİN** in partial fulfillment of the requirements for the degree of **Master of Science in Civil Engineering Department**, **Middle East Technical University** by,

Prof. Dr. Gülbin Dural Ünver ____________________
Dean, Graduate School of **Natural and Applied Sciences**

Prof. Dr. İsmail Özgür Yaman
Head of Department, **Civil Engineering** ____________________

Assistant Prof. Talia Ekin Tokyay Sinha
Supervisor, **Civil Engineering Dept., METU** ____________________

Examining Committee Members:

Prof. Dr. A. Burcu Altan Sakarya ____________________
Civil Engineering Dept., METU

Asst. Prof. Dr. Talia Ekin Tokyay Sinha ____________________
Civil Engineering Dept., METU

Assoc. Prof. Dr. Yakup Darama ____________________
Civil Engineering Dept., Atılım University

Asst. Prof. Dr. Aslı Numanoğlu Genç ____________________
Civil Engineering Dept., Atılım University

Asst. Prof. Dr. M. Tuğrul Yılmaz
Civil Engineering Dept., METU ____________________

Date: 27.01.2017

I hereby declare that all information in this document has been obtained and presented in accordance with academic rules and ethical conduct. I also declare that, as required by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

Name, Last name : İlker, Bilgin

Signature :

ABSTRACT

FINANCIAL COMPARISON OF THE ALTERNATIVE WATER SUPPLY SYSTEMS IN WATER SCARCE COUNTRIES UNDER THE HIGHLIGHT OF MILLENNIUM DEVELOPMENT GOALS OF UNITED NATIONS – A CASE STUDY ON AVŞA ISLAND

Bilgin, İlker
M.S., Department of Civil Engineering
Supervisor: Asst. Prof. Dr. Talia Ekin Tokyay Sinha
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Water is indispensable for life. Although it is abundant on earth, only 3% of it is freshwater and it is not distributed evenly over the world. Distribution of fresh water is unfortunately not linked to the distribution of population. This means natural water resources are not available in every human settlement. Furthermore, some of existing natural water resources are managed inappropriately, for instance in poorer underdeveloped or developing nations water resources might get polluted due to lack of sanitation systems, whereas in developed countries same is true if there is a lack of enforcement of environmental policies. Thus, firstly existing water resources need to be saved with basic investments to achieve Millennium Development Goals (MDGs), some of which are directly related to the solution of water scarcity problem. Then, for the rest of water scarce countries, evaluation of alternative methods to supply water demand, which are called alternative water supply systems, is compulsory. However, these systems are expensive compared to regular water supply systems. Thus, for a water poor country, financial comparison of alternative water supply systems has great significance. This study aims to compare those alternative water supply systems financially over a case study on Avşa Island, Turkey. For the island, three alternative water supply systems are considered. Two of these require purchasing water from a nearby municipality on the mainland and the third option investigates the possibility of a reverse osmosis plant to convert Marmara Sea water to potable water. Financial comparison of these alternatives reveals that the most viable option for Avşa Island is to build a reverse osmosis plant.
Keywords: Alternative Water Supply Systems, Financial Comparison

ÖZ

SU YOKSUNU ÜLKELERDE ALTERNATİF SU KAYNAKLARI SİSTEMLERİNİN BİRLEŞMİŞ MİLLETLER YENİ BİNYİL HEDEFLERİ IŞIĞINDA MALİ KARŞILAŞTIRILMASI – AVŞA ADASI VAKA İNCELEMESİ

Bilgin, İlker
Yüksek Lisans, İnşaat Mühendisliği Bölümü
Tez Yöneticisi: Yrd. Doç. Dr. Talia Ekin Tokyay Sinha
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Su hayat için olmazsa olmazdır. Dünya üzerindeki en yaygın kaynak yine su olmasına rağmen, bu miktarın ancak yüzde üçü temiz sudur ve bu miktarda dünya üzerinde eşit şekilde dağılmamıştır. Temiz suyun dünya üzerindeki dağılımı ne yazık ki nüfusun dünya üzerindeki dağılımına da bağlı değildir. Bu, insanların yerleşim halinde oldukları her bölge için temiz su kaynaklarının mevcut olmadığı anlamına gelir. Dahası bazı mevcut temiz su kaynakları da yanlış yönetilmektedir. Örneğin daha yoksul gelişmemiş veya gelişmekte olan ülkelerde mevcut su kaynakları, atık su sisteminin olmaması nedeni ile kirlenebilmektedir. Bu durum, çevre politikaları üzerine bir denetleme olmaması durumunda gelişmiş ülkelerde de görülebilmektedir. Dolayısı ile öncelikle mevcut su kaynakları temel yatırımlar ile korunmalı, bazısı su kıtlığı probleminin çözümü ile doğrudan alakalı olan Yeni Bin Yıl Hedefleri'ne ulaşılmaya çalışılmalıdır. Bu durumun dışındaki su kıtlığı olan ülkeler içinse alternatif su temin sistemlerinin kıyaslanması bir gerekliliktir. Fakat bu sistemler sıradan su temin sistemlerine göre daha pahalıdır. Bu nedenle su fakiri bir ülke için alternatif su temin sistemlerinin mali kıyaslanması büyük önem taşır. Bu çalışma Türkiye'deki Avşa Adası'nın vaka incelemesi üzerinden alternatif su temin sistemlerini finansal olarak kıyaslamayı amaçlar. Ada için üç farklı alternatif su temin sistemi dikkate alınmıştır. Bu alternatiflerden ikisi, suyun anakarada bulunan yakın bir belediyeden satın alınması, üçüncü alternatif ise ters ozmos sistemi arıtma tesisi ile Marmara Denizi'nin tuzlu suyundan içme suyu sağlanması olasığını inceler. Bu alternatiflerin mali olarak kıyaslanması, Avşa Adası için en uygun çözümün ters ozmos sistemi ile çalışan bir arıtma tesisi olduğunu göstermiştir.

Anahtar Kelimeler: Alternatif Su Temin Sistemleri, Finansal Kıyas

To My Love

Whenever I lose my way, she just shows the right one with her love.

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LIST OF ABBREVIATIONS

AIDS	Acquired Immune Deficiency Syndrome
ANSI	American National Standards Institude
ASTM	American Society for Testing and Materials
AWWA	American Water Works Association
BoQ	Bill of Quantities
BWRO	Brackish Water Reverse Osmosis
CIESIN	Center for International Earth Science Information Network
DEPA	Danish Environmental Protection Agency
ED	Electrodialysis
EDR	Electrodialysis Reversal
FAO	Food and Agriculture Organization of the United Nations
GPW	Gridded Population of the World
HDPE	High-Density Polyethylene
HIV	Human Immunodeficiency Virus
ICWE	International Conference on Water and the Environment
IDA	International Desalination Association
IFPRI	International Food Policy Research Institute
IPCC	International Panel on Climate Change
JMP	Joint Monitoring Programme
kWh	KiloWatt Hour
LCAA	Life Cycle Cost Analysis
MDG	Millennium Development Goal
MED	Multiple Effect Distillation
MF	Microfiltration
MGD	Million Gallons Per Day
MSF	Multi Stage Flash
MCM	Million Cubic Meter
NSF	National Sanitation Foundation
PH	Potential of Hydrogen
PN	Nominal Pressure in bars that a pipe can support with water at 20^{o}C
RO	Reverse Osmosis
SCADA	Supervisory Control and Data Acquisition
SWRO	Sea Water Reverse Osmosis
TDS	Total Dissolved Solid
TWAS	World Academy of Sciences
UN	United Nations
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCO	United Nations Educational, Scientific and Cultural Organization

UNICEF	United Nations Children's Fund
UPC	Unit Product Cost
USA	United States of America
USD	United States Dollar
VCD	Vapor Compression Distillation
WHO	World Health Organization
WRI	World Resources Institute
WSSD	World Summit for Sustainable Development
WWC	World Water Council

CHAPTER 1

INTRODUCTION

1.1 General

Water is vital for life, and it does not have any alternative. Every living creature needs water. As mentioned by Rothschild and Mancinelli (2001), “In the past few decades we have come to realize that where there is liquid water on Earth, virtually no matter what the physical conditions, there is life”. Due to the fact that without life nothing has meaning or value, water is the most important and indispensable material in the world. However, it is a known fact that water is not evenly distributed over the world. 60% of the World’s available freshwater supply belongs to ten countries; Brazil, Russia, China, Canada, Indonesia, U.S., India, Columbia and the Democratic Republic of Congo (Fry, 2005). This situation forces water disadvantaged countries to find most appropriate alternative water supply system in order to supply water as much as their population needs. The most appropriate water supply method a water scarce country could select depends on the finances of that country. The financial perspective varies based on geography, economy, population, and required amount of water by that country.

Throughout the history, water was the primary focus of the societies for survival and for prosperity. According to Mays (2000), the oldest archaeological evidence on the island of Crete in Greece shows that existence of water transport systems dated from as early as 3500 years ago. Similarly, a pipe found in Anatolia proves that there was a water transportation line in that geography approximately 3000 years ago.

Water is significant in all aspects of economy directly or indirectly from agriculture to energy, industry to tourism. While societies located near a water source has important advantage of having a better life quality, in societies located in water scarce lands even survival becomes a challenge. It is desirable for those countries in water scarce lands to solve their water related problems with a long-term solution rather than a short-term one. Even though intrastate water trade and sharing would be the obvious solution to the scarcity; many conflicts might rise during the trade between states. According to water conflict chronology prepared by Gleick and Heberger (2014), violence over water going back nearly 5000 years with numerous events. In the 20th century, the oil has become an important natural source and has been greatly sought-after by many communities. Many conflicts has risen in the oil-rich states. Secretary-General of the United Nations Conference on Human Settlement, remind the importance of the water to world with his statement; "I suspect that in the next 50 years, we will see a shift from oil to water as the cause of great conflicts between nations and peoples." (N'Dow, 1996)

Although, water is the birthright for all living creatures, it is reported that the majority of the World's population, especially in most parts of Africa and Asia, does not have access to safe drinking water and 6 million children dies daily because of waterborne diseases linked to scarcity of safe drinking water or sanitation (TWAS, 2002). Based on United Nations (UN) estimations, Sub-Saharan Africa loses 40 billion hours per year collecting water, that number is nearly equal to entire year's labor in all of France (UNDP, 2006).

Some basic investments are required to better manage the water resources and avoid their pollution. Those investments should aim to achieve Millennium Development Goals (MDGs) of UN, some of which are directly related to the solution of the water scarcity problem. Better water supply and sanitation will result in less illness. As a result, it is estimated that meeting MDGs of UN on water supply and sanitation will gain 322 million working days. Annual global value of adult working days has been nearly estimated as $ 750 million (Young & Esau, 2013).

Main idea of water supply systems is transmitting water from a reservoir to demand. Reservoir is a natural or artificial place where water is collected and stored. Dams, lakes and groundwater aquifers are the examples of reservoirs. However, if filled reservoir conditions could not be reached locally and naturally in a region, then alternative water supply systems for that region could be considered. The most important disadvantage of the alternative water supply systems is their cost because in alternative water supply systems, water is transferred from great distances or produced with advanced technology such as reverse osmosis.

1.2 Aim of Study

This study summarizes the most popular alternative water supply systems in water scarce countries based on mainly financial considerations, which varies with geography, economy, population, and required amount. Additionally, this study includes a local evaluation of alternative water supply system in Avşa Island of Turkey.

Generally, the capital costs of alternative water supply systems are considerably high. Therefore, the financial comparison of viable methods and their feasibility is very important before making any investment on any of these alternative systems in a water scarce country.

In this study, life cycle cost analysis is used for each method to compare them. Life cycle cost analysis is a simple and straightforward economic evaluation method, which takes into account all costs among its service life. This method is convenient when all project alternatives has completely different costs but all of them fulfill the demand requirements. There are some other commonly used methods. These are net savings (or net benefits), savings to investment ratio (or savings benefit to cost ratio), internal rate of return, and payback period (Fuller, 2010). Life cycle cost analysis is chosen for this study because life cycle cost analysis considers all the costs related with the product for its entire life cycle. In this study the desired service life of each alternative water supply system considered for Avşa Island is more than 30 years. The purpose is to estimate overall costs of all project alternatives to choose the system, which has the lowest overall cost over its entire service life.

During the life cycle of the facilities, costs can be grouped under three main titles. These are initial cost, maintenance cost and cost of operation. Firstly, initial cost is the capital necessary to make the facility ready to work. This cost includes preliminary investment (legal fees, land registration and purchase, capital for preparation of plans, prefeasibility, feasibility, business plan, drawings and maps), construction cost and equipment cost. Secondly, operational costs are the capital required to produce repetitive outputs. Operational costs includes salaries, energy cost, taxes, rents and cost of consumable materials, market research, advertising, account management, sales promotions, etc. Finally, maintenance cost is the capital to keep machines, building and any others in working condition.

In order to compare practically all alternatives financially, unit product cost (UPC) will be calculated based on all those cost components, facility life, annual operating and maintenance cost, facility capacity and facility availability by using the Equation 1.1.

$$\text{UPC} = \frac{\frac{\text{Capital Cost}}{\text{Facility Life}} + \text{Annual Operating and Maintenance Cost}}{\text{Facility Capacity x Facility Availability}} \tag{1.1}$$

CHAPTER 2

FRESH WATER POTENTIAL IN THE WORLD AND WATER USAGE SITUATION

2.1 Water Potential in the world and its usage

It is a known fact that water is the most widespread material on the earth and exist in three form; solid, liquid and gas. It is a widespread estimation those 1,386,000,000 cubic kilometers (km^3) of water exists on, in, and above the Earth. Roughly, 97% of this cumulative amount is saline in the oceans and seas. The remaining 3% being freshwater and its 68.7% is locked in glaciers and ice-sheets, while most of the rest, 30.1%, is groundwater (Shiklomanov, 1992). The global distribution of water is shown in Figure 2.1 and is given Table 2.1. These numbers are just general estimations due to the dynamics of Earth's hydrological water cycle.

Generally, freshwater resources can be divided into two groups. These are static form and dynamic form. On the global scale glaciers, groundwater and lakes are the most dominant part of the freshwater in static form. On the other hand, rivers are most dominant part of the fresh water in dynamic form. Among the static form of water resources groundwater is the most dominant one in global scale because it is often cheaper, more convenient and less vulnerable to pollution. Basically, groundwater is the water stored in geological formations. Although groundwater has important advantages and commonly used; in global scale the amount supplied from groundwater are not large compared with the amount supplied from river runoff. (Shiklomanov, 1998)

It is a generally used estimation in hydrology that dynamic water volume on Earth is about 577,000 km^3/year. Resource of this dynamic water is evaporation from ocean surface and land. Evaporation amounts are estimated as 502,800 km^3/year from ocean, 74,200 km^3/year from land. Those entire evaporated amount of water is fall back to ocean and land as precipitation. Precipitation amounts are estimated as

458,000 km^3/year on ocean, 119,000 km^3/year on land (Shiklomanov, 1998). According to Equation (2.1), the difference between precipitation on land, P and the evaporation from land, E, gives the total run-off amount on land, R. Total run-off on land is calculated as 44,800 km^3/year given in Equation (2.2). According to World Resources Institute, renewable freshwater is replaced completely each year by rain and snow, then flows through rivers and various waterways to ocean (Sprague, 2002). However, this statement ignores storage effect. In order to use fresh water, it is necessary to store it and this causes an increase in evaporation called storage effects. Therefore, values calculated based on Equation (2.1) are the maximum quantity of freshwater available on average each year. Some of that amount taken by hydraulic structures for three main purposes, this removal of water is called water withdrawal. These three purposes are agricultural (including irrigation, livestock and aquaculture), municipal (including domestic) and industrial.

$$P - E = R \tag{2.1}$$

$$119{,}000 - 74{,}200 = 44{,}800 \text{ km}^3\text{/year} \tag{2.2}$$

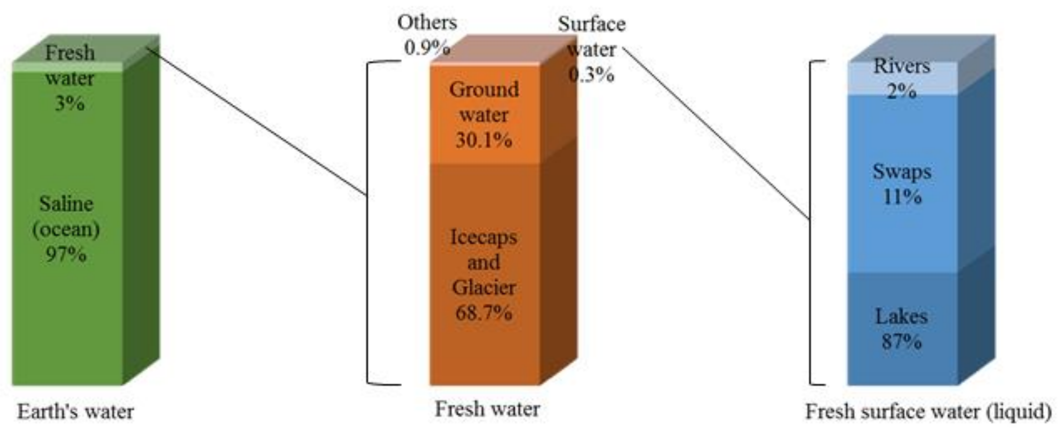

Figure 2. 1 Global distribution of water (Modified from Web 1)

Table 2. 1 Volumes of water in global water bodies (Shiklomanov, 1992)

Water source	**Water volume (cubic kilometers)**	**Percent of Freshwater**	**Percent of total water**
Oceans, seas and bays	1,338,000,000	-	96.5
Ice caps, glaciers and permanent snow	24,064,000	68.7	1.74
Groundwater	23,400,000	-	1.7
Fresh	10,530,000	30.1	0.76
Saline	12,870,000	-	0.94
Soil moisture	16,500	0.05	0.001
Ground ice and permafrost	300,000	0.86	0.022
Lakes	176,400	-	0.013
Fresh	91,000	0.26	0.007
Saline	85,400	-	0.006
Atmosphere	12,900	0.04	0.001
Swamp water	11,470	0.03	0.0008
Rivers	2,120	0.006	0.0002
Biological water	1,120	0.003	0.0001
Total	1,386,000,000	-	100

In global scale, 69% of the withdrawn water is consumed by agriculture. On the other hand, industry consumes 19% of the accessible freshwater. Only remaining 12% is used for local or municipal use for domestic consumption or other direct uses (Web 2). However, findings are not same when the situation is checked in continent level as shown in Figure 2.2. The ratio is mainly dependent on climate and economic benefits of agriculture and industry.

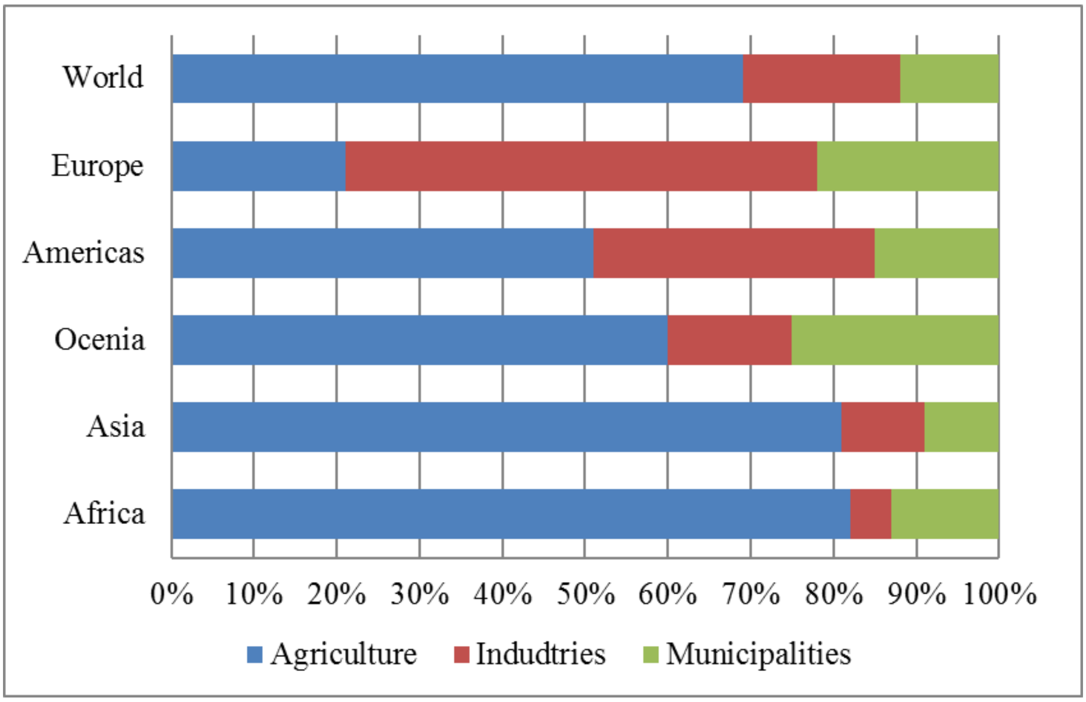

Figure 2. 2 Water withdrawal ratios by continent (Web 2)

Figure 2.3 shows the global population and water withdrawal over time. Although water withdrawal term does not include evaporation amount, it is shown as a storage effect. Storage effect is the additional evaporation amount to cumulative amount, which occurs because of manmade structures such as reservoir. Figure 2.3 gives a clear perspective about how water demand will change over years. In the past 120 years, water withdrawal amount has risen to roughly six times more, although population has increased to roughly four times. This means; addition to increase in fresh water demand with increase in population, water consumption per capita has increased as well. While demand grows, the resources remain finite. Furthermore, fresh water amount is decreasing over the world due to climate change, pollution, urbanization, etc. Clearly, after a period of time, global fresh water capacity will be too low with respect to fresh water demand. There are two basic probable result of this trend in future. Firstly, even today alternative water supply systems are widely used in world; possibly, in future they will be inevitable for many countries. Secondly, expensive water price could be expected in future as a consequence of supply-demand imbalance.

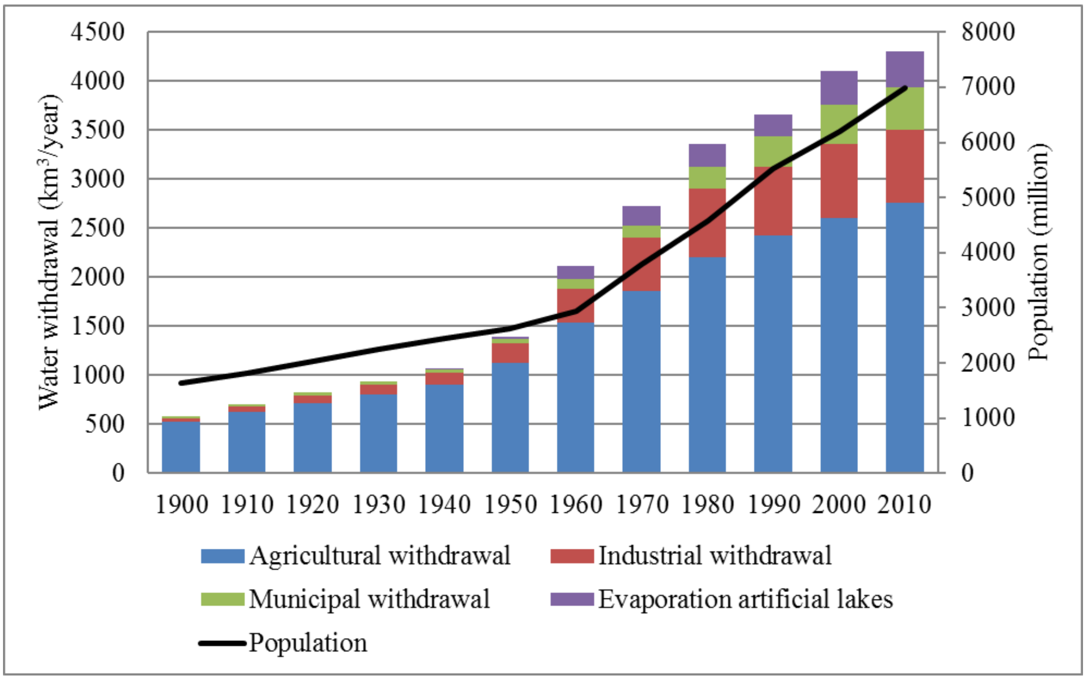

Figure 2. 3 Global population and water withdrawal over time (Web 2)

2.2 Water Distribution over the World and Supply-Demand Imbalance

Similar to human population, fresh water is not evenly distributed over world. There is disparity between population and fresh water availability in certain parts of the world. This could create an imbalanced supply and demand. Based on size and sign of that imbalance, water availability can be evaluated. From this perspective, Falkenmark indicator is an effective norm to detect and understand the amount of water availability for a country or region.

Falkenmark indicator is a clear and commonly used classification tool in order to classify countries about their water richness, which is defined as the volume of renewable water resources per capita. It is the ratio of an effectively unalterable measure of the natural resources and the size of the country's population, named for the eminent Swedish hydrologist Malin Falkenmark (1989). This index is commonly used to assess a country to form an opinion on its water availability. As shown in Table 2.2, based on the area, water conditions can be categorized as no stress, stress, scarcity and absolute scarcity. The index thresholds of 1,700 m^3 and 1000 m^3 per capita per year are used between water stressed and scarce areas, respectively (Falkenmark, 1989).

Table 2. 2 Water barrier differentiation (Falkenmark, 1989)

Index (m^3 per capita)	**Category/ Condition**
>1,700	No stress
1,000-1,700	Stress
500-1,000	Scarcity
<500	Absolute scarcity

Absolute scarcity, scarcity and stress are the definitions used for classification of the countries based on insufficiency level of their fresh water capacity with respect to their population. Scarcity and absolute scarcity can be defined as lack of access to sufficient available water supply to meet human and environmental needs. On the other hand, water stress refers to limited water supply conditions for human and environmental needs.

Based on this index, a country, which has high total water availability, may not be a water-rich country. Many countries in Asia are good examples for such situation. As shown in Figure 2.4, despite all its huge fresh water capacity, Asia is a water-poor land just because of its population. On the other hand, the situation is opposite in Australia.

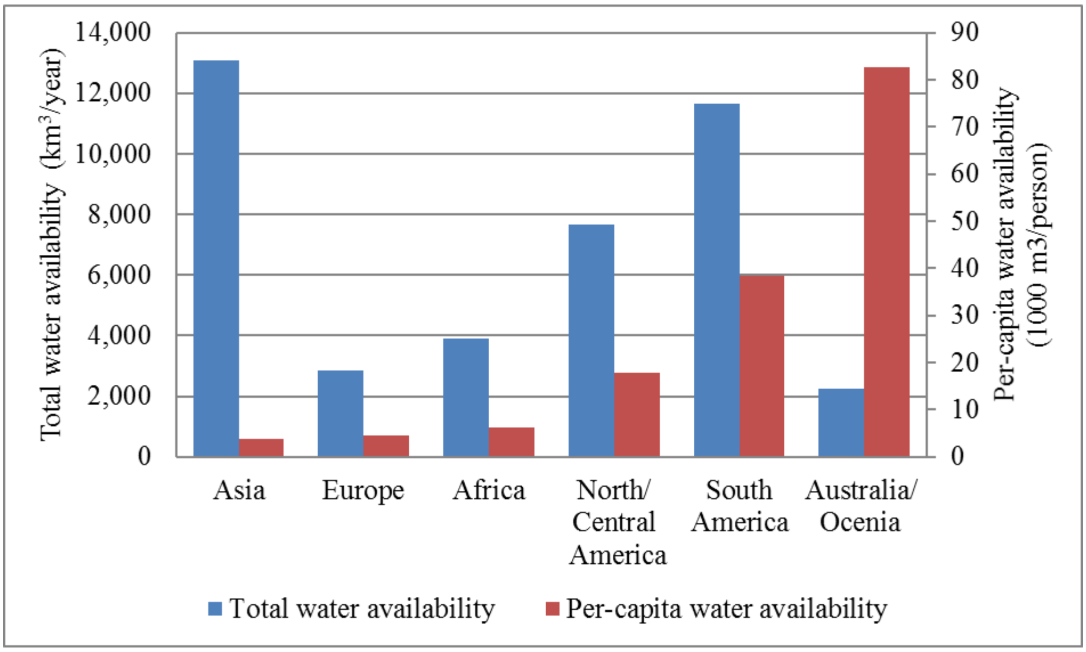

Figure 2. 4 Continental total and per-capita blue water availability (Shiklomanov, 1998)

Per capita renewable water supply calculated based on river basin is shown in Figure 2.5. It shows Falkenmark Index and its distribution all over the World.

A parameter called water footprint is used in order to measure consumption of fresh water in volumes of water consumed and/or polluted, which includes both direct and virtual use of water. Water footprint concept is categorized as blue, green and grey water footprint. “Blue” is used to define groundwater and surface water that can be collected, transported, used for purposes like agriculture, irrigation, etc. (Web 3). To define capillary water in the soil or stored in plants “green footprint” is used and generally, it is used for local farming and forestry (Web 3). Lastly, “grey footprint” is used for contaminated water which is utilized in agriculture after proper treatment (Web 3).

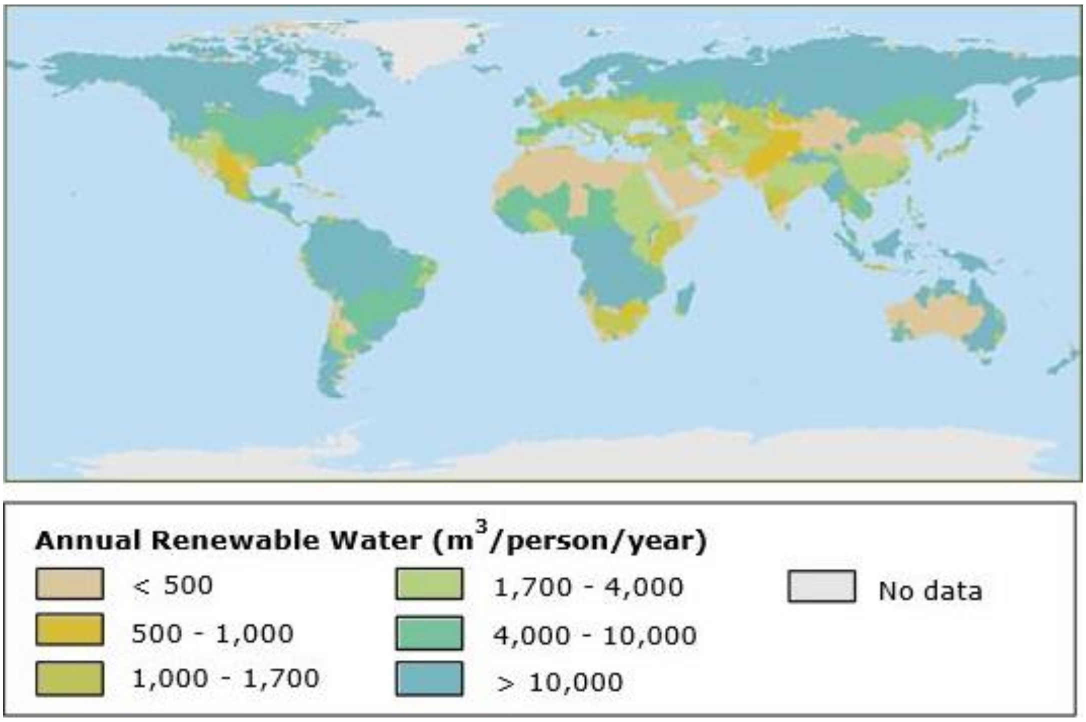

Figure 2. 5 Annual renewable water supply per person by River Basin, 1995 (CIESIN et al., 2000)

According to Gleick's (1996) study, water scarcity index should be based on the ability to meet all water requirements for basic human needs such as drinking water for survival, water for human hygiene, water for sanitation services, and modest household needs for food preparation. All those needs and their amounts are listed in Table 2.3. It shows that water requirement to meet basic human needs adds up to a total demand of 50 liters per person per day.

Table 2. 3 All water requirements for basic needs (Gleick, 1996)

	Minimum requirement (liters per person per day)
Minimum drinking water requirement	5
Basic requirements for sanitation	20
Basic water requirements for bathing	15
Basic requirements for food sanitation	10
Total	50

$$\text{Basic Water Need} = 50 \text{ l/person/day} \times 365/1000 = 18.25 \text{ m}^3\text{/person/ year} \qquad (2.3)$$

As shown in Equation 2.3, 50 l/person/day equals to 18.25 m^3/person/year. International organizations and water providers recommend to adopt this overall basic water requirement as a new threshold to satisfy the basic needs, independent of climate, technology, and culture (Gleick, 1996). Among the developing countries of the world such as Ghana and Liberia (Web 4), one in five people lack access to minimum of 20 liters/day, while average water use in Europe and the United States of America ranges between 200 and 600 liters/day (UNDP, 2006). Dramatically, it is reported that people in the slums of developing countries typically pay 5–10 times more per unit of water than people with access to piped water (UNDP, 2006).

To conclude, the reason behind the water scarcity problem is not only the growing demands to a finite source, but also the supply-demand imbalance over the world. Solution of this problem is crucial for water scarce countries whose natural resources are not sufficient for their population. In order to eliminate this problem, alternative water supply systems could be employed. These are producing water from seawater, brackish water and wastewater; or importing and transporting water from water-rich to water-poor countries with international pipelines, supertankers, and water bags produced with advanced technology.

2.3 Global climate change and its effects on water resources

Climate change is a change in long-term average weather conditions or variation of weather in the time. Earth's climate has always been changing. From 1880 to 2012, average over all land and ocean surface temperatures warmed roughly 1.53 degrees Fahrenheit (0.85 degrees Celsius) (Intergovernmental Panel on Climate Change, 2013). Even though this amount seems so small, effect of it is definitely huge. These effects are various from sea level, evaporation and precipitation amounts to human health. However, for this study, among all its effects, the main one is its effect on water resources.

Alteration of evaporation and precipitation amounts is the direct effect of climate change on water resources because those variables are the determinative factors of availability and amount of usable water. Due to global climate change, as temperature increases, evaporation rate and atmospheric capacity to hold water increases. This causes, in global scale, higher frequency and intensity of the droughts.

Although, increase in evaporation might mean increase in precipitation; in average high temperature, resultant precipitation is not as effective as it is in low average temperature. Firstly, due to higher temperature, precipitation type is often rain. Although more rain than snow seems to have a positive impact, it causes water shortages. Snow melts slowly from spring to summer and flow through reservoirs without causing an overflow. On the other hand, reservoirs quickly fill in the winter if precipitation falls as rain; excess water cannot be stored, so flows as a run-off river. Secondly, even in snow-rare regions, global warming causes increment at both frequency and intensity of the storm events with similar consequences mentioned above.

Furthermore, in higher temperatures, all living things consume larger amount of water due to transpiration. Both for irrigation and livestock activities, required amount of water increases, hence the demand increases.

Climate change is a fact and changes the future. If the management of water is not improved, water distress condition can be expected widespread over the world especially in highly populated areas. According to the estimations of Population Action International (PAI), in 2025 only few countries will not be suffering from water stress (Web 5). Therefore, adaptation and taking precautions are essential. Predicting effects and results, taking appropriate actions are the way to minimize the damage and taking advantage of opportunities. Today, all over the world; countries like Germany, Brazil, and Japan had climate change policies and strategies adopted officially other than the agreements like Kyoto Protocol to stop climate change (Web 6). Those strategies include how to save water reservoirs, how to decrease wastewater and how to manage it more effectively.

CHAPTER 3

WATER RIGHTS, UNITED NATIONS AND THEIR MILLENNIUM GOALS

3.1 United Nations and Millennium Development Goals

The UN is an international organization aims to maintain international peace and security, develop friendly relations among nations, promoting human rights and fundamental freedom, achieve international co-operation, encourage social, cultural, economic and humanitarian character, and be a center for harmonizing the actions of nations in the attainment of these common ends (Charter of the United Nations, 1945). The organization established with its 51 members in 24 October 1945 after the end of Second World War. Today organization has 193 Member States.

The General Assembly, the Security Council, the Economic and Social Council, the Trusteeship Council, the International Court of Justice, and the UN Secretariat are the main organs of the UN. All these organs principally work independently from each other. Each of them includes specialized agencies, research and training institutions, programs and funds, and other UN entities. The UN and its agencies are immune from the laws of the countries where they operate according to The Convention on the Privileges and Immunities of the United Nations.

For all fresh water and sanitation issues UN-Water is the United Nations inter-agency coordination mechanism. The United Nations High Level Committee on Programs formalized it in 2003. Its purpose is to join efforts and facilitate synergy for the success and complement of the existing programs and projects. Thus effectively and coordinately supports Member States in order to achieve their time-bounded goals, targets and actions stated as Millennium Development Goals. The scope of UN-Water covers all aspects of freshwater and sanitation, including surface and groundwater resources, the interface between freshwater and seawater, and water-related disasters.

UN-Water has one specific programme with its own work plan, budget, and an executing agency coordinating the implementations, and this programme is called World Health Organization (WHO)/ United Nations International Children's Emergency Fund (UNICEF) Joint Monitoring Programme (JMP) on Water Supply and Sanitation. JMP is established in 1990, implemented and supervised by WHO and UNICEF. It regularly publishes global reports on water and sanitation in order to contribute better planning and management at the national level. However, the main purpose of JMP is monitoring global progress toward the MDGs targets for drinking water and sanitation.

In September 2000, the largest gathering of world leaders in history adopted the UN Millennium Declaration at the Millennium Summit; all 189 United Nations member states committed to a new global partnership to set out a series of time-bound targets with a deadline of 2015, which is called Millennium Development Goals. The MDGs are the eight international development goals, which-cover eradicating extreme poverty and hunger, achieving universal primary education, promoting gender equality and empowering women, reducing child mortality, improving maternal health, and combating Human Immunodeficiency Virus (HIV)/Human Immunodeficiency Virus (AIDS), malaria and other diseases, ensuring environmental sustainability, developing a global partnership for development (United Nations Millennium Declaration, 2000). Each of those goals has specific targets, target dates and indicators to monitor the progress.

Water scarcity is not only one of the targets embedded in the MDGs, but also critical factor for successful achievement of most of the other MDGs. This situation is recognized and in August 2002; at the Johannesburg World Summit for Sustainable Development (WSSD) reapproved and additional targets related water were added under the Johannesburg Plan of Implementation. Importance of the sanitation for health and poverty reduction as much as safe water was affirmed by this action. According to UN-Water report, Table 3.1 shows how coping with water scarcity can affect the success of the Millennium Development Goals.

Table 3. 1 How dealing with water scarcity can affect the Millennium Development Goals (UN Water, 2007)

MDG	**Linkage with water scarcity**
Eradicating extreme poverty and hunger	Reducing poverty and improving food security associated with access to water for domestic and productive uses like agriculture, industry, other economic activities; droughts directly related vulnerability of water; both irrigated and rainfed agriculture for improved grain production, subsistence production, livestock, etc. dependent on water scarcity; capacity to produce cheap food impact on nutrition in rural and urban areas.
Achieving universal primary education	Overcoming droughts with educational attainment and drought preparedness programs.
Promoting gender equality and empowering women	Impact of accessing water in scarce resources on women's social and economic lives in terms of leadership, earnings, network opportunities.
Reducing child mortality and improving maternal health	Improving nutrition and food security decreased the possibility of being ill; reliable water resource management programs affect to experience poor people's vulnerability to shocks; which provides them more secure and fruitful lives with their children.
Combating HIV/AIDS, malaria and other diseases	Reducing the risk of being ill- such as malaria, dengue fever, etc. related to accessing water and improving and wastewater management in human settlements.
Ensuring environmental sustainability	Improved water management main factor in sustainability of ecosystem functions and services; proper treatment of wastewater protecting human and environmental health.
Promoting global partnerships	Overcoming the water scarcity required international cooperation in improved water productivity and financing opportunities; an improved environment sharing the benefits of scarce water management upon in caring their children.

3.2 Water as a Social and Economic Good

Water has accepted as a social good due to its ecological value, cultural value and indispensability for human existence. Within the framework of all the conditions of existence included both organic and inorganic, the entire science dealing with the relations of the organism to the surrounding exterior world is called ecology (Haeckel, 1866). Place of the water in this system is fundamental and interconnected. To achieve sustainable water management, water cycle is crucial as a biophysical process, and natural freshwater generation directly depends on the continued healthy functioning of ecosystems (UNESCO, 2012). Thus, ecologic value of the water is indispensable. Despite all its negative effect to natural system, human is a part of ecology from biological perspective, so same situation is valid for human. Water is indispensable for human as well. Moreover, essentiality of water is the reason, which makes it a key part of culture. Water always has important role in cultural activities, social behaviors and religions.

On the other hand, domestic, industrial and agricultural demands for fresh water push the entrepreneurs to create wide range of markets for water. Today, water is used as a commodity in both bottled and bulk forms within both national and international borders that makes it economic good. However, assessing and trading a resource as fundamental and vital as water, is still a controversial topic. In global agenda, first explicit recognition of water as an economic good was at one of the four Dublin Statements affirmed from the International Conference on Water and the Environment (ICWE) in Dublin, Ireland. This statement was “Water has an economic value in all its competing uses and should be recognized as an economic good” (ICWE, 1992). In parallel, same idea was improved at Earth Summit, which is a United Nations Conference on Environment and Development in June 1992. Agenda 21 is non-binding, voluntarily implemented action plan of the United Nations with regard to sustainable development; states “integrated water resources management is based on the perception of water as an integral part of the ecosystem, a natural resource and a social and economic good, whose quantity and quality determine the nature of its utilization" (United Nations, 1992). These statements were criticized in global scale and it caused reaction with both supports and protests.

Proponents of public provision of water argue that treating water as commodity governed by rules of the market causes unacceptable situation. It will leave certain people without vital fresh water resources. Water is a human right and one of the governments' responsibilities should be providing water to its people whatever their economic situation is. Moreover, water policies should be set based on human rights in order to save people and obligate governments. Opponents of this proposal claims that making it available at subsidized prices can lead to inefficient use and short supply.

Generally, accepted broad approach on water management is that it must be a practice, which allows the poor to satisfy their basic water needs, but reduces wasteful use of water. That practice does not require transforming the water to a commodity in all aspects. For instance, increasing block tariff is an appropriate application for the explained purpose. In this application, price per unit of water increases as the volume of consumption increases. Thus, consumers using excessive amount of water pays higher unit prices and low volume of water consumers pay lower unit water price (Gleick et al., 2002).

CHAPTER 4

ALTERNATIVE WATER SUPPLY SYSTEMS

4.1 Importing Water

Importing water is one of the solutions for water scarce countries to supply the demand. Most of the time, water scarcity is regional and neighbors of the water scarce countries are water poor as well. At this stage, the distance which water is transported will be higher and it will directly affect the cost. Most of the time transportation is the biggest expense due to those long distances. Thus, the system used to transport water has crucial importance from cost wise perspective. Water bags, tankers, international pipelines are the systems that are used to transport water. All these systems are summarized one by one in this chapter.

Furthermore, importing water from another country could be very risky for countries itself. The reasons behind this situation are firstly water is expected to be 'blue gold' of the future and, secondly, importer country could possibly be addicted to the exporter country due to its indispensability.

Since water is started to be accepted as a commodity as stated in Dublin in 1992 for the first time; arguments and ideas, which support and improve that statement grow significantly. In the Second World Forum, hosted by World Water Council (WWC) in The Hague in 2000; it is stated that the water must have a market value and its price should be calculated and defined on the basis of the total cost of production. This statement is published in the declaration as "To manage water in a way that reflects its economic, social, environmental and cultural values for all its uses, and to move towards pricing water services to reflect the cost of their provision."(WWC, 2000). This statement suggests a significant increase in market price of water and shows that it will be "the blue gold" of the 21th century. Thus, importing water rather than producing it is not a compelling approach if the cost of import and cost of production are comparable.

Secondly, importing water from another country gives a political advantage to exporter country. Alternative water supply system investments are generally huge and it takes time to activate them for operation. Water is not a kind of material for which the demand can be suspended for a while. Therefore, if exporter country threatens importer country on any subject, probably importer country will not have variety of options. This situation affects the autarky, in other words self-sufficiency of the importer country.

Despite all these handicaps, for some countries without natural water resources such as rivers, lakes and groundwater, importing water could still be the best solution. The alternative water supply systems are limited and not all of them may be applicable in all countries. For instance, desalination is not applicable for the countries, which do not have coast or brackish water resources.

4.1.1 Water Market

Today, there is no international trading market for water. However, there is indirect and non-transparent water trade in all over the world. Importing and exporting water intensive goods like food, clothes, paper etc. is referred as virtual water trade. As mentioned before, water is directly or indirectly an input to all kinds of productions, so the water used for production is called virtual water. For instance, in order to produce 1 kg of rice, averagely 3000 liters of water is required. Therefore, importing 1 kg of rice means importing 3000 liters of water as well.

Importing water intensive goods and exporting the goods, which require very less water during the production is very reasonable approach for water scarce countries. On the other hand, water rich countries can dominate water intensive goods so they can create a chance to export their water indirectly with additional value (Hoekstra and Hung, 2002).

Actually, global economy tends to make the balance itself but critical point is water prices are not the only factor effecting global market prices. Global variation of labor price, technological level of the countries, their geographic location, etc. are the other factors, which directly affect global supply demand balance and routes. Generally, in water scarce countries water is valuable and expensive; which makes water intensive goods expensive as well. Due to competitive pricing in global market, an expensive good may not be preferred; therefore, an investors in a water-poor country tends to invest on products, which require less water during the production process. On the other hand, investors in the water-rich countries normally prefer water intensive goods to use their natural advantage so they will have less cost, less competition and higher selling prices. Figure 4.1 shows geographic distribution of virtual water import and export. As shown in the figure, global virtual water trade does not exactly fit to the scenario explained above, this is due to the other factors such as labor price, location etc. as mentioned before.

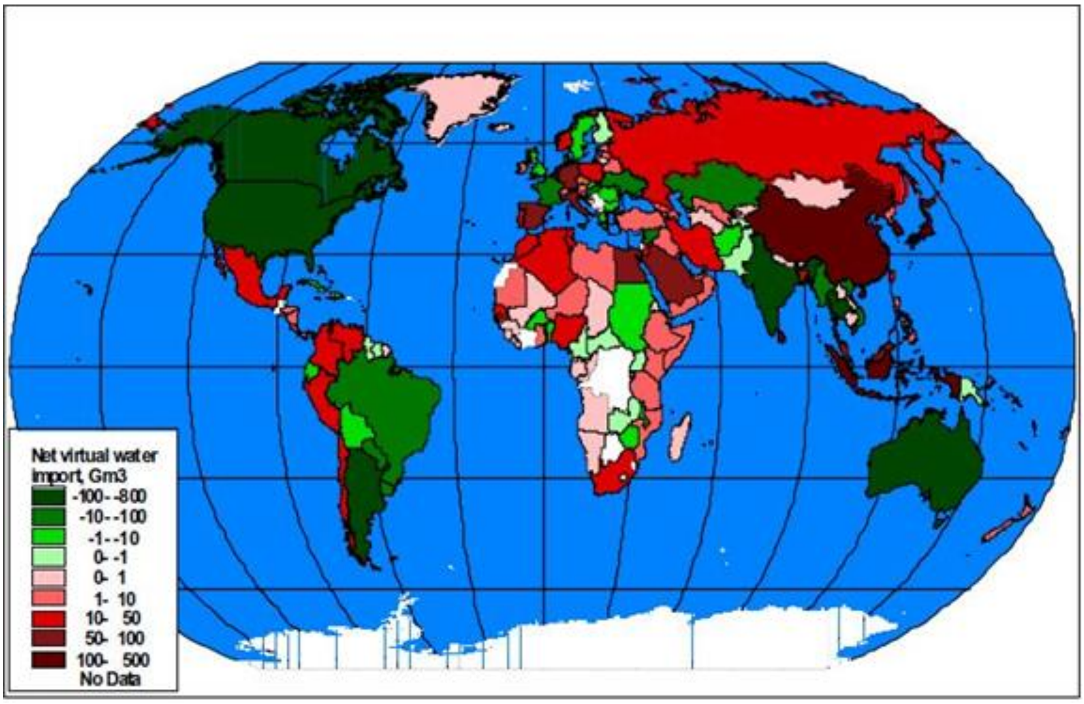

Figure 4. 1 National virtual water trade balances over the period 1995-1999.Green colored countries have net virtual water export. Red colored countries have net virtual water import (Perveen, 2004)

Canada roughly fits to the scenario explained above. Canada has the biggest fresh water reserves in the world. It has 9% of the world inventory and its Falkenmark index is 94.353 m^3/year/capita (FAO, 2002). On the other hand, considering the period 1995-1999 Canada is the second largest virtual water exporter in the world. Its net export volume is $272.5x10^9$ m^3 over 1995-1999 (Hoekstra and Hung, 2002). Canada uses 70% of its fresh water withdrawal on agriculture and annually its total virtual water export through agriculture is 44.5 billion m^3 (Rahman et al., 2011).

Regarding water management and virtual water trade, Denmark is a country, which does not fit the general scenario explained. It is a water stressed country based on Falkenmark index, 1,128 m^3/year/capita (FAO, 2002). Furthermore, in period 1997-2001 water footprint of the Denmark is 1,440 m^3/year/capita which is 16% higher than the average of the world water footprint, 1,240 m^3/year/capita (Chapagain and Hoekstra, 2004).Thus, Denmark's water footprint is higher than its water availability. This means consumption amount is more than the renewable amount and over time, freshwater ecosystems degrade. In order to decrease that excessive amount of water consumption, water prices have increased gradually over the years as shown in Figure 4.3 and Denmark has the highest water price in Europe as shown in Figure 4.2. That increase in price resulted in decrease of household water consumption as shown in Figure 4.3. However, basic reason behind the excessive amount of water consumption is not domestic water use, but agricultural and industrial use. Contrary to the decrease of domestic use of water, agricultural and industrial goods are exported more than 55 countries and the water used in production of those goods are almost 66% of all water used in Denmark (Bidstrup, 2012). Moreover, Denmark is one of the net virtual water exporters in the world. It has $1,029x10^6$ m^3 net virtual water export in 1995. (Hoekstra and Hung, 2002).

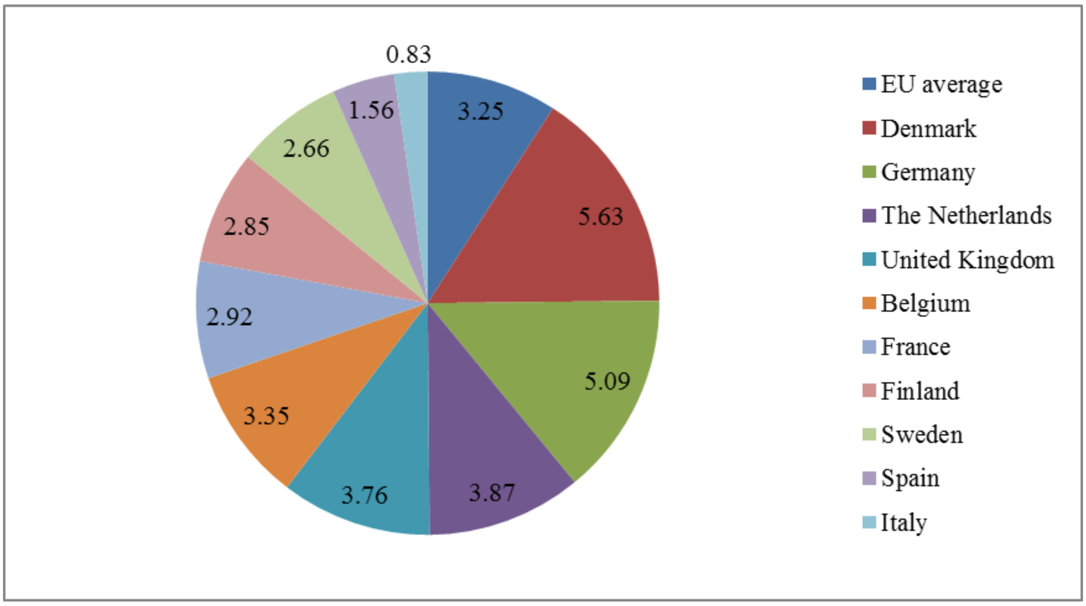

Figure 4. 2 Unit Water prices in Europe (€/m^3) (McKinney, 2012)

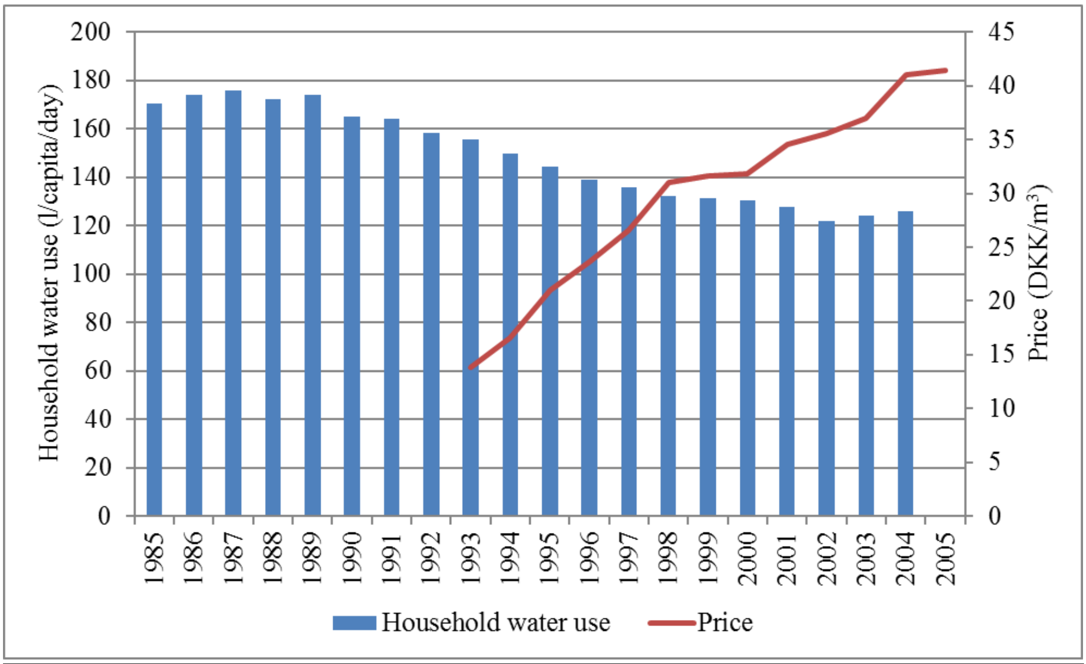

Figure 4. 3 Household water usage and water price in Europe (DEPA, 2004)

Before feasibility studies and employment of the alternative water supply systems, water poor countries should first study their virtual water trade situation. It could be the best solution or an important progress in fighting against water scarcity if country could optimize its virtual water trade and improve the water management strategy instead of investing million dollars to alternative supplies. Trading water in virtually with respect to selling or buying directly is more appropriate for both exporter and importer countries although for some countries this kind of trade is not enough to supply the demand. From exporter point of view, bulk water export is similar to selling raw material and economically it is not a desired action. Export of value added product, which is a processed good resulting from conversion of raw material to final product based on needs of the client, contributes to a more stable and diverse economy. In this study, virtual water trade is not compared with alternative water supply systems, however it should be noted that for better assessment of water supply options virtual water trade of a country should also be considered.

Bottled water sales is another alternative form of trading water in addition to trade it in bulk or virtually. Although, not as much as virtual water trade, bottled water export has economic advantages compared to bulk water trade because there is an additional value to the bottled water. It is a rapidly growing industry in the world as shown in Figure 4.4 and given in Table 4.1.

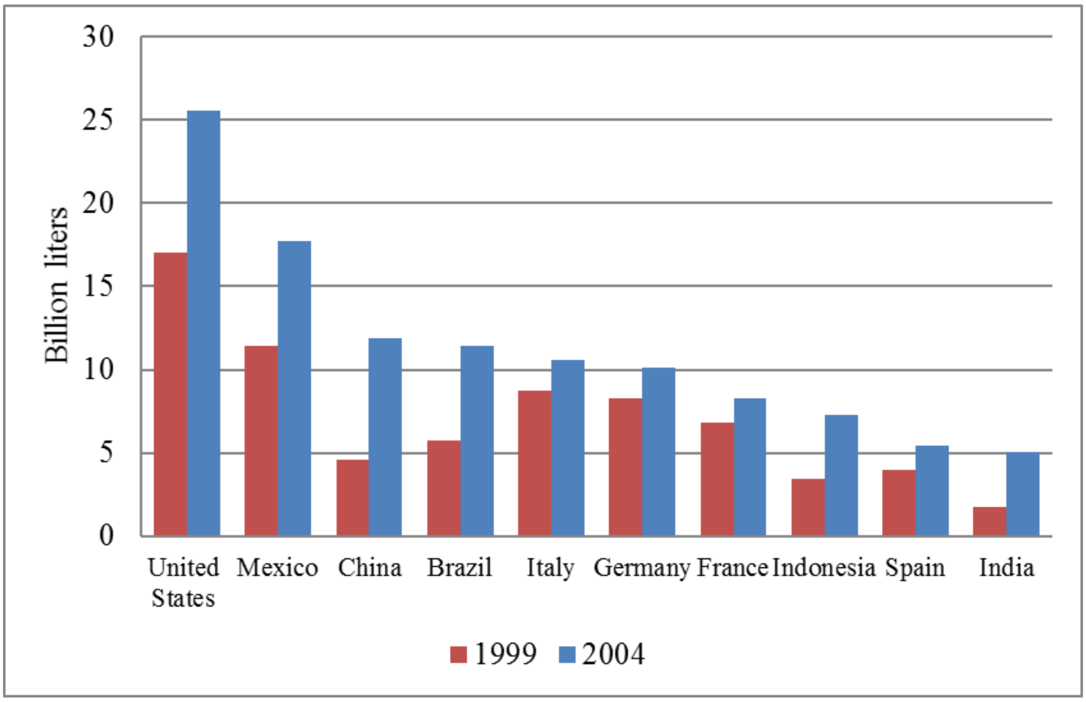

Figure 4. 4 Bottled water consumption in top ten countries, 1999 and 2004 (Beverage Marketing Corporation, 2004)

Table 4. 1 Global bottled water sales (Web 7)

Country/ Region	1996 sales (Million liters)	Projected 2006 sales (Million liters)	Annual percentage of growth (%)
Australia	500	1,000	11
Africa	500	800	4
CIS	600	1,500	13
Asia	1,000	5,000	12
East Europe	1,200	8,500	14
Middle East	1,500	3,000	3
South America	1,700	4,000	7
Pacific Rim	4,000	37,000	18
Central America	6,000	25,000	11
North America	13,000	25,000	4.5
Western Europe	27,000	33,000	2.5
Total	57,000	143,800	

Exporting bottled water can be hundreds of times more expensive than exporting bulk water. The reason behind the cost difference is generally not about improvement in quality but the cost of transport, the process of bottling and amount of profit. Thus, this alternative is definitely not preferable for many countries but public preference is quite the opposite globally. People prefer bottled water instead of tap water. According to a survey completed in 1993, reasons to choose bottled water are given in Figure 4.5 as a circular chart. As in Figure 4.5, dominant reason for preference of bottled water is that it was conceived as a healthier choice than tap water. However, tests and studies show that bottled water does not mean that it is totally safe and pure. According to Olson's study (1999), snapshot testing of more than 1000 bottles of 103 brands of water showed that most bottled water tested was of good quality. However, one third of the bottled water, in at least one test, contained significant contamination in terms of chemical or bacterial contaminants exceeding those allowed under a state or industry standard or guideline.

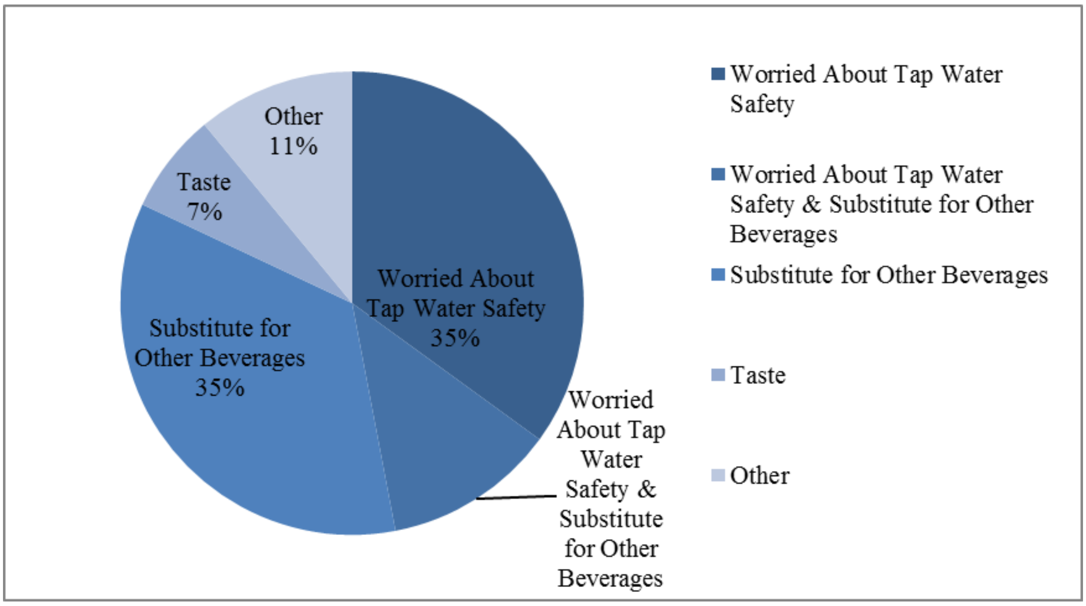

Figure 4. 5 The reasons why people drink bottled water (Hurd, 1993)

Unfortunately, perception management is a known strategy of today's globally active companies. Will Roger's (1931) statement of "Advertising is the art of convincing people to spend money they don't have for something they don't need" give a clear picture about perception management. Therefore, water-poor countries should solve any kind of problems in their tap water such as quality, contamination, continuity, taste, smell, etc. as much as they could and fight with perception management of the foreign exporter companies. They have to build trust with people about tap water by transparency after the specific problems of the local tap water is completely solved. Even if bottled water is not exported and all brands consumed are local, bottled water costs more than tap water.

According to 2004 UN Bottled Water Exporter and Importer Countries Map (attached in Appendix A), France is the leader exporter of bottled water. China is the second largest bottled water exporter in the world. The rest of the bottled water exporters are United States, Canada, United Kingdom, Belgium, Germany, Luxembourg, Italy and Turkey. On the other hand, United States is the leader bottled water importer in the world. Canada, United Kingdom, France, Belgium, Luxembourg, Switzerland, Germany, Russian Federation, China and Japan are the rest of the bottled water importers in the world. Interestingly, United States, Canada, China, France, United Kingdom, Belgium, Luxemburg and Germany are the counties both importing and exporting bottled water. Based on their water trade, countries could be classified as no trade, one-way trade (export or import), and two-way trade (both export and import) countries. According to the study of Helpman et al. (2008), over the last few decades, 30-40% of the countries studied are in two-way trade, about 10-20% of them are in one-way trade and about 50-60% of them have no trade at all.

Importing and exporting water might result in many challenges for the countries in terms of environmental, economic and political issues. After assessing any issues that might rise, several options to transport water could be considered; these are pipeline systems, canal systems, exchange systems, usage of water bags and tankers.

4.1.2 Importing Water by Tanker or Water Bag

This is an alternative, where water is transported by a sea or ocean pass.

Realization of the any kind of project takes time based on the scope, budget, cost, quality expectations, level of application, expertise of the project realization team and contractors, etc. During the realization time of the project, the system or facility aimed to be built cannot serve as expected as it would after its completion. Thus, if the need is an urgent one, then time of realization of the project becomes quite important. The greatest advantage of importing water by tanker or water bag is time required of realization of the project is less than many other alternatives, therefore it could be considered as one of the fastest method to supply water. Especially, water bags, small tankers, and barges are very practical. Trading with large tankers requires a port, however, water bags, small tankers and barges may not need a port to deliver water. In urgent situations, these agents are very preferable and advantageous. For instance, during the Gulf War, water is supplied from Turkey for American Troops by ships (Anderson & Landry, 2011).

The method used in transporting water with tankers and water bags is very similar. In transporting with water bag, water is filled to a bag then the water bag is towed by a tugboat in the sea. In transporting with tanker, water is filled to tanker and transported to its destination. Generally transporting with tanker costs more than transporting with water bags. Main differences are the operational cost (crew, maintenance, boat staff expenses, insurance, fuel etc.) and the investment cost. Usually, these costs are higher for transportation with tanker, which directly affects the cost of water. Thus, although transporting water with water bag has non-negligible operational challenges that might rise under rough sea conditions, it is very practical and has important cost advantage with respect to transporting water with tanker.

Mostly, barges and small tankers are used to import small amounts of water for short distance; larger tankers are often not used as internationally. Small amount of water import with barges and small tankers are in use by Bahamas, Japan, Taiwan, and Korea (Gleick, 1998). Global prices of water import via small and large tankers are as follows. In the mid-1980s, transporting water from Dominica over distances 100km to 1000 km with barges costs US$1.40 to US$5.70 per m^3; with ships between 20,000 to 80,000 dead weight tonnage, it costs US$1.60 to US$3.30 per m^3 (Priscoli & Wolf, 2009). According to UNESCO, depending on distance and type and size of tanker, transportation of water with large tankers varies from US$1.50 to US$3.50 (1985 value) per m^3 (Meyer, 1987). Additionally, loading cost varies between US$0.20 to US$0.75 per m^3, oil removal cost varies between US$0.05 and US$0.20 per m^3 should also be considered. Additionally, based on UNESCO, transport from Puerto Rico to St. Thomas in early 1980s costs US$4. 65 per m^3 with tankers and barges with capacity of 3,800 to 11,500 dwt (Brewster & Buros, 1985) over the distance of 100 km. Lastly; based on UNEP (1998), transporting water from Dominica to Antigua costs US$20 per 1000 gallons which is equal to nearly US$5.28 for roughly 210 km distance.

4.1.3 Importing Water by Pipeline and/or Channel

Pipeline or channel is another alternative to transmit water from one country to another. Although transmitting water with channel is applicable only for land pass; pipeline is applicable for both land and ocean pass. Technically, channels are designed and operated with open channel principles, on the other hand, water supply pipelines are pressurized system.

International water trade generally means transmitting water for long distances from exporter to importer, therefore, geography between the exporting and importing countries is an important variable, which directly affects the possible route and preference among channel or pipeline alternatives.

Unit investment cost of channels are directly related with design, the quality requirement, cost of items required, etc. but costlier expenditures are excavation process, backfilling (if excavated material is appropriate) process, filling and cover material (sand, gravel, concrete, etc.) and their application. On the other hand, expenditure items of land pipeline are not completely different from channel line. Excavation, pipe, backfilling materials (excavated material if appropriate, sand, gravel, etc.), pumps (if required) and its requirements (like pump station building), reservoirs and tanks to store are the general expenditure items of the land pipeline. For sea or ocean pass, there are three possible application alternatives. These are laying the pipes on the seabed, laying the pipes below it inside a trench, and floating and tethered pipeline.

4.2 Producing Water

For water-poor countries, buying water from water-rich countries is not the only option. Water production is an alternative solution provided by today's technology. This solution is very attractive to the countries that care about autarky as mentioned before. This technology offers possibility to convert inconvenient type of water into fresh water for any kind of use. Beginning of this technology dates back to 17th century. According to report prepared by Richard Hawkins, he had been able to supply his men with fresh water by shipboard distillation in 1662 (Birkett, 2003). Since that time, this technology has improved continuously and during this period, plants working with different technologies were constructed all over the world. In 2013, global capacity of installed plants was daily 80.9-million m^3 domestic water which is used by more than 300 million people (Web 8). Based on resource; in global scale 63% of the produced water was processed from seawater, 5% from wastewater, 19% from brackish water, 8 % from river water as shown in Figure 4.6 (Lattemann, 2010). On the other hand, Basaran (2015) noticed by using DSI Database and stated that, statistically, 83% of the produced water is used for domestic purposes, 21% for industry, 2% for irrigation, 1% military purposes and 1% for touristic purposes in global scale.

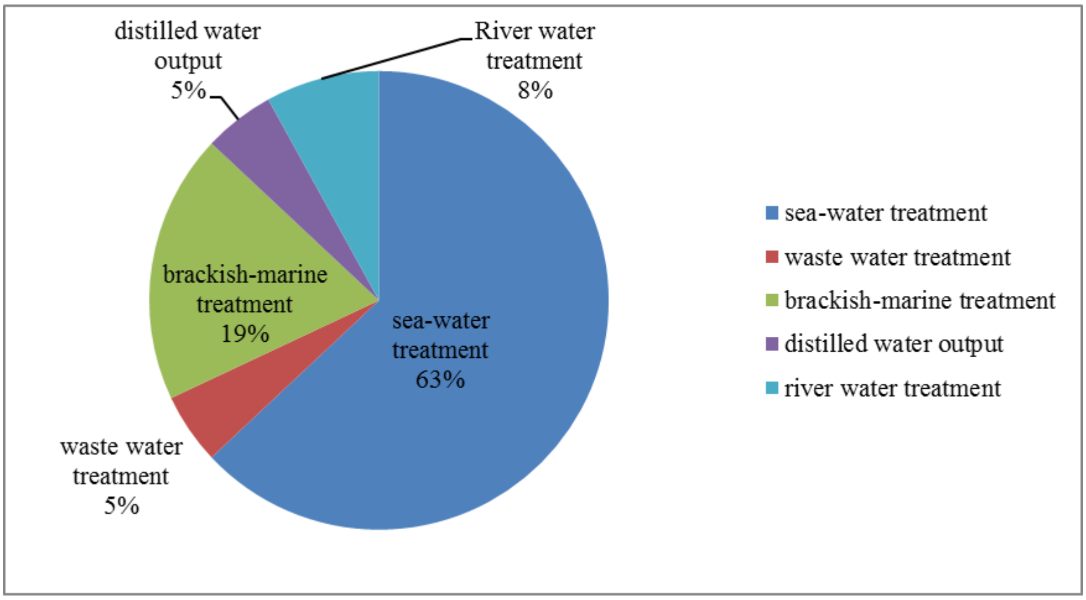

Figure 4. 6 Global desalination processes usage rates on the basis of resources (Lattemann, 2010)

Desalination is the most wide spread water production process that reduces the amount of dissolved substances in the water. Eliminating the amount of dissolved substance is the main process of the water production since human being cannot drink water, which contains highly dissolved solids. Classification of water according to its concentration of solid and the palatability of water according to its total dissolved solids (TDS) concentration are given in Table 4.2 and Table 4.3.

As a result of desalination process; most of the time pure water is achieved which is highly acidic, corrosive and tastes unpleasant. Therefore, dissolved substances contribute flavor to pure water. Thus, if desalinated water is planned for municipal use, adjustment of PH and hardness is necessary. This final treatment is called post-treatment. Importance and the necessity of the post-treatment varies based on the method used and level of salinity of the input water. In other words, the content of the product changes based on the quality of the input and the method used. For example, processes called membrane desalination processes may not reduce the salt content as much as the processes called thermal desalination processes.

Table 4. 2 The classification of water according to its total dissolved solid concentration (National Research Council, 2004)

Description	**Dissolved solids (mg/l)**
Drinking water	less than 1,000
Mildly brackish	1,000 to 5,000
Moderately brackish	5,000 to 15,000
Heavily brackish	15,000 to 35,000
Average seawater	35,000

Table 4. 3 The palatability of water according to its total dissolved solid concentration (WHO, 1984)

Palatability	**Dissolved solids(mg/l)**
Excellent	less than 300
Good	300 to 600
Fair	600 to 900
Poor	900 to 1,200
Unacceptable	more than 1,200

For a long period of time, desalination was a very high cost and energy required solution to water scarcity. It was feasible mainly for the countries where energy abundant and cheap. However, recent advances in technology, especially improvement in membrane technology, made this supply system cheaper with respect to past and more competitive with costs of alternatives. The cost of the process, removing saturated materials, is not an insurmountable obstacle anymore. Meanwhile, availability of the freshwater is decreasing and cost of it is increasing due to climate change, pollution, urbanization, etc.; desalination has become more attractive solution day by day.

Desalination is an industrial process so it has environmental effects like any other industrial processes. Although not all impacts of desalination plants to environment is known especially in long term; greenhouse gas emissions from energy requirements, effects of intake and brine disposal are directly affecting operations of desalination process to environment. Firstly, in most of the desalination plants using sea or ocean as source, water is taken directly through open water. Organisms like of fishes, planktons, fish, larvae, etc. are taken with water into process die due to crash with high-pressure membranes or high temperature. However, effect of open water intake can be reduced by some improved design, technology and operations. Moreover, subsurface intakes can be used to overcome this problem. For subsurface intakes, sand works as a natural filter and eliminates organisms from withdrawn water. This pre-filtration contributes to reduce the operational costs in long term. However, disposal of the highly concentrated salt brine contains chemicals used throughout the process is another environmental problem about desalination process. Without exception, all large coastal desalination plants dispose brine into the ocean, which is twice as saline as ocean. In spite of this, the short and long term effects of brine disposal are not completely known even today. However, one thing is certain that it has negative effects detected on marine ecosystem. Finally, desalination process consumes important amount of energy and some of the energy production process; every country uses at least a few of them, causes greenhouse gas emissions. Although it is the indirect effect of desalination, it should be considered.

4.2.1 Desalination Methods

Although there are numerous methods for desalination, they can broadly be classified as membrane desalination and distillation based on their technology. Membrane is a selective barrier, which allows passage of water molecules but not the larger and undesirable molecules such as viruses, bacteria, metals, and salts (American Water Works Association, 1999). Therefore, the portion flowing through membrane is free of high amount of contaminants and dissolved solids. Membrane desalination processes can be classified as pressure driven desalination and electric driven desalination. Membrane desalination processes are Electrodialysis (ED), Electrodiaysis reversal (EDR), Reverse Osmosis (RO). Especially, RO process is the most widely used method in the world. Other membrane desalination methods are used very rarely with respect to RO.

Distillation methods are also referred as thermal desalination processes. Thermal desalination works with evaporation and condensation of input. Feeding water is heated to produce water vapor, then that water vapor is condensed to achieve fresh water. Process is very effective on very salty water and furthermore, its cost does not depend on TDS concentration. Therefore, thermal desalination is rarely used for brackish water or water with low TDS concentration. Multi-Effect Distillation (MED), Multistage Flash (MSF) and Vapor Compression (VC) are the most popular thermal desalination systems.

After RO, MSF and MED are the popular desalination options. According to the International Desalination Association (IDA) Desalination Yearbook (2014), variation of worldwide installed desalination capacity for different processes is given in Figure 4.7.

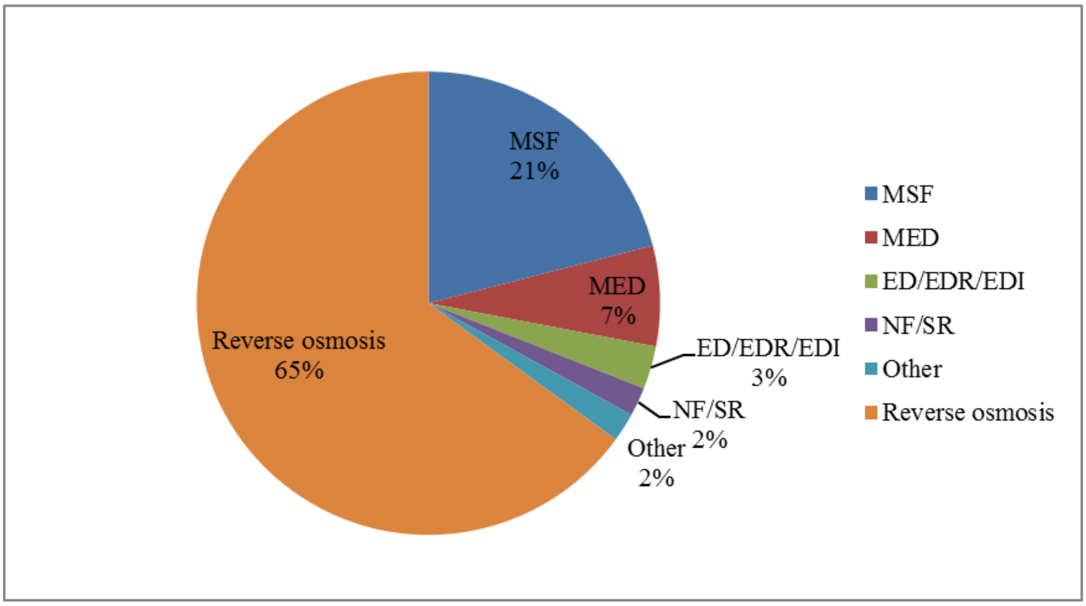

Figure 4. 7 Worldwide installed desalination capacity for the different processes (IDA, 2014)

4.2.2 Cost of Producing Water

According to the study of Wittholz et al. (2007), which is prepared based on the cost database of more than 300 desalination plants; cost of desalination has been decreasing over the years. Although average UPC was US$4.5 and US$1.5 in 1980, it decreased to range US$2.0 and $0.5 up to 2005 and today average UPC is around US$1 and US$0.5. Although, it not prepared for all types of desalination processes, Figure 4.8 gives a clear perspective how UPC for desalination decreases over the years. Despite of the fact, UPC depends on many factors like plant location, technology used, plant capacity, and type of water treated the plant and land costs, civil operating costs include costs of chemicals, energy requirements, spare parts and maintenance, and labor; the main reason of that decrease is improvement in technology.

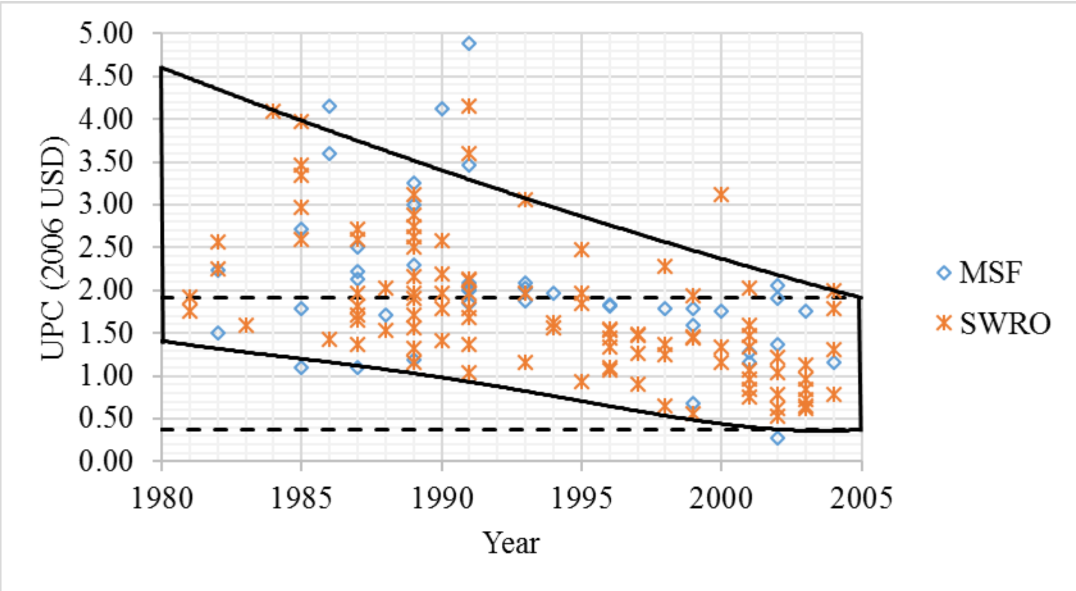

Figure 4. 8 Decrease in UPC for large-scale seawater RO and MSF plants (Wittholz et al., 2007)

During the feasibility studies and the comparison of the technologies for producing water, detailed research is required because all those systems have different cost components and all those components varies based on geography, capacity, content of the feeding water, etc. However; by taking into account, the data from the desalination plants from the different locations of the world and the studies based on those data, it might be possible to make some generalizations. It should be noted that there can always be exceptions to these generalizations. For example, in general operating cost of RO is higher than thermal desalination processes for the same capacity, however, investment cost of a thermal desalination plant is higher than the

RO based plant for many cases. When all costs are considered, RO processes are the cheapest desalination processes in general (Wittholz et al., 2007). In Table 4.4, investment cost and UPC for various size plants for different technologies is given.

Table 4. 4 Decrease in UPC for large-scale seawater RO and MSF plants (Wittholz et al., 2007)

	Capacity (m^3/d)	**Capital cost(US$×$10^6$)**	**UPC(US$)**
	10,000	20.1	0.95
SWRO	50,000	74.0	0.70
	275,000	293.0	0.50
	500,000	476.7	0.45
	10,000	8.1	0.38
BWRO	50,000	26.5	0.25
	275,000	93.5	0.16
	500,000	145.4	0.14
	10,000	48.0	1.97
MSF	50,000	149.5	1.23
	275,000	498.1	0.74
	500,000	759.6	0.62
	10,000	28.5	1.17
MED	50,000	108.4	0.89
	275,000	446.7	0.67
	500,000	734.0	0.60

Israel is pioneer, innovative and successful country about water systems but especially desalination. In 2013, annually 540 million cubic meter (MCM) of fresh water capacity of five desalination plants along Israel’s Mediterranean coast are in operation. That amount is nearly 85% of the domestic water consumption of the Israel. In 2020, by expansion of the existing plants and planned new plants, fresh water production capacity will increase to 750 MCM annually which is expected to be equal to whole domestic fresh water demand of Israel (GLOBES, 2011). Absolute scarcity and increasing demand are the reasons pushing Israel to that situation. Israel is an absolute water scarce country based on Falkenmark index, which is 223 m^3/year/capita (FAO, 2002).

In one of those desalination plants of Israel located in Tel Aviv, test case UPC was calculated as US$0.63/ m^3 based on a 50 MCM/year capacity with a 20-year amortization and a 7% interest rate in 2003 (Moatty, 2001). Break down of that price is given in Table 4.5. However, in 2012 the cost of supplying desalinated water has fallen to around US$0.5/ m^3 (Abazza, 2012).

Table 4. 5 Test Case UPC for Tel Aviv (Moatty, 2001)

Volume, Mm^3	100
Investment, US$ mil	300
Capital, US$/$m^3$	0.17
Energy, US$/$m^3$	0.26
O&M, US$/$m^3$	0.20
Total, US$/$m^3$	0.63

Cost of producing water is not only a financial one. It should not be ignored that all those desalination technologies have important environmental effects simply because they are using high amount of energy. Zhou and Tol (2004) claimed that 85% of operational cost in the thermal desalination plants is energy cost. On the other hand, according to Wittholz et al. (2007), energy cost is 75% of the operational cost in RO desalination plants. These percentages show the energy consumption in desalination plants. Hence, they are directly related to excessive levels of CO_2 emission resulting from the burning of fossil fuels. CO_2 emission causes global warming, variation in climatic conditions, sea level rise etc.

4.2.3 Examples from Turkey

Turkey uses many of these alternative water supply systems to meet the demand not only domestically but also as an international exporter. Some of the projects that Turkey has been involved in is summarized in this subsection.

Importing water with water bags had been experienced by Northern Cyprus for few years starting from 25th of June, 1998 until the end of 2002. It was a short-term solution and water was carried from Soguk Su River in Turkey to Kumkoy in North Cyprus. Two big water bags (called Normeds produced in Norway) were used, one of them had 10.000 m^3 and the other had 20.000 m^3 water storage capacity. After a while, it is observed that this system is not easy to operate. On 2nd of December, 1999, one of the water bags was lost in the sea and the other was damaged due to a storm. However, the water bags were renewed and operation was continued. At the end of 2002, contract of the carrier company was terminated. Despite the problems and reduced hours of operation, during this 4-year period, 2 million tons of water is estimated to be exported to Northern Cyprus. The cost of water using this method was US$ 0.55 per m^3 for North Cyprus and the distance of travel was 60 nautical miles (Maden, 2013).

For Northern Cyprus, tanker option was also considered to transfer Manavgat River's water from Turkey. The most detailed study on this option was prepared by Bicak and Jenkins (2000). According to that study, transportation cost was calculated as US$ 0.40 per m^3. When infrastructure investments, which were compulsory for operation, was considered that number reached to US$ 0.79 per m^3. Ariyoruk (2003) considers the possible leakage in the system as 30% of the total discharge designed to carry, this increases the cost to US$ 1.13 per m^3. Lastly, cost of raw water is assumed as US$0.15 per m^3, which would be charged by Turkey. Totally, UPC of water was calculated as US$1.28 per m^3 by Bicak and Jenkins (2000) for transporting water with tankers from Manavgat, Turkey to Northern Cyprus.

Today, fresh water is supplied to Northern Cyprus with an international pipeline, which is an important example of large-scale international water transfer project because system includes both land pass and three possible alternative of sea passages. In the system, water of the Dragon River is initially stored in Alaköprü Dam. Then, it is transferred through Anamur and Mediterranean Sea to Güzelyalı Pump Station. After getting elevated, it is transferred to Geçitköy Small Dam in Northern Cyprus for storage. From this reservoir, water is distributed for irrigation, industrial usage and public needs. Detailed schematic profile of the Turkey to Northern Cyprus bulk water transfer system is given in Appendix B.

From Alaköprü Dam to coast, water is transferred with ductile iron pipe of 1,500 mm (60 inch) diameter and a total length of 23 km (14.4 miles) pressurized gravity pipeline. This pipeline ends with Anamur valve chamber. Then line continues with 80 km (50 miles) of sea crossing with 1,600 mm diameter (63 inch) high-density polyethylene (HDPE) pipe and consists of three different divisions.

Among the sea crossing, pipeline tends to float through surface of the seawater, due to the fact that density of fresh water is less than density of the sea water and the density of the HDPE pipe is less than 1 g/cm^3 so total density of the pipeline is less than the density of the sea water. In order to overcome this problem, several different methods are employed. First part of the line starts from coasts of both Turkey and North Cyprus and goes up to 20 m (66 feet) depth below the Mediterranean Sea. At this depth round concrete blocks and gravel cover are used around the pipeline to fix the line to the sea floor against floatation. Second part of the pipeline is not covered with any kind of backfilling material. Pipeline lies at a depth of 280 m. However, concrete blocks are used as in the first part to fix the pipeline to sea floor. Lastly, the third part of the line lies at a depth of 280-250m (820-918 feet) below the surface of the Mediterranean Sea. In order to avoid floatation pipe joints were fixed with a steel rode to anchor the line into the seabed. From Northern Cyprus coast, 1400 mm (55 inch) ductile iron pipe transfers the water to Güzelyalı Pumping Station. In this facility water is elevated and transported to Geçitköy Dam. Then water is distributed for public usage, irrigation and industrial usage with an existing system from Geçitköy Dam.

With this project, annually 75 million m^3 of water (2.38 m^3/sec) is expected to be transferred from Turkey to North Cyprus. Thus, both public need and industrial /agricultural development is supported. Turkey funds the project and approximately the total cost of investment was US$ 533 million including all structures and utilities in Northern Cyprus, Turkey and pipeline in Mediterranean Sea, as stated by ex-Prime Minister of Turkey, Ahmet Davutoğlu (Al-Monitor, 2016). Nazım Çavusoğlu, Foreign Minister of Turkey, has also stated that UPC of water to the local council of Northern Cyprus is 2.30 TL (US$0.70) per m^3 (Web 9).

Transporting water with large tankers was the highlighted option during the Israel and Turkey negotiations about the bulk water trade. Water from Manavgat River in Turkey was planned to be imported by Israel. In March 2004, agreement called “water for arms” signed. With this deal, Israel was allowed to purchase 50 MCM of water each year for next two decades from Turkey and Israel would provide certain high-tech weapons to Turkey (Cohen, 2004). In April 2006, the project was suspended due to non-feasibility of the project. Although price component of the negotiation has been kept private, small details and numbers about the negotiations were stated in some studies. According to Feehan (2001) and Blanche (2001), Turkey desired to sell water for US$ 0.23 per m^3. Including the transportation via tankers, UPC of water to Israel including all expenses was expected to be US$ 0.55- US$ 0.60. However, Israel insisted to buy water from US$ 0.15 per m^3, which reduces the UPC to be around US$ 0.50- US$ 0.55. However, some researchers such as Ariyoruk (2003) claims that the UPC of Turkish water to Israel supplied from Manavgat River could be as high as US$ 0.80 per m^3

The final water supply project summarized in this subsection is a national example. The Blue Tunnel is an important project in Turkey completed in May 2015. In this domestic project, water is transferred from south to central Anatolia, Turkey. The fresh water is supplied to Konya by 17 km-long tunnel from Bağbaşı Dam in the upper part of Göksu Watershed. Each year tunnel is planned to transmit 414 MCM of water into Konya from Göksu River (Web 10). This water is not only used for irrigation purposes but also for domestic water demand. Construction of Blue Tunnel and Bağbaşı Dam is tendered by DSI and contract is signed at 2007 with a tender value of 93.000.000 Euro (Web 10).

CHAPTER 5

CASE STUDY FOR AVŞA ISLAND

5.1 General

Avşa is the one of the smaller islands located in south west of the Marmara Sea with an area of about 20.62 square kilometers, belongs to the Marmara District of Balıkesir Province in Northwestern Turkey. Figure 5.1 shows the location of the island on a map of Marmara Sea and surrounding land.

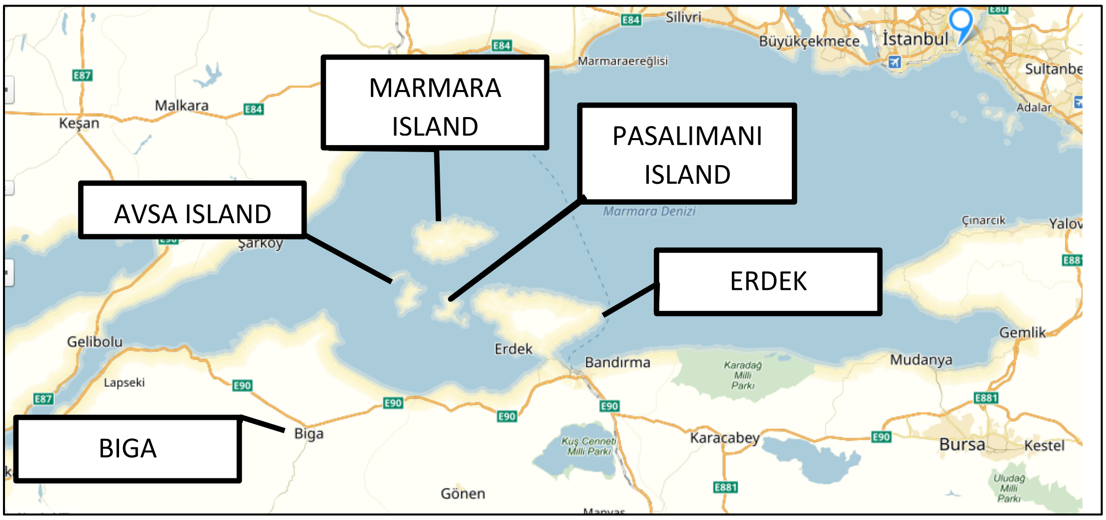

Figure 5. 1 Location of the Avşa Island (Web 11)

It is possible to reach the island with maritime transportation. The distance from Istanbul to Avşa is around 72 nautical miles, from Erdek to Avşa it is around 18 nautical miles, from Marmara Island to Avşa it is around 4 nautical miles.

Tourism is the main economic activity of the island. Hotels and hostels are very widespread over the island. This situation is considered during the capacity calculations of the systems compared. Projected future demand and the capacity are calculated based on projected populations and potential of the Avşa Island.

Meeting the water demand of Avşa Island using its natural resources is not possible. Ground water capacity is too low and not appropriate for daily use. Although some small wells are available over the island, capacity and the quality of the water from those wells are very low. On the other hand, from the hilly parts of the island small rivers flow to the South and merge forming the largest stream of the island called Kar Dere. However, capacity of that stream is far less compared to the demand. Thus, alternative water supply systems are the only option for the island. Currently, water is supplied from the sea water reverse osmosis (SWRO) desalination plant, installed in 2010. Capacity of the plant is around 4,000 m^3/day and project cost was US$ 4,400,000 (Basaran, 2015).

In this study, three alternative water supply systems that are applicable to Avşa Island are investigated. These systems are designed based on population predictions, which is discussed further in the next sub-section. The total project life of the systems compared in this study are assumed to be 35 years. 2 years of that time period is predicted as the construction time of each system. The next 33 years period is predicted as service life of each one of them.

5.2 Population Projection

In order to design the systems, the highest water demand should be calculated for the system capacity during its project life, which is directly related with future population of the land. In this study, as mentioned before, total project life is taken as 35 years. Therefore, the population of the island after 35 years is to be estimated.

Future population of the island will be investigated in three subtitles for Avşa Island. These are 1) local population, who lives constantly in the island, 2) the vacation house population, who comes and accommodates only in summer, and 3) tourist population. Historical population data is used for the projection of the population. Population projection is possible by extrapolation of historical data.

5.2.1 Local Population Projection

Historical change in population of the Avşa Island will be used for local population projection, as given in Table 5.1.

Table 5. 1 Population of the Avşa Island from 1965 to 2014

Year	Population
1965	798
1970	777
1975	994
1980	1,228
1985	1,319
1990	2,617
2000	2,611
2007	1,969
2008	2,661
2009	2,613
2010	2,602
2011	2,559
2012	2,527
2013	2,500
2014	2,884

Exponential Projection, Geometric Projection, Logarithmic Projection, Arithmetic Projection, Least Squares Projection and Iller Bank Projection Methods are the population projection methods given in Iller Bank Specifications (2013). Thus, those methods are used in this study. Projection calculations with each of those methods are given in Appendix C and the result are given in Figure 5.2 and Table 5.2. As seen, projection result varies between 4,000 and 19,000 for 2051. When these projection results, Development Plan of Avşa Island (1991) and the projection results used in other infrastructure projects of the Avşa Island are considered, annual rate of growth is taken as 3% for this study and geometric projection method is selected as the population projection method appropriate for the island. Calculated results are given in Table 5.3 and those results are used for the rest of the study.

Table 5. 2 Compression of the projected populations

	Years							
Methods	**2016**	**2021**	**2026**	**2031**	**2036**	**2041**	**2046**	**2051**
Exponential	3,041	3,473	3,967	4,530	5,174	5,909	6,749	7,707
Geometric	3,039	3,465	3,950	4,504	5,135	5,854	6,674	7,609
Logarithmic	3,039	3,465	3,950	4,504	5,135	5,854	6,674	7,609
Least Squares	2,841	3,046	3,252	3,457	3,663	3,868	4,073	4,279
Arithmetic	2,969	3,182	3,395	3,608	3,821	4,033	4,246	4,459
Iller Bank-1	3,192	4,113	5,299	6,828	8,799	11,337	14,609	18,824
Iller Bank-2	3,119	3,794	4,615	5,614	6,829	8,306	10,104	12,290
Iller Bank-3	3,030	3,429	3,880	4,390	4,968	5,621	6,361	7,198

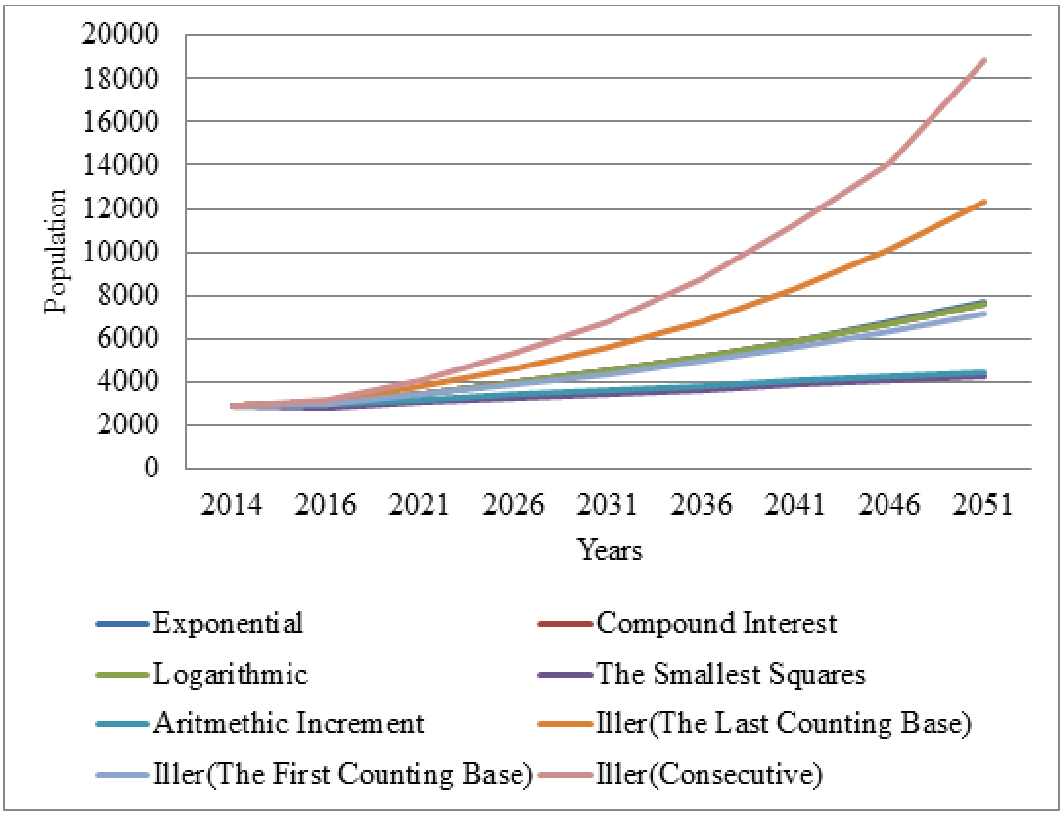

Figure 5. 2 The projected local population curves of Avşa Island based on multiple methods

Table 5. 3 Local Population Projection over Years

Year	Local Population Projection
2016	3,060
2021	3,547
2026	4,112
2031	4,767
2036	5,526
2041	6,406
2046	7,427
2051	8,609

5.2.2 Vacation Houses Population Projection

According to information taken from Marmara Islands Municipality, in 2016 there were 4,400 vacation houses in the island. People who occupy these houses prefer to be in Avşa only during the summer season. Based on the assumption that on average four people stay in each of these residences, current vacation house capacity of the island in summer is 17,600 people. Until 2051, same amount of growth in vacation house population with local population is expected for Avşa Island. Thus, annual rate of growth is taken same as 3% and by using geometric projection method, calculated results are given in Table 5.4.

Table 5. 4 Vacation House Population Projection

Year	Tourist Population Projection
2016	17,600
2021	20,404
2026	23,652
2031	27,420
2036	31,788
2041	36,852
2046	42,720
2051	49,524

5.2.3 Tourist Population Projection

In Avşa, although today the total capacity of the licensed tourist accommodation facilities is around 8,000 people, actual number of tourist population is not certain but assumed to be much higher due to illegal accommodation facilities (Akin, 2014). Development Plan of Avşa (1991) suggests that the tourist accommodation facilities are not expected to expand in the future as the land is already occupied at its maximum by such facilities. Thus, despite the fact that improvement in quality of those accommodation facilities is expected, tourist capacity is not expected to increase in the future. Therefore, for water demand calculations, tourist population is taken for peak amount and constant over years. Based on the Development Plan, and other infrastructure project reports of the Avşa, maximum tourist potential of the island is accepted as 28,500 people.

5.3 Water Demand of the Avşa at the Target Year

In order to estimate the water demand at a target year, the water consumption over the land has to be determined. Once the water demand by all possible activities over the land are estimated, the target year water demand could be calculated by using unit water demand discharges. Unit water demand discharges have been studied by many institutions, universities and corporations in Turkey such as The General Directorate of State Hydraulic Works (DSI), Ministry of Environment and Urban Planning, Istanbul Water and Sewerage Administration, etc.; however, in this study unit water demand rates of discharge for related water demand components are taken from Iller Bank Specifications (2013).

Domestic water demand, touristic activity demand, commercial demand, leakage amount are the main water consumption components of the Avşa. There is no agricultural activity in a big scale in the island, therefore consumption for this activity is not considered. According to Iller Bank Specifications (2013), unit domestic water demand varies based on population ranges and unit domestic water demand is taken based on the range of population. Those ranges and related unit domestic water demand values are given in the Table 5.5. Local population and summer house population is considered to make the total population that demands water for domestic use. Total population in each year is multiplied with related unit domestic water demand based on the range given in Table 5.5. The total domestic water demand in each year is given in the Table 5.6.

Table 5. 5 According to Iller Bank Specifications (2013), Unit Domestic Water Demand Over Population Ranges

Population	Unit Domestic Water Demand
Population ≤ 50,000	80 - 100
50,000 < Population ≤ 100,000	100 - 120
100,000 < Population	120 - 140

Table 5. 6 Domestic Water Demand Calculation over Years

Year	Local Population Projection	Vacation House Population Projection	Total Domestic Population	Unit Domestic Water Demand (l/person/day)	Domestic Water Demand (l/s)
2016	3,060	17,600	20,660	80	19.13
2021	3,547	20,404	23,951	83	23.01
2026	4,112	23,652	37,764	86	37.59
2031	4,767	27,420	32,187	90	33.53
2036	5,526	31,788	37,314	94	40.60
2041	6,406	36,852	43,258	99	49.57
2046	7,427	42,720	50,147	104	60.36
2051	8,609	49,524	58,133	110	74.01

Potential maximum tourist population for Avşa is accepted as constant over years and it is accepted as 28,500. According to Iller Bank Specifications (2013), unit domestic water demand for the type of touristic facilities at the Avşa Island can be taken as 190 l/person/day. Thus, touristic water demand is calculated as 62.67 l/s in Equation 5.1.

$$28{,}500 \times 190 \,/\, (24 \times 60 \times 60) = 62.67 \text{ l/s} \qquad (5.1)$$

Related with commercial water demand, Iller Banks Specifications (2013), states that if there is no statistical data about the commercial water consumption of the land, it can be taken as 5% to 10% percent of the net water demand of the land based on the level of the commercial activities. For this study, commercial water consumption is taken as 10% of the net water demand and calculated over the years in Table 5.7.

Table 5. 7 Commercial Water Demand Calculation Over Years

Year	Domestic Water Demand (l/s)	Touristic Water Demand (l/s)	Net Water Demand (l/s)	Commercial Water Demand (l/s)	Total Water Demand (l/s)
2016	19.13	62.67	81.80	8.18	89.98
2021	23.01	62.67	85.68	8.57	94.25
2026	37.59	62.67	100.26	10.03	110.29
2031	33.53	62.67	96.20	9.62	105.82
2036	40.60	62.67	103.27	10.33	113.59
2041	49.57	62.67	112.24	11.22	123.46
2046	60.36	62.67	123.03	12.30	135.34
2051	74.01	62.67	136.68	13.67	150.35

Lastly, about leakage discharge, Iller Bank Specifications (2013) states that although all kinds of actions, which decrease the leakage during the life cycle of the facilities, should be taken into account; at the design stage, the leakage amount can be taken as the 10% to 20% of the net discharge. In this study, leakage amount for target year is taken as 10% and calculated in Table 5.8.

Table 5. 8 Leakage and Total Discharge Calculation

Year	Total Water Demand (l/s)	Leakage (l/s)	Total Discharge (l/s)
2016	89.98	9.00	98.98
2021	94.25	9.42	103.67
2026	110.29	11.03	121.31
2031	105.82	10.58	116.4
2036	113.59	11.36	124.95
2041	123.46	12.35	135.81
2046	135.34	13.53	148.87
2051	150.35	15.04	165.39

5.4 Alternative Water Supply Systems

As mentioned before, natural water resources of the Avşa is inappropriate or insufficient for supplying the demand. Therefore, alternative water supply systems are the only option for the island.

According to Feasibility Study of Avşa Island (2005) prepared by Iller Bank; Biga in Canakkale and Gönen Stream in Balikesir are the suitable water resources in order to transfer water to Avşa Island. In that feasibility study, it is shown that transferring water to Avşa Island from Biga is cheaper than transferring water from Gönen River. Thus, in the current study, only Biga alternative will be evaluated as a water resource to transfer water to Avşa Island.

Purchasing bulk water from Biga in Çanakkale by using a pipeline, purchasing bulk water from Biga in Çanakkale using a pipeline on land and tankers to pass over sea, and producing water from seawater are the alternatives evaluated and compared based on their cost in this study.

In case study, water bag option is not taken into account because, although it is a practical solution and it has important advantage on cost, transporting water with water bag has non-negligible operational problems in case of rough sea conditions.

5.4.1 Purchasing Bulk Water by Using Pipeline from Çanakkale (Alternative-1)

Supplying water to Avşa from the groundwater resource of Biga is one of the options to solve water problem of the island. Biga belongs to Çanakkale Providence in northwestern Turkey and it is nearly 40 km away from the Avşa. In order to execute this option, firstly water wells need to be drilled in Biga. According to average capacity of the wells in this region, six water wells will be required. Biga is at a lower elevation with respect to Avşa so pump station is compulsory to transport the water into Avşa. Thus, water supplied from those wells should be collected in a pump station near the wells and the water should be pumped into water storage facility at an elevation high enough for gravity to drive the flow to existing water storage facility in Avşa Island. Lastly, in order to cut off the flow in the case of leakage in the sea pass, a valve room must be located at the start and end point of the sea pass. The selected route is given in Figure 5.3, this route involves 21 km-long land pass and 19 km-long sea, pass.

Figure 5. 3 Project route of the Alternative-1 (General Command of Mapping, 2001)

In this option, pipe material is selected as High Density Polyethylene (HDPE). This type of pipe has been used frequently in potable water applications since the 1960s. It is specified and approved in AWWA C901, AWWA C906, NSF 14, NSF 61 and ASTM International D3035. It has important advantages when transporting potable water. It is flexible and it has high resistance capacity against external impacts, water hammer, corrosion and chemical reactions. Its service life is predicted as minimum as 50 years.

5.4.1.1 Hydraulic Calculations

According to Feasibility Study of Avşa Island (2005) prepared by Iller Bank; wells drilled in Biga, can supply water around 27 l/s. In Table 5.8, total water demand in 2051 is calculated as 165 l/s, so six wells are enough for target year discharge, and each well is planned to supply 27.50 l/s water as calculated in Equation 5.2.

$$\text{Planned Water Withdrawal Amount For Each Well} = 165/6 = 27.50 \text{ l/s} \qquad (5.2)$$

According to Iller Bank Specifications (2013), average velocity should be around 1 m/s in the pipe. Thus, 225 mm diameter, PN10, HDPE pipe is chosen for the line from wells to catchment room of the pump station in Çanakkale. The pipe has 13 mm of wall thickness. In Equation 5.3, inner diameter is calculated as 199 mm. Then, in equation 5.4, velocity is calculated as 0.89 m/s. PN10 is chosen because pressure in the pipeline is predicted as less than 100m however, this value will be checked after pump head is calculated.

$$D_{inner}=225-2x13=199 \text{ mm} \qquad (5.3)$$

$$V=0.0275/(0.199\times0.199\times\pi/4)=0.89 \text{ m/s} \qquad (5.4)$$

As mentioned in Iller Bank Specifications (2013), Hazen-Williams formula used for calculation of head loss, and it is given in Equation 5.5. In this equation, J is used for unit head loss, Q is discharge and D_{inner} is the inner pipe diameter, and C is roughness coefficient. For HDPE pipe, C is used as 149 based on HDPE pipe Manufacturer's Catalog (Web 12). Then in Equation 5.6, total head loss along the pipeline is calculated.

$$J=((10.675 \times Q^{1.852})/(C^{1.852} \times D_{inner}{}^{4.87})) \quad (5.5)$$

$$\text{Head Loss}=J\times L\times=\left(\frac{10.675 \times 0.0275^{1.852}}{149^{1.852} \times 0.199^{4.87}}\right)\times 500=1.69 \quad (5.6)$$

In order to calculate pump head, well depth, geometric elevation difference, head loss and operating pressure at the end of the line should be considered. Well depth is taken as 40 m based on Feasibility Study of Avşa Island (2005) prepared by Iller Bank. Operating pressure is taken as 3 m and 1.69 m of head loss is calculated in Equation 5.6. Lastly, elevation difference should be calculated. The elevation at location of the wells is around 50 m and the maximum planned water level at catchment room of the pump station in Canakkale is 52 m. Using the energy equation the pump head could be calculated including the head loss and elevation difference between the two ends of the pipeline. Thus, based on all these data, required pump head, H_m, is calculated as 47 m in Equation 5.7.

$$H_m=40+1.69+3+(52-50) \approx 47m \quad (5.7)$$

Before calculating pump power, pressure class of the pipeline should be checked. Pressure class is selected as PN10, therefore the pipeline could operate up to 100 m of pressure. Pressure class could satisfy the requirements of H_m value calculated since this value is below 100m.

During the calculation of the pump power, N_m, pump efficiency (η_p) and engine efficiency (μ_m) is required. These are directly obtained from the manufacturer. Thus, based on H_m and Q values, one of the manufacturer's (Web 13) product catalog is checked and those efficiency values are used.

$$N_m=\frac{H_m\times Q}{102\times\eta_p\times\mu_m} \quad (5.8)$$

$$N_m=\frac{47\times 0.0275}{102\times 0.71\times 0.88}=20.20 \text{ kW} \quad (5.9)$$

For the line from pump station in Çanakkale to Water Storage Facility in Çanakkale, 560 mm diameter, PN16, HDPE pipe is chosen in order to comply with the Iller

Bank Specifications (2013) on velocity and pressure. Wall thickness of the chosen pipe is 51 mm. PN16 is chosen because pressure in the pipeline is predicted as less than 160 m. This value is later checked based on the pump head calculated.

$$D_{inner}=560-2x51=458 \text{ mm} \quad (5.10)$$

$$V=0.0275/(0.458\times0.458\times\pi/4)=1.00 \text{ m/s} \quad (5.11)$$

$$J=((10.675\times Q^{1.852})/(C^{1.852}\times {D_{inner}}^{4.87})) \quad (5.12)$$

$$\text{Head Loss}=J\times L=\left(\frac{10.675\times 0.165^{1.852}}{149^{1.852}\times 0.458^{4.87}}\right)\times 3000=4.82 \quad (5.13)$$

Operating pressure is taken as 3 m and 4.82 m of head loss is calculated in Equation 5.13. Lastly, elevation difference should be calculated. The minimum planned water level at catchment room of the pump station in Canakkale is 49 meter and the maximum planned water level at water storage facility in Canakkale is 154 m. Thus, based on all these data, pump head is calculated as 113 m in Equation 5.14. For this line PN16 pressure class is chosen so maximum head should be less than 160 m. H_m is calculated as 113 m so the selected pressure class is appropriate. Then, in Equation 5.16, pump power is calculated. Pump efficiency (η_p) and Engine efficiency (μ_m) are taken from the one of the manufacturer's (Web 13) product catalog as well.

$$H_m=(154-49)+4.82+3\approx 113\text{m} \quad (5.14)$$

$$N_m=\frac{H_m\times Q}{102\times\eta_p\times\mu_m} \quad (5.15)$$

$$N_m=\frac{113\times 0.055}{102\times 0.74\times 0.92}=89.50 \text{ kW} \quad (5.16)$$

For the line from Water Storage Facility in Çanakkale to Water Storage Facility in Avsa, 560 mm diameter, PN16, HDPE pipe is chosen in order to comply with the Iller Bank Specifications (2013) on velocity and pressure.

$$D_{inner}=560-2\times51=458 \text{ mm} \quad (5.17)$$

$$V=0.0275/(0.458\times 0.458\times \pi/4)=1.00\ m/s \quad (5.18)$$

$$J=((10.675\times Q^{1.852})/(C^{1.852}\times D_{inner}^{4.87})) \quad (5.19)$$

$$\text{Head Loss}=J\times L=\left(\frac{10.675\times 0.165^{1.852}}{149^{1.852}\times 0.458^{4.87}}\right)\times 37{,}000=59.46m \quad (5.20)$$

$$\text{Operating Pressure at Water Storage Facility at Avsa}=(z_1-z_2-h_l) \quad (5.21)$$

In Water Storage Facility in Canakkale minimum water level is planned to be 151 m so as shown in equation 5.22, minimum operating pressure is calculated as 4.54 m.

$$H_{\text{Operating at Avsa water storge facility}}=(151-87-59.46)=4.54\ m \quad (5.22)$$

5.4.1.2 Cost Calculations

Based on hydraulic calculations, quantity survey is prepared. Then, cost charts for water wells, pipeline over sea and land, and cost charts for facilities are prepared using unit prices of Turkey published by government agencies of Turkey given in Appendix D. In order to check the source of the unit prices, the code of unit price could be searched. Cost of electric, supervisory control and data acquisition (SCADA) and automation systems are decided approximately based on the cost of similar projects. On the other hand, expropriation cost is decided according to the information taken from Marmara Islands Municipality and Çanakkale Municipality. However, during the execution of the project, there will be some additional expenses due to site conditions. Thus, 15% of unpredictable costs are considered. Based on all of these components, construction cost summary is formed. Design and consulting are the indispensable work items of this alternative so those costs should also be considered. For the projects of this size, design and consulting cost can be estimated as 15% of the construction cost. Total cost of the project is given in Table 5.9.

Table 5. 9 Estimation of the Construction Cost and Total Cost of the Alternative-1

Facilities	**Calculated Construction Cost of Facilities (TL)**	**Unpredictable Costs (%15) (TL)**	**Total Cost of Facilities (TL)**	**Design and Consulting Cost (%15) (TL)**	**Total Cost (TL)**
Water Wells (6 Piece)	462,000	69,300	531,300	79,695	610,995
Pipeline Between Wells and Pump Station	72,000	10,800	82,800	12,420	95,220
Pump Station (included Catchment Room) and Water Storage Facility	420,000	63,000	483,000	72,450	555,450
Pipeline Between Pump Station and Water Storage Facility	2,280,000	342,000	2,622,000	393,300	3,015,300
Pipeline Between Water Storage Facility and Karabiga Valve Chamber	11,160,000	1,674,000	12,834,000	1,925,100	14,759,100
Sea Passing Pipeline	58,000,000	8,700,000	66,700,000	10,005,000	76,705,000
Pipeline Between Avsa Valve Chamber and Avsa Water Storage Facility	2,400,000	360,000	2,760,000	414,000	3,174,000
Electric, SCADA and Automation Systems	5,000,000	750,000	5,750,000	862,500	6,612,500
Expropriation	2,400,000	-	2,400,000	-	2,400,000
Total	82,194,000	11,969,100	94,163,100	13,764,465	107,927,565

The project is evaluated in all aspects in 2016. Then construction period is estimated as two years, therefore, at the end of 2018 construction will be completed. At the end of the first year of the construction stage, expropriation and half of the pipeline work are predicted to be completed. Remaining part of the pipeline, water wells, pumps station, water storage facility, electrical and mechanical equipment are assumed to be completed at the end the second year of the construction. Based on that rough construction plan, cost of the project over years are given at Table 5.10

Table 5. 10 Cash flow over years during the construction period

Facility	Cost (TL)	Years	
		1.Year (2017) (TL)	2. Year (2018) (TL)
Pipe Line	97,748,620	48,874,310	48,874,310
Water Wells,Pump Station and Water Storage Facility	1,166,445	-	1,166,445
Electric, SCADA and Automation Systems	6,612,500	-	6,612,500
Expropriation	2,400,000	2,400,000	-
Total		51,274,310	56,653,255

During the cost evaluation, energy consumption cost is an important variant due to pumps in wells and the pump station. Therefore, amount of energy consumption is calculated based on discharge and pump head for a period of 2019 and 2051 in Table 5.11. This is taken as the operation time period of the project. Furthermore, cost of the energy over service life is calculated in Table 5.12

Table 5. 11 Energy Consumption of the Pumps

Pumps	Discharge at 2019 (l/s)	Discharge at 2051 (l/s)	Pump Head (m)	Nm at 2019 (kW/hour)	Nm at 2051 (kW/hour)	Nm at 2019 (kW/year)	Nm at 2051 (kW/year)
Well Pumps	102	165	47	75	122	658,963	1,065,969
Pump Station Pumps	102	165	113	166	268	1,453,995	2,352,051

Table 5. 12 Cost of the energy over service life

Year	Daily Energy Consumption of Wells (kWh)	Daily Energy Consumption of Pump Station-1 (kWh)	Total Annual Energy Consumption (kWh)	Cost of Total Annual Energy Consumption (0,208 TL/kWh) (TL)
2019	75	166	2,112,958	439,495
2020	77	169	2,153,741	447,978
2021	78	172	2,194,525	456,461
2022	80	176	2,235,308	464,944
2023	81	179	2,276,091	473,427
2024	82	182	2,316,874	481,910
2025	84	185	2,357,657	490,393
2026	85	188	2,398,441	498,876
2027	87	192	2,439,224	507,359
2028	88	195	2,480,007	515,841
2029	90	198	2,520,790	524,324
2030	91	201	2,561,573	532,807
2031	93	204	2,602,357	541,290
2032	94	208	2,643,140	549,773
2033	96	211	2,683,923	558,256
2034	97	214	2,724,706	566,739
2035	98	217	2,765,489	575,222
2036	100	220	2,806,273	583,705
2037	101	224	2,847,056	592,188
2038	103	227	2,887,839	600,671
2039	104	230	2,928,622	609,153
2040	106	233	2,969,405	617,636
2041	107	236	3,010,189	626,119
2042	109	240	3,050,972	634,602
2043	110	243	3,091,755	643,085
2044	112	246	3,132,538	651,568
2045	113	249	3,173,321	660,051
2046	114	252	3,214,105	668,534
2047	116	256	3,254,888	677,017
2048	117	259	3,295,671	685,500
2049	119	262	3,336,454	693,982
2050	120	265	3,377,237	702,465
2051	122	268	3,418,021	710,948

Finally, maintenance, operational cost and renewing cost are calculated as the last components of the total cost. According to Iller Bank Specifications (2013), yearly maintenance and operational cost is accepted as constant over service life and it could be estimated by multiplying the construction cost of the facilities with a factor. However, this amount does not consist of energy cost, so it is calculated separately. Results are given in Table 5.13. On the other hand, in order to calculate renewing cost, time of renewal of the facilities and percent cost of renewal is taken from Iller Bank Specifications (2013). Results are given in Table 5.14.

Table 5. 13 Maintenance and operational cost calculation (energy cost excluded)

Facility	Total Cost of the Facilities (TL)	Maintenance and Operational Cost Factor	Yearly Maintenance and Operational Cost in 2016 (TL)
Pipe Line	84,998,800	0.01	849,988
Water Wells, Pump Station and Water Storage Facility	1,014,300	0.01	10,143
Electric, SCADA and Automation Systems	5,750,000	0.02	115,000
Total			975,131

Table 5. 14 Renewing Cost Calculation

Facility	Time of Renew	Percentage of Renew	Total Cost of the Facilities (TL)	Renewing Cost (20 years) (TL)	Renewing Cost (35 years) (TL)
Pipe Line	35	50	84,998,800	-	42,499,400
Water Wells, Pump Station	20	50	1,014,300	507,150	-
Electric, SCADA and Automation Systems	20	100	5,750,000	5,750,000	-
Total				6,257,150	42,499,400

All cost components calculated are listed and yearly total of these components are given in Table 5.15. In order to calculate the total cost according to 2016 value, cost of each year is converted into its value in 2016. During this calculation inflation rate is taken as 8%. Yearly costs according to its value in 2016 and planned discharge are given in Table 5.16.

Table 5. 15 Annual Total Cost Calculation

Year	Cost of the Project (TL)	Cost of the Revision (TL)	Cost of Total Energy Consumption (TL)	Maintenance Operational Cost (TL)	Total Cost (TL)
2017	51,274,310				51,274,310
2018	56,653,255				56,653,255
2019			439,495	975,131	1,414,626
2020			447,978	975,131	1,423,109
2021			456,461	975,131	1,431,592
2022			464,944	975,131	1,440,075
2023			473,427	975,131	1,448,558
2024			481,910	975,131	1,457,041
2025			490,393	975,131	1,465,524
2026			498,876	975,131	1,474,007
2027			507,359	975,131	1,482,490
2028			515,841	975,131	1,490,972
2029			524,324	975,131	1,499,455
2030			532,807	975,131	1,507,938
2031			541,290	975,131	1,516,421
2032			549,773	975,131	1,524,904
2033			558,256	975,131	1,533,387
2034			566,739	975,131	1,541,870
2035			575,222	975,131	1,550,353
2036			583,705	975,131	1,558,836
2037			592,188	975,131	1,567,319
2038		6,257,150	600,671	975,131	7,832,952
2039			609,153	975,131	1,584,284
2040			617,636	975,131	1,592,767
2041			626,119	975,131	1,601,250
2042			634,602	975,131	1,609,733
2043			643,085	975,131	1,618,216
2044			651,568	975,131	1,626,699
2045			660,051	975,131	1,635,182
2046			668,534	975,131	1,643,665
2047			677,017	975,131	1,652,148
2048			685,500	975,131	1,660,631
2049			693,982	975,131	1,669,113
2050			702,465	975,131	1,677,596
2051			710,948	975,131	1,686,079

Table 5. 16 Annual total cost, transferred amount of water and their value in 2016

Year	Total Cost (TL)	2016 Value of the Total Cost (TL)	Daily Average Discharge (m^3/day)	Yearly Average Discharge (m^3/year)	2016 Value of the Average Discharge (m^3/year)
2017	51,274,310	47,476,213			
2018	56,653,255	48,571,035			
2019	1,414,626	1,122,976	8,554	3,122,064	2,478,395
2020	1,423,109	1,046,028	8,732	3,187,107	2,342,619
2021	1,431,592	974,318	8,910	3,252,150	2,213,359
2022	1,440,075	907,492	9,088	3,317,193	2,090,394
2023	1,448,558	845,220	9,266	3,382,236	1,973,502
2024	1,457,041	787,194	9,445	3,447,279	1,862,458
2025	1,465,524	733,127	9,623	3,512,322	1,757,035
2026	1,474,007	682,750	9,801	3,577,365	1,657,012
2027	1,482,490	635,814	9,979	3,642,408	1,562,166
2028	1,490,972	592,086	10,157	3,707,451	1,472,280
2029	1,499,455	551,347	10,336	3,772,494	1,387,138
2030	1,507,938	513,394	10,514	3,837,537	1,306,532
2031	1,516,421	478,039	10,692	3,902,580	1,230,256
2032	1,524,904	445,105	10,870	3,967,623	1,158,111
2033	1,533,387	414,427	11,048	4,032,666	1,089,904
2034	1,541,870	385,851	11,227	4,097,709	1,025,448
2035	1,550,353	359,235	11,405	4,162,752	964,560
2036	1,558,836	334,445	11,583	4,227,795	907,066
2037	1,567,319	311,357	11,761	4,292,838	852,797
2038	7,832,952	1,440,797	11,939	4,357,881	801,591
2039	1,584,284	269,828	12,118	4,422,924	753,292
2040	1,592,767	251,178	12,296	4,487,967	707,749
2041	1,601,250	233,811	12,474	4,553,010	664,821
2042	1,609,733	217,639	12,652	4,618,053	624,369
2043	1,618,216	202,579	12,830	4,683,096	586,262
2044	1,626,699	188,557	13,009	4,748,139	550,374
2045	1,635,182	175,500	13,187	4,813,182	516,587
2046	1,643,665	163,343	13,365	4,878,225	484,785
2047	1,652,148	152,024	13,543	4,943,268	454,860
2048	1,660,631	141,486	13,721	5,008,311	426,708
2049	1,669,113	131,675	13,900	5,073,354	400,231
2050	1,677,596	122,541	14,078	5,138,397	375,336
2051	1,686,079	114,037	14,256	5,203,440	351,932
Total	165,346,357	111,972,447	376,358	137,370,816	37,029,930

Based on the results of Table 5.16, in Equation 5.23 unit cost of the water is calculated as 3.02 TL/m^3, which is equal to US$0.89 per m^3 as calculated in equation 5.24 according to 3.40 US Dollar-Turkish Lira exchange rate of November 22nd , 2016.

$$\frac{111,972,447}{37,029,930}=3.02 \text{ TL/m}^3 \quad (5.23)$$

$$\frac{3.02 \text{ TL/m}^3}{3.40}=0.89 \text{ \$/m}^3 \quad (5.24)$$

During the unit cost calculation of the water, water-selling price is also considered. Based on Ariyoruk's (2003) study, cost of raw water is assumed as US$0.15 per m^3. In equation 5.25, UPC is calculated as US$1.04 per m^3.

$$\text{US\$0.89+US\$0.15=US\$1.04 per m}^3 \quad (5.25)$$

5.4.2 Purchasing Bulk Water from Çanakkale by Using Pipeline over Land and Tankers to Transport over the Sea (Alternative-2)

In this option, Avşa is supplied from groundwater resource of the Biga Plant as well and water transmission route is designed same as Alternative-1 up to Çanakkale shore however, tankers are planned to be used for transportation over sea. Thus, planned wells in Biga Plant, pump station, water storage facility and valve chamber in shore of Çanakkale, are valid for this option as well. After getting transported by tankers, the water will be discharged to a Pump Station located at the shore of the Avşa and it will be pumped to the existing water storage facility of the Avşa. Selected route is given in Figure 5.4.

Figure 5. 4 Project route of the Alternative-2 (General Command of Mapping, 2001)

In this option, same project criteria with Alternative-1 are considered, so pipe material is identical to Alternative-1 and selected as HDPE.

5.4.2.1 Hydraulic Calculations

In this option wells to pump station near the wells, pump station to water storage facility in Çanakkale is identical with Alternative-1 so hydraulic calculations for that line are not repeated. However, for the rest of the line hydraulic calculations are prepared.

For the line from Water Storage Facility in Çanakkale to Valve Chamber in Canakkale Shore, 560 mm diameter, PN16, HDPE pipe is chosen in order to comply with the Iller Bank Specifications (2013) on velocity and pressure.

$$D_{inner}=560-2x51=458 \text{ mm} \quad (5.26)$$

$$V=0.0275/(0.458\times0.458\times\pi/4)=1.00 \text{ m/s} \quad (5.27)$$

$$J=((10.675 \times Q^{1.852})/(C^{1.852} \times D_{inner}{}^{4.87})) \quad (5.28)$$

$$\text{Head Loss}=J\times L=\left(\frac{10.675 \times 0.165^{1.852}}{149^{1.852} \times 0.458^{4.87}}\right)\times15{,}000=24.11 \text{ m} \quad (5.29)$$

$$\text{Operating Pressure at Water Storage Facility at Avsa}=(z_1-z_2-h_l) \quad (5.30)$$

$$H_{\text{Operating at Avsa water storge facility}}=(151-5-24.11)=121.89 \text{ m} \quad (5.31)$$

For the line from pump station in Avsa to Water Storage Facility in Avsa, 560 mm diameter, PN16, HDPE pipe is chosen in order to comply with the Iller Bank Specifications (2013) on velocity and pressure. Wall thickness of the chosen pipe is 51 mm. PN16 is chosen because pressure in the pipeline is predicted to be less than 160m. This value is re-checked after pump head is calculated.

$$D_{inner}=560-2x51=458 \text{ mm} \quad (5.32)$$

$$V=0.0275/(0.458\times0.458\times\pi/4)=1.00 \text{ m/s} \quad (5.33)$$

$$J=((10.675 \times Q^{1.852})/(C^{1.852} \times D_{inner}{}^{4.87})) \quad (5.34)$$

$$\text{Head Loss}=J\times L=\left(\frac{10.675\times 0.165^{1.852}}{149^{1.852}\times 0.458^{4.87}}\right)\times 3000=5.28 \quad (5.35)$$

$$H_m=100+5.28+4\approx 109m \quad (5.36)$$

$$N_m=\frac{H_m\times Q}{102\times\eta_p\times\mu_m} \quad (5.37)$$

$$N_m=\frac{109\times 0.055}{102\times 0.74\times 0.92}=86.33\ kW \quad (5.38)$$

Calculated pump head, H_m, satisfies the PN16 pipe selection. Pump efficiency (η_p) and Engine efficiency (μ_m) are taken from the one of the manufacturer's (Web 13) product catalog as well.

5.4.2.2 Cost Calculations

In this alternative, water wells, pipeline between wells and pump station, pump station and water storage facility, pipeline between pump station and water storage facility, pipeline between water storage facility and Karabiga valve chamber, land pipeline in Avşa are exactly same as Alternative-1, therefore, cost of those components are taken from Alternative-1 bill of quantities (BoQ), given in Appendix D. In order to connect the tanker to onshore pipeline 1.5 km of offshore pipelines and boat for anchoring and connecting pipes at each shore are necessary. Cost of that offshore pipeline and Pump Station in the Avşa Shore are the new cost component given in Appendix E. Lastly, total cost of the tanker with 40,000 m^3 capacity, offshore mooring systems at each shore, boats for anchoring tanker and connecting-disconnecting pipes at each shore are estimated as 40,808,500 TL based on 2016 global market prices and Bicak & Jenkins's (2000) study. Each cost component is listed in Table 5.17. Design and consulting costs are taken as 15% of the construction cost as in Alternative-1. Based on that approach, cost calculations are prepared and given in Table 5.18.

Table 5. 17 Cost of Tanker, Two Boats and Two Offshore Mooring Systems

Facility or Item	Cost (TL)
Cost of Tanker	27,200,000
Cost of Offshore Mooring System for Çanakkale	6,800,000
Cost of Offshore Mooring System for Avşa	6,800,000
Cost of boat for anchoring tanker and connecting-disconnecting Pipes for Çanakkale	8,500
Cost of boat for anchoring tanker and connecting-disconnecting Pipes for Avşa	8,500
Total	40,817,000

Table 5. 18 Estimation of the Construction Cost and Total Cost of the Alternative-2

Facilities	Construction Cost of Facilities (TL)	Unpredictable Costs (%15) (TL)	Total Cost of Facilities (TL)	Design and Consulting Cost (%15) (TL)	Total Cost (TL)
Water Wells (6 Piece)	462,000	69,300	531,300	79,695	610,995
Pipeline Between Wells and Pump Station in Canakkale	72,000	10,800	82,800	12,420	95,220
Pump Station (Catchment Room included) and Water Storage Facility in Canakkale	420,000	63,000	483,000	72,450	555,450
Pipeline Between Pump Station and Water Storage Facility in Canakkale	2,280,000	342,000	2,622,000	393,300	3,015,300
Pipeline Between Water Storage Facility and Karabiga Valve Chamber in Canakkale	11,160,000	1,674,000	12,834,000	1,925,100	14,759,100
Pump Station in Avsa Shore (Catchment Room included)	240,000	36,000	276,000	41,400	317,400
Offshore Pipeline from buoy to shore, 1.5 km at Each Side (Total 3 km)	9,500,000	1,425,000	10,925,000	1,638,750	12,563,750
Pipeline Between Avsa Pump Station and Avsa Water Storage Facility	2,400,000	360,000	2,760,000	414,000	3,174,000
Electric, SCADA and Automation Systems	5,000,000	750,000	5,750,000	862,500	6,612,500
Tanker, Two Boats and Two Offshore Mooring Systems	40,817,000	-	40,817,000	-	40,817,000
Expropriation	2,400,000	-	2,400,000	-	2,400,000
Total	74,751,000	4,730,100	79,481,100	5,439,615	84,920,715

Construction duration is taken as two years as well. Among the first year of that time period, half of the pipeline work is assumed to be completed. Rest of the work is assumed to be completed at the second year of the construction duration. Based on those assumptions, cash flow over the construction duration is given in Table 5.19.

Table 5. 19 Cash flow over years during the construction period

Facility	**Cost (TL)**	**Years**	
		1.Year (2017)	**2. Year (2018)**
Pipe Line	33,607,370	16,803,685	16,803,685
Water Wells, Pump Stations and Water Storage Facility	1,483,845	-	1,483,845
Tanker, Two Boats and Two Offshore Mooring Systems	40,817,000	20,408,500	20,408,500
Electric, SCADA and Automation Systems	6,612,500	-	6,612,500
Expropriation	2,400,000	2,400,000	-
Total		39,612,185	45,308,530

In order to calculate cost of energy through the service life of the system, electric consumption amount of the pumps based on discharge and pumped head are calculated and given in Table 5.20. Furthermore, cost of the energy over service life is calculated in Table.5.21. Different from Alternative-1, in this option cost of fuel and diesel oil needed to be calculated due to tanker consumption. In order to calculate it, firstly yearly number of round trips are calculated by dividing yearly demand to capacity of the tanker. According to Bicak & Jenkins's (2000) study and 2016 global market prices, for the 19 km-long tanker route, cost of the fuel oil per round trip can be taken as US$ 410 and cost of diesel oil can be taken as US$180 per round trip. Therefore, as calculated in Equation 5.39, cost of a round trip is calculated as 2,006 TL by assuming an exchange rate of 3.40 US Dollar to Turkish Lira. By multiplying this unit price with annual number of trips, total cost of fuel and diesel oil is estimated. Estimated cost of fuel and diesel oil are given in Table 5.22.

$$(410\times3.40)+(180\times3.40)=2{,}006 \text{ TL per round trip} \quad (5.39)$$

Table 5. 20 Energy Consumption of the Pumps

Pumps	**Discharge at 2019 (m^3/sec)**	**Discharge at 2051 (m^3/sec)**	**Pump Head (m)**	**Nm at 2016 (kW/ hour)**	**Nm at 2051 (kW/ hour)**	**Nm at 2016 (kW/ year)**	**Nm at 2051 (kW/ year)**
Well Pumps	102	165	47	75	122	658,963	1,065,969
Pump Station-1 Pumps	102	165	113	166	268	1,453,995	2,352,051
Pump Station-2 Pumps	102	165	109	150	243	1,316,294	2,129,300

Table 5. 21 Cost of the energy over service life of the pumps

Year	Daily Energy Cons. of Wells (kWh)	Daily Energy Cons. of Pump Station-1 (kWh)	Daily Energy Cons. of Pump Station-2 (kWh)	Total Annual Energy Cons. (kWh)	Cost of Total Annual Energy Cons. (0,208 TL/kWh) (TL)
2019	75	166	150	3,429,253	713,285
2020	77	169	153	3,495,442	727,052
2021	78	172	156	3,561,632	740,819
2022	80	176	159	3,627,821	754,587
2023	81	179	162	3,694,011	768,354
2024	82	182	165	3,760,201	782,122
2025	84	185	168	3,826,390	795,889
2026	85	188	171	3,892,580	809,657
2027	87	192	173	3,958,770	823,424
2028	88	195	176	4,024,959	837,192
2029	90	198	179	4,091,149	850,959
2030	91	201	182	4,157,338	864,726
2031	93	204	185	4,223,528	878,494
2032	94	208	188	4,289,718	892,261
2033	96	211	191	4,355,907	906,029
2034	97	214	194	4,422,097	919,796
2035	98	217	197	4,488,287	933,564
2036	100	220	200	4,554,476	947,331
2037	101	224	202	4,620,666	961,098
2038	103	227	205	4,686,855	974,866
2039	104	230	208	4,753,045	988,633
2040	106	233	211	4,819,235	1,002,401
2041	107	236	214	4,885,424	1,016,168
2042	109	240	217	4,951,614	1,029,936
2043	110	243	220	5,017,803	1,043,703
2044	112	246	223	5,083,993	1,057,471
2045	113	249	226	5,150,183	1,071,238
2046	114	252	229	5,216,372	1,085,005
2047	116	256	231	5,282,562	1,098,773
2048	117	259	234	5,348,752	1,112,540
2049	119	262	237	5,414,941	1,126,308
2050	120	265	240	5,481,131	1,140,075
2051	122	268	243	5,547,320	1,153,843

Table 5. 22 Cost of the fuel over service life

Year	Daily Average Discharge (m^3/day)	Yearly Average Discharge (m^3/year)	Number of Round Trips	Cost of Fuel and Diesel Oil (TL)
2019	8,554	3,122,064	78	156,468
2020	8,732	3,187,107	80	160,480
2021	8,910	3,252,150	81	162,486
2022	9,088	3,317,193	83	166,498
2023	9,266	3,382,236	85	170,510
2024	9,445	3,447,279	86	172,516
2025	9,623	3,512,322	88	176,528
2026	9,801	3,577,365	89	178,534
2027	9,979	3,642,408	91	182,546
2028	10,157	3,707,451	93	186,558
2029	10,336	3,772,494	94	188,564
2030	10,514	3,837,537	96	192,576
2031	10,692	3,902,580	98	196,588
2032	10,870	3,967,623	99	198,594
2033	11,048	4,032,666	101	202,606
2034	11,227	4,097,709	102	204,612
2035	11,405	4,162,752	104	208,624
2036	11,583	4,227,795	106	212,636
2037	11,761	4,292,838	107	214,642
2038	11,939	4,357,881	109	218,654
2039	12,118	4,422,924	111	222,666
2040	12,296	4,487,967	112	224,672
2041	12,474	4,553,010	114	228,684
2042	12,652	4,618,053	115	230,690
2043	12,830	4,683,096	117	234,702
2044	13,009	4,748,139	119	238,714
2045	13,187	4,813,182	120	240,720
2046	13,365	4,878,225	122	244,732
2047	13,543	4,943,268	124	248,744
2048	13,721	5,008,311	125	250,750
2049	13,900	5,073,354	127	254,762
2050	14,078	5,138,397	128	256,768
2051	14,256	5,203,440	130	260,780

Maintenance and operational costs are calculated in Table 5.23. However, this amount does not consist of energy, fuel and crew personnel expenses. Therefore, all these components are calculated separately. Calculated maintenance and operational costs are taken as constant over the years according to Iller Bank Specifications (2013), similarly to calculation of Alternative-1. Furthermore, cost of renewal is calculated in Table 5.24.

Table 5. 23 Maintenance and operational cost calculation (energy, fuel and crew cost excluded)

Facility	**Total Cost of the Facilities (TL)**	**Maintenance and Operational Cost Factor**	**Yearly Maintenance and Operational Cost (TL)**
Pipe Line	29,223,800	0.01	292,238
Water Wells ,Pump Stations and Water Storage Facility	1,290,300	0.01	12,903
Tanker, Two Boats and Two Offshore Mooring Systems	40,817,000	0.02	816,340
Annual Insurance Cost of the Tanker	27,200,000	0.02	544,000
Electric, SCADA and Automation Systems	5,750,000	0.02	115,000
Total			1,780,481

Table 5. 24 Renewing Cost Calculation

Facility	Time of Renew	Percentage of Renew	Total Cost of the Facilities (TL)	Renewing Cost (20 years) (TL)	Renewing Cost (35 years) (TL)
Pipe Line	35	50	29,223,800	-	9,149,400
Tanker, Two Boats and Two Offshore Mooring Systems	35	50	40,817,000	-	40,817,000
Water Wells, Pump Station	20	50	1,290,300	645,150	-
Electric, SCADA and Automation Systems	20	100	5,750,000	5,750,000	-
Total				6,395,150	49,966,400

Different from all other alternatives, crew expenses for tanker and boats are needed to be calculated for Alternative-2. They are given in Table 5.25 and Table 5.26, respectively based on 2016 market prices and study of Bicak and Jenkins (2000). These salaries are increased 3% annually as given in Table 5.27. However, tanker and boats will start to work on 2019, therefore crew expenses are shown in Table 5.28 starting from year 2019.

Table 5. 25 Tanker Crew Expenses

Tanker Crew	Monthly Salary for 2016 (TL)	Annual Salary for 2016 (TL)
Four Captain	27,200	326,400
Four Engineer	24,480	293,760
One communications officer	4,420	53,040
Eight above-deck and eight below-deck crew members	65,280	783,360
Two cooks and four stewards	18,360	220,320
Total	139,740	1,676,880

Table 5. 26 Boat Crew Expenses

Boat Crew	Monthly Salary for 2016 (TL)	Annual Salary for 2016 (TL)
One Captain For Avşa Boat	2,720	32,640
One Machanical Engineer for Avşa Boat	2,720	32,640
Two Boat Crew For Avşa Boat	4,080	48,960
Six Water Resources Department Employees For Avşa Boat	12,240	146,880
One Captain For Avşa Side Boat For Avşa Boat	2,720	32,640
One Machanical Engineer For Avşa Boat	2,720	32,640
Two Boat Crew For Avşa Boat	4,080	48,960
Six Water Resources Department Employees For Avşa Boat	12,240	146,880
Total	34,000	408,000

Table 5. 27 Crew expenses over years

Year	Crew Expenses (TL)	Boat Staff Expenses (TL)	Total Crew Expenses (TL)
2016	1,676,880	408,000	2,084,880
2017	1,727,186	420,240	2,147,426
2018	1,779,002	432,847	2,211,849
2019	1,832,372	445,833	2,278,205
2020	1,887,343	459,208	2,346,551
2021	1,943,964	472,984	2,416,947
2022	2,002,282	487,173	2,489,456
2023	2,062,351	501,789	2,564,139
2024	2,124,221	516,842	2,641,064
2025	2,187,948	532,347	2,720,296
2026	2,253,586	548,318	2,801,904
2027	2,321,194	564,767	2,885,962
2028	2,390,830	581,710	2,972,540
2029	2,462,555	599,162	3,061,717
2030	2,536,431	617,137	3,153,568
2031	2,612,524	635,651	3,248,175
2032	2,690,900	654,720	3,345,620
2033	2,771,627	674,362	3,445,989
2034	2,854,776	694,593	3,549,369
2035	2,940,419	715,430	3,655,850
2036	3,028,632	736,893	3,765,525
2037	3,119,491	759,000	3,878,491
2038	3,213,075	781,770	3,994,846
2039	3,309,468	805,223	4,114,691
2040	3,408,752	829,380	4,238,132
2041	3,511,014	854,261	4,365,276
2042	3,616,345	879,889	4,496,234
2043	3,724,835	906,286	4,631,121
2044	3,836,580	933,474	4,770,055
2045	3,951,678	961,479	4,913,156
2046	4,070,228	990,323	5,060,551
2047	4,192,335	1,020,033	5,212,368
2048	4,318,105	1,050,634	5,368,739
2049	4,447,648	1,082,153	5,529,801
2050	4,581,077	1,114,617	5,695,695
2051	4,718,510	1,148,056	5,866,566

All cost components calculated are listed and yearly total of these components are given in Table 5.28. Cost of each year on its 2016 value and planned discharge with its 2016 value are given in Table 5.29.

Table 5. 28 Annual Total Cost Calculation

Year	Cost of the Project	Cost of the Revision	Energy and Oil Cost	Maintenance and Operation Cost	Crew Expenses	Total Cost
2017	39,612,185					39,612,185
2018	45,308,530					45,308,530
2019			869,753	1,780,481	2,278,205	4,928,439
2020			887,532	1,780,481	2,346,551	5,014,564
2021			903,305	1,780,481	2,416,947	5,100,733
2022			921,085	1,780,481	2,489,456	5,191,022
2023			938,864	1,780,481	2,564,139	5,283,484
2024			954,638	1,780,481	2,641,064	5,376,183
2025			972,417	1,780,481	2,720,296	5,473,194
2026			988,191	1,780,481	2,801,904	5,570,576
2027			1,005,970	1,780,481	2,885,962	5,672,413
2028			1,023,750	1,780,481	2,972,540	5,776,771
2029			1,039,523	1,780,481	3,061,717	5,881,721
2030			1,057,302	1,780,481	3,153,568	5,991,351
2031			1,075,082	1,780,481	3,248,175	6,103,738
2032			1,090,855	1,780,481	3,345,620	6,216,956
2033			1,108,635	1,780,481	3,445,989	6,335,105
2034			1,124,408	1,780,481	3,549,369	6,454,258
2035			1,142,188	1,780,481	3,655,850	6,578,519
2036			1,159,967	1,780,481	3,765,525	6,705,973
2037			1,175,740	1,780,481	3,878,491	6,834,712
2038		6,395,150	1,193,520	1,780,481	3,994,846	13,363,997
2039			1,211,299	1,780,481	4,114,691	7,106,471
2040			1,227,073	1,780,481	4,238,132	7,245,686
2041			1,244,852	1,780,481	4,365,276	7,390,609
2042			1,260,626	1,780,481	4,496,234	7,537,341
2043			1,278,405	1,780,481	4,631,121	7,690,007
2044			1,296,185	1,780,481	4,770,055	7,846,721
2045			1,311,958	1,780,481	4,913,156	8,005,595
2046			1,329,737	1,780,481	5,060,551	8,170,769
2047			1,347,517	1,780,481	5,212,368	8,340,366
2048			1,363,290	1,780,481	5,368,739	8,512,510
2049			1,381,070	1,780,481	5,529,801	8,691,352
2050			1,396,843	1,780,481	5,695,695	8,873,019
2051			1,414,623	1,780,481	5,866,566	9,061,670

Table 5. 29 Annual total cost, transferred amount of water and their value in 2016

Year	Total Cost (TL)	2016 Value of the Total Cost (TL)	Daily Average Discharge (m^3/day)	Yearly Average Discharge (m^3/year)	2016 Value of the Average Discharge (m^3/year)
2017	39,612,185	36,677,949			
2018	45,308,530	38,844,762			
2019	4,928,439	3,912,354	8,554	3,122,064	2,478,395
2020	5,014,564	3,685,854	8,732	3,187,107	2,342,619
2021	5,100,733	3,471,473	8,910	3,252,150	2,213,359
2022	5,191,022	3,271,224	9,088	3,317,193	2,090,394
2023	5,283,484	3,082,862	9,266	3,382,236	1,973,502
2024	5,376,183	2,904,584	9,445	3,447,279	1,862,458
2025	5,473,194	2,737,960	9,623	3,512,322	1,757,035
2026	5,570,576	2,580,255	9,801	3,577,365	1,657,012
2027	5,672,413	2,432,801	9,979	3,642,408	1,562,166
2028	5,776,771	2,294,035	10,157	3,707,451	1,472,280
2029	5,881,721	2,162,697	10,336	3,772,494	1,387,138
2030	5,991,351	2,039,822	10,514	3,837,537	1,306,532
2031	6,103,738	1,924,153	10,692	3,902,580	1,230,256
2032	6,216,956	1,814,670	10,870	3,967,623	1,158,111
2033	6,335,105	1,712,182	11,048	4,032,666	1,089,904
2034	6,454,258	1,615,172	11,227	4,097,709	1,025,448
2035	6,578,519	1,524,322	11,405	4,162,752	964,560
2036	6,705,973	1,438,754	11,583	4,227,795	907,066
2037	6,834,712	1,357,755	11,761	4,292,838	852,797
2038	13,363,997	2,458,180	11,939	4,357,881	801,591
2039	7,106,471	1,210,341	12,118	4,422,924	753,292
2040	7,245,686	1,142,640	12,296	4,487,967	707,749
2041	7,390,609	1,079,161	12,474	4,553,010	664,821
2042	7,537,341	1,019,062	12,652	4,618,053	624,369
2043	7,690,007	962,688	12,830	4,683,096	586,262
2044	7,846,721	909,543	13,009	4,748,139	550,374
2045	8,005,595	859,221	13,187	4,813,182	516,587
2046	8,170,769	811,989	13,365	4,878,225	484,785
2047	8,340,366	767,448	13,543	4,943,268	454,860
2048	8,512,510	725,266	13,721	5,008,311	426,708
2049	8,691,352	685,651	13,900	5,073,354	400,231
2050	8,873,019	648,132	14,078	5,138,397	375,336
2051	9,061,670	612,882	14,256	5,203,440	351,932
Total	313,246,540	135,377,843	376,358	137,370,816	37,029,930

Based on the results of Table 5.29, in Equation 5.40 unit cost is calculated as 3.66 TL/m^3, which is equal to US$1.08 per m^3 as calculated in Equation 5.41. Raw water price is taken as US$0.15 per m^3 as in Alternative-1. In equation 5.42, UPC is calculated as US$1.23 per m^3.

$$\frac{135{,}377{,}843\ TL}{37{,}029{,}930} = 3.66\ \text{TL}/m^3 \tag{5.40}$$

$$\frac{3.66\ \text{TL/m}^3}{3.40} = 1.08\ \$/\text{m}^3 \tag{5.41}$$

$$\text{US\$1.08 + US\$0.15 = US\$1.23 per m}^3 \tag{5.42}$$

5.4.3 Producing Water (Alternative-3)

Actually, this option is the current water supply system of Avşa as mentioned before. In this option, water is not transported from Çanakkale. It is produced from seawater and collected in the pump station, which is designated in the same location in Alternative-2. Water is planned to pump into Water Supply Facility of Avşa. The selected route is given in the Figure 5.5.

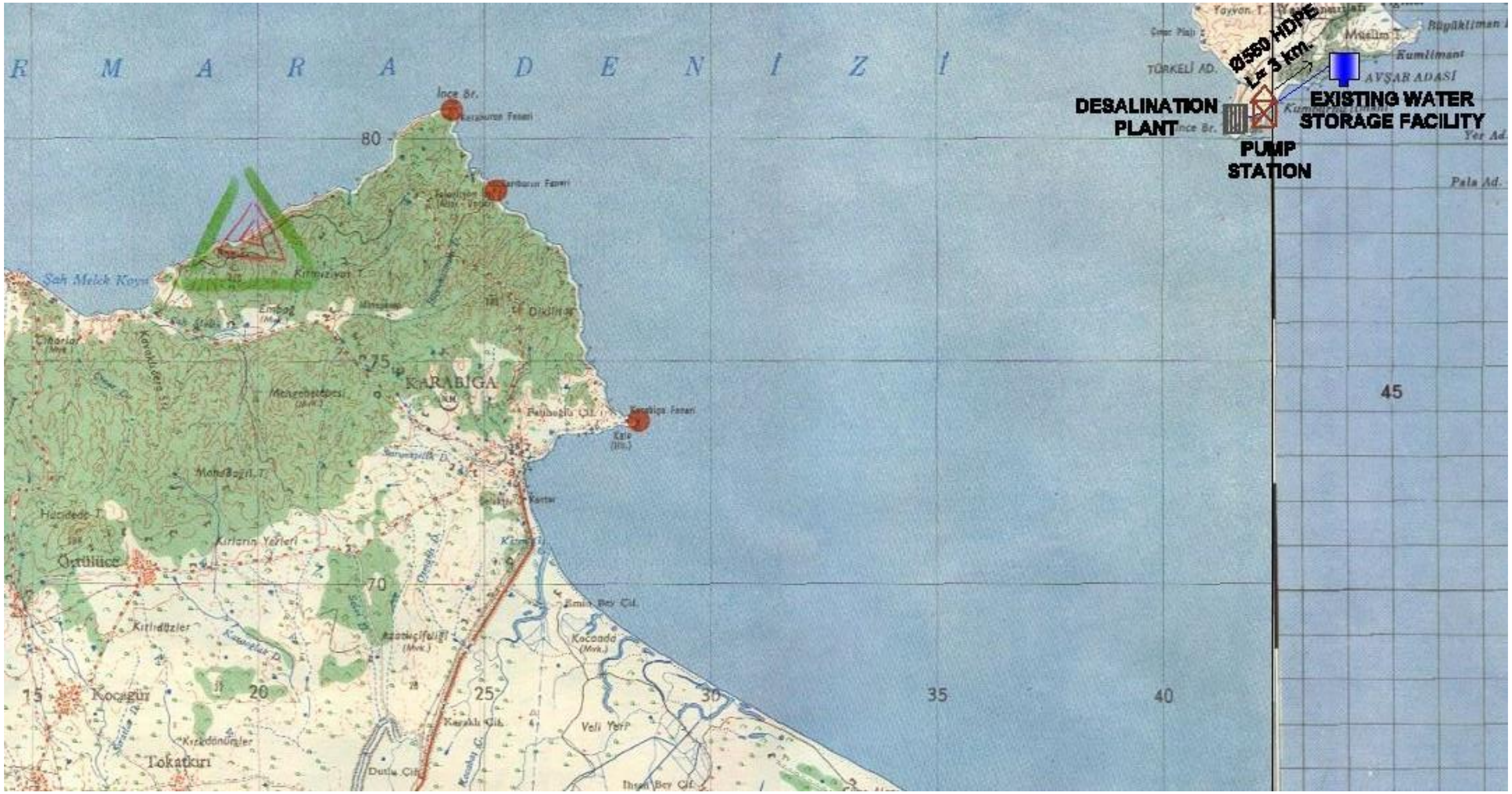

Figure 5. 5 Project route of the Alternative-3 (General Command of Mapping, 2001)

For the pipeline, which will carry the water from Desalination Plant to Avşa Water Supply Facility, same criteria with other alternatives are considered; as a result, HDPE pipes are selected for this alternative as well. In this option, as mentioned before pump station is identical to Alternative-2. Therefore, the pipeline from this pump station to existing water storage facility is identical. Hydraulic calculations for that line prepared in Alternative-2 and it is valid for this option, therefore they are not repeated. Based on those hydraulic calculations, cost components of the project for this alternative solution are prepared and they are given in Table 5.30. In this alternative project, desalination plant, pump station, pipeline between pump station to existing water storage facility are the cost components. Cost of the pump station and pipeline between pump station and Avşa water storage facility are exactly same with Alternative-2 so, those cost components are taken from Appendix D and Appendix E. Cost estimation of the desalination plant is taken from Marmara Islands Municipality and Piramit Engineering Consulting, whose specialty is the construction of desalination plants. A new seawater desalination plant working with reverse osmosis principle with a capacity of 165 l/s, is estimated to cost around 50,000,000 TL. Design and consulting cost is taken as 15% of the construction cost like Alternative-1 and Alternative-2. Similarly, unpredictable cost are taken as 15% of total cost.

Table 5. 30 Estimation of the Construction Cost of the Alternative 3

Facilities	Calculated Construction Cost of Facilities (TL)	Unpredictable Costs (%15) (TL)	Total Cost of Facilities (TL)	Design and Consulting Cost (%15) (TL)	Total Cost (TL)
Pump Station in Avsa Shore	240,000	36,000	276,000	41,400	317,400
Pipeline Between Avsa Pump Station and Avsa Water Storage Facility	2,400,000	360,000	2,760,000	414,000	3,174,000
Electric, SCADA and Automation Systems	1,000,000	150,000	1,150,000	172,500	1,322,500
Desalination Plant	50,000,000	7,500,000	57,500,000	8,625,000	66,125,000
Expropriation	2,400,000	-	2,400,000	-	2,400,000
Total	56,040,000	8,046,000	64,086,000	9,252,900	73,338,900

Construction duration is taken as two years. Among the first year of that time period, half of the construction work is assumed to be completed. Rest of the work is assumed to be completed at the second year of the construction duration. Based on those assumptions, cash flow over the construction duration is given in Table 5.31.

Table 5. 31 Cash flow over years during the construction period

Facility	Cost (TL)	Years	
		1.Year (2017)	2. Year (2018)
Pipe Line	3,174,000	1,587,000	1,587,000
Pump Stations and Water Storage Facility	317,400	158,700	158,700
Desalination Plant	66,125,000	33,062,500	33,062,500
Electric, SCADA and Automation Systems	1,322,500	-	1,322,500
Expropriation	2,400,000	2,400,000	-
Total		37,208, 200	36,130,700

In order to calculate energy cost through the service life of the system, electric consumption of the pumps based on discharge and pump head are calculated and given in Table 5.32. Furthermore, cost of the energy over service life is calculated in Table 5.33. In Table 5.33, unit energy consumption is taken as 3.01 kWh per m^3, which is the current energy consumption of the existing desalination plant in Avşa according to Oruc's (2009) study.

Table 5. 32 Energy Consumption of the Pump

Pumps	Q at 2019 (m^3/sec)	Discharge at 2051 (m^3/sec)	Pump Head (m)	Nm at 2016 (kW/ hour)	Nm at 2051 (kW/ hour)	Nm at 2016 (kW/ year)	Nm at 2051 (kW/ year)
Pump Station Pumps	102	165	109	150	243	1,316,294	2,129,300

Table 5. 33 Cost of the energy over service life of the pump and desalination plant

Year	Daily Energy Cons. of Pump Station (kWh)	Daily Water Production (m³/day)	Daily Energy Cons. of Desalination Plant (kWh)	Annually Total Energy C Cons. (kWh)	Cost of Total Annual Energy Cons. (0.208 TL/kWh) (TL)
2019	150	8,813	1,105	10,998,477	2,287,683
2020	153	8,983	1,127	11,210,764	2,331,839
2021	156	9,153	1,148	11,423,051	2,375,995
2022	159	9,323	1,169	11,635,338	2,420,150
2023	162	9,493	1,191	11,847,624	2,464,306
2024	165	9,663	1,212	12,059,911	2,508,462
2025	168	9,833	1,233	12,272,198	2,552,617
2026	171	10,004	1,255	12,484,485	2,596,773
2027	173	10,174	1,276	12,696,771	2,640,928
2028	176	10,344	1,297	12,909,058	2,685,084
2029	179	10,514	1,319	13,121,345	2,729,240
2030	182	10,684	1,340	13,333,632	2,773,395
2031	185	10,854	1,361	13,545,919	2,817,551
2032	188	11,024	1,383	13,758,205	2,861,707
2033	191	11,194	1,404	13,970,492	2,905,862
2034	194	11,364	1,425	14,182,779	2,950,018
2035	197	11,534	1,447	14,395,066	2,994,174
2036	200	11,705	1,468	14,607,353	3,038,329
2037	202	11,875	1,489	14,819,639	3,082,485
2038	205	12,045	1,511	15,031,926	3,126,641
2039	208	12,215	1,532	15,244,213	3,170,796
2040	211	12,385	1,553	15,456,500	3,214,952
2041	214	12,555	1,575	15,668,786	3,259,108
2042	217	12,725	1,596	15,881,073	3,303,263
2043	220	12,895	1,617	16,093,360	3,347,419
2044	223	13,065	1,639	16,305,647	3,391,575
2045	226	13,235	1,660	16,517,934	3,435,730
2046	229	13,406	1,681	16,730,220	3,479,886
2047	231	13,576	1,703	16,942,507	3,524,041
2048	234	13,746	1,724	17,154,794	3,568,197
2049	237	13,916	1,745	17,367,081	3,612,353
2050	240	14,086	1,767	17,579,367	3,656,508
2051	243	14,256	1,788	17,791,654	3,700,664

Maintenance and operational cost is calculated in Table 5.34. This amount does not consist of energy cost. Therefore, energy cost is calculated separately. Calculated maintenance and operational cost is taken as constant over the years according to Iller Bank Specifications (2013), similarly to calculation of Alternative-1. Furthermore, renewal cost is calculated at Table 5.35.

Table 5. 34 Maintenance and operational cost calculation (energy cost excluded)

Facility	Total Cost of the Facilities (TL)	Maintenance and Operational Cost Factor	Yearly Maintenance and Operational Cost in 2016 (TL)
Pipe Line	2,760,000	0.01	27,600
Pump Stations	276,000	0.01	2,760
Electric, SCADA and Automation Systems	1,150,000	0.02	23,000
Desalination Plant	57,500,000	0.02	1,150,000
Total			1,203,360

Table 5. 35 Renewing Cost Calculation

Facility	Time of Renew	Percentage of Renew	Total Cost of the Facilities (TL)	Renewing Cost (20 years) (TL)	Renewing Cost (35 years) (TL)
Pipe Line	35	50	2,760,000	-	1,380,000
Pump Stations	20	50	1,014,300	507,150	-
Electric, SCADA and Automation Systems	20	100	1,150,000	575,000	-
Desalination Plant	20	50	57,500,000	28,750,000	
Total				29,832,150	1,380,000

All cost components calculated are listed and yearly total of these components are given in Table 5.36. Cost of each year on its 2016 value and planned discharge with its 2016 value are given in Table 5.37.

Table 5. 36 Annual Total Cost Calculation

Year	Cost of the Project (TL)	Cost of the Revision (TL)	Cost of Total Energy Consumption (TL)	Maintenance Operational Cost (TL)	Total Cost (TL)
2017	37,208,200				37,208,200
2018	36,130,700				36,130,700
2019			2,287,683	1,203,360	3,491,043
2020			2,331,839	1,203,360	3,535,199
2021			2,375,995	1,203,360	3,579,355
2022			2,420,150	1,203,360	3,623,510
2023			2,464,306	1,203,360	3,667,666
2024			2,508,462	1,203,360	3,711,822
2025			2,552,617	1,203,360	3,755,977
2026			2,596,773	1,203,360	3,800,133
2027			2,640,928	1,203,360	3,844,288
2028			2,685,084	1,203,360	3,888,444
2029			2,729,240	1,203,360	3,932,600
2030			2,773,395	1,203,360	3,976,755
2031			2,817,551	1,203,360	4,020,911
2032			2,861,707	1,203,360	4,065,067
2033			2,905,862	1,203,360	4,109,222
2034			2,950,018	1,203,360	4,153,378
2035			2,994,174	1,203,360	4,197,534
2036			3,038,329	1,203,360	4,241,689
2037			3,082,485	1,203,360	4,285,845
2038		29,832,150	3,126,641	1,203,360	34,162,151
2039			3,170,796	1,203,360	4,374,156
2040			3,214,952	1,203,360	4,418,312
2041			3,259,108	1,203,360	4,462,468
2042			3,303,263	1,203,360	4,506,623
2043			3,347,419	1,203,360	4,550,779
2044			3,391,575	1,203,360	4,594,935
2045			3,435,730	1,203,360	4,639,090
2046			3,479,886	1,203,360	4,683,246
2047			3,524,041	1,203,360	4,727,401
2048			3,568,197	1,203,360	4,771,557
2049			3,612,353	1,203,360	4,815,713
2050			3,656,508	1,203,360	4,859,868
2051			3,700,664	1,203,360	4,904,024

Table 5. 37 Annual total cost, transferred amount of water and their value in 2016

Year	Total Cost (TL)	2016 Value of the Total Cost (TL)	Daily Average Discharge (m^3/day)	Yearly Average Discharge (m^3/year)	2016 Value of the Average Discharge (m^3/year)
2017	37,208,200	34,452,037			
2018	36,130,700	30,976,252			
2019	3,491,043	2,771,303	8,554	3,122,064	2,478,395
2020	3,535,199	2,598,477	8,732	3,187,107	2,342,619
2021	3,579,355	2,436,049	8,910	3,252,150	2,213,359
2022	3,623,510	2,283,426	9,088	3,317,193	2,090,394
2023	3,667,666	2,140,048	9,266	3,382,236	1,973,502
2024	3,711,822	2,005,382	9,445	3,447,279	1,862,458
2025	3,755,977	1,878,924	9,623	3,512,322	1,757,035
2026	3,800,133	1,760,197	9,801	3,577,365	1,657,012
2027	3,844,288	1,648,749	9,979	3,642,408	1,562,166
2028	3,888,444	1,544,155	10,157	3,707,451	1,472,280
2029	3,932,600	1,446,009	10,336	3,772,494	1,387,138
2030	3,976,755	1,353,930	10,514	3,837,537	1,306,532
2031	4,020,911	1,267,559	10,692	3,902,580	1,230,256
2032	4,065,067	1,186,554	10,870	3,967,623	1,158,111
2033	4,109,222	1,110,595	11,048	4,032,666	1,089,904
2034	4,153,378	1,039,379	11,227	4,097,709	1,025,448
2035	4,197,534	972,619	11,405	4,162,752	964,560
2036	4,241,689	910,047	11,583	4,227,795	907,066
2037	4,285,845	851,408	11,761	4,292,838	852,797
2038	34,162,151	6,283,803	11,939	4,357,881	801,591
2039	4,374,156	744,986	12,118	4,422,924	753,292
2040	4,418,312	696,765	12,296	4,487,967	707,749
2041	4,462,468	651,600	12,474	4,553,010	664,821
2042	4,506,623	609,303	12,652	4,618,053	624,369
2043	4,550,779	569,698	12,830	4,683,096	586,262
2044	4,594,935	532,616	13,009	4,748,139	550,374
2045	4,639,090	497,902	13,187	4,813,182	516,587
2046	4,683,246	465,408	13,365	4,878,225	484,785
2047	4,727,401	434,997	13,543	4,943,268	454,860
2048	4,771,557	406,537	13,721	5,008,311	426,708
2049	4,815,713	379,906	13,900	5,073,354	400,231
2050	4,859,868	354,991	14,078	5,138,397	375,336
2051	4,904,024	331,681	14,256	5,203,440	351,932
Total	241,689,661	109,593,290	376,358	137,370,816	37,029,930

Based on the results of Table 5.37, in Equation 5.43 UPC is calculated as 2.96 TL/m^3, which is equal to US$ 0.87 per m^3 as calculated in Equation 5.44.

$$\frac{109{,}593{,}290}{37{,}029{,}930} = 2.96\ \text{TL/m}^3 \tag{5.43}$$

$$\frac{2.96\ \text{TL/m}^3}{3.40} = 0.87\ \$/\text{m}^3 \tag{5.44}$$

In this option, water production is planned to increase over years from 8,554 m^3/day to 14,256 m^3/day as shown in Table 5.37. According to Table 4.4 in Chapter 4, UPC is around US$ 0.95 in a SWRO desalination plant with 10,000 m^3/day capacity and US$ 0.70 in a SWRO desalination plant with 50,000 m^3/day capacity. Thus, calculated result in Equation 5.44 is very reasonable and in the range reported by Wittholz et al. (2007).

5.5 Comparison of Alternatives

In the beginning of the case study, as an initial blind guess, among all the alternatives Alternative-2 was predicted to be the most cost-effective as it does not require pipe installation as in Alternative-1, while the Alternative-3 was predicted to be the most expensive as it involves relatively newer technology. However, calculations revealed that Alternative-2 is the most expensive alternative as one has to consider the cost of fuel and the crew as an addition onto the total cost of other components. Alternative-3 comes out as the most cost-effective alternative for Avşa Island. However, if the MDGs listed in Chapter 3 are considered, the sustainability of these alternatives has to be further assessed with long-term predictions and/or observations. For instance, the net environmental effect of a desalination plant to the Island can be assessed by long-term observation of the changes in the ecology of the Island as a desalination plant is already in operation in the Island. Based on the literature, the desalination plant has to release the solids/salt it has eliminated. This back-release could affect the salt content of the water around the Island effect the aquatic life. Similarly, in Alternative-2 use of fuel might cause an increase in CO2 values in the atmosphere, therefore its environmental effects has to be assessed. The use of fuel might act contrary to the “ensuring environmental sustainability” target of MDGs of UN.

Therefore, Alternative-2 is not only financially expensive but also requires better environmental assessment. In Alternatives 1 and 2, the groundwater use in Biga and its effect on water table should be considered under the highlight of the sustainability goal of MDGs. In all the alternatives energy used in operation of pumps should also be carefully assessed for the environmental concerns. In regard of the sustainability goal of MDGs, Alternative-1 might be the most sustainable option for the Island. However, further studies are required to have a full conclusion on the subject.

CHAPTER 6

CONCLUSION AND FUTURE WORK

6.1 Conclusion

Resources of the world is limited, and the population is increasing day by day. This situation pushes the mankind to find solutions in order to use those resources more efficiently or producing more from those resources. One of those limited resources is fresh water. Fresh water is a resource, which is distributed over the world independently from population. Therefore, there is supply-demand imbalance over the world. The countries, which are on the unlucky side of this imbalanced situation, have a problem that cannot be ignored or skipped. In this case, alternative water supply systems are the only option to evaluate. Actually, alternative water supply systems are not very desired solutions and they should not be considered if there is enough natural water resource. In general, the cost of water supplied through alternative water supply systems is high. As a result, if alternative water supply systems are the only option, financial comparisons of these systems have great importance.

Employing alternative water supply systems means either producing water or importing water. In this study, these two options are presented in detail and in Chapter 5, case study for Avşa Island is prepared. Avşa Island is introduced and inadequacy of its natural water resources are mentioned. Thus, alternative water supply systems are the only option to supply fresh water demand in the Island. In this framework, three different alternative water supply systems are investigated for Avşa Island and UPC is calculated for each of them. Results of those calculations are given in Table 7.1. Alternative-3, which involves production of water via reverse osmosis of seawater, is the cheapest alternative for Avşa Island.

Table 6. 1 UPC for each alternative water supply system investigated

UPC of Purchasing Bulk Water by Using Pipeline from Çanakkale (Alternative-1)	UPC of Purchasing Bulk Water from Çanakkale by Using Pipeline over Land and Tankers to Transport over the Sea (Alternative-2)	UPC of Producing Water (Alternative-3)
1.04 $/m^3	1.23 $/m^3	0.87 $/m^3

Cost is not the only advantage of Alternative-3. In Alternative-1 and Alternative-2, fresh water is planned to be supplied from another city. This situation causes lot of problems between Municipalities. For instance, price of the water could be one of them. Municipality of Avşa would like to buy water as cheap as possible because of its indispensability for human life. Therefore, Avşa Municipality would recognize this transfer of water from a humanitarian perspective. On the other hand, Çanakkale Municipality would recognize the transfer from commercial perspective as an extra income for their Municipality hence; Çanakkale Municipality might price the water differently. Another problem is, the direct dependency of island to another city, which is not a desired situation. In such dependency, any problem in water supply in Çanakkale might directly affect the Island as well. In macro perspective, such dependency is equally undesirable for countries. Considering all these in the case study of Avşa Island, Alternative-3 is selected as the best option in order for island to have self-sufficiency.

Although this study's main focus is cost, those alternative resources has different advantages, disadvantages and effects. Thus, during the evaluation of alternatives, cost should not be the only criterion. Other considerations such as environmental effects, sustainability, social benefits should be evaluated. One of the Millennium Development Goals of United Nations is ensuring environmental sustainability, therefore all the alternatives investigated in this study should be further assessed from the environmental point of view to better evaluate their possible effect to Avşa Island.

6.2 Future Work

In this study, most widely used alternative water supply systems are investigated and compared, however thanks to today's improving technology, new techniques and methods are discovered every day. For instance, generating water from atmosphere is one of those. Thus, those new systems needed to be assessed.

On the other hand, in supplying water to a water scarce land, optimization of the alternative water supply system might be necessary to achieve the best possible results financially. Use of hybrid systems could also be considered. Thus, in the continuation of this study, optimization of the different alternative water supply systems for various demands could be investigated.

Related with case study of Avşa Island, more alternatives can be analyzed. For instance, although Biga is selected due to its proximity to Avşa, transporting water from other water resources in Balıkesir and Çanakkale can be analyzed. Furthermore, as a continuation of this study, improvements in water bag technology and durability of them could be analyzed, and financial comparison can be repeated including water bag alternative for Avşa Island.

The Millennium Development Goals of United Nations states that before employing the alternative water supply systems, other basic investments to solve water scarcity problems should be checked. For instance, the short-comings of the already existing water supply system in Avşa Island could be determined and certain solutions could be proposed to enhance the system. The finances of these solutions could be compared, this would reveal if any of the alternative systems investigated in this study would really be necessary for the Island in future.

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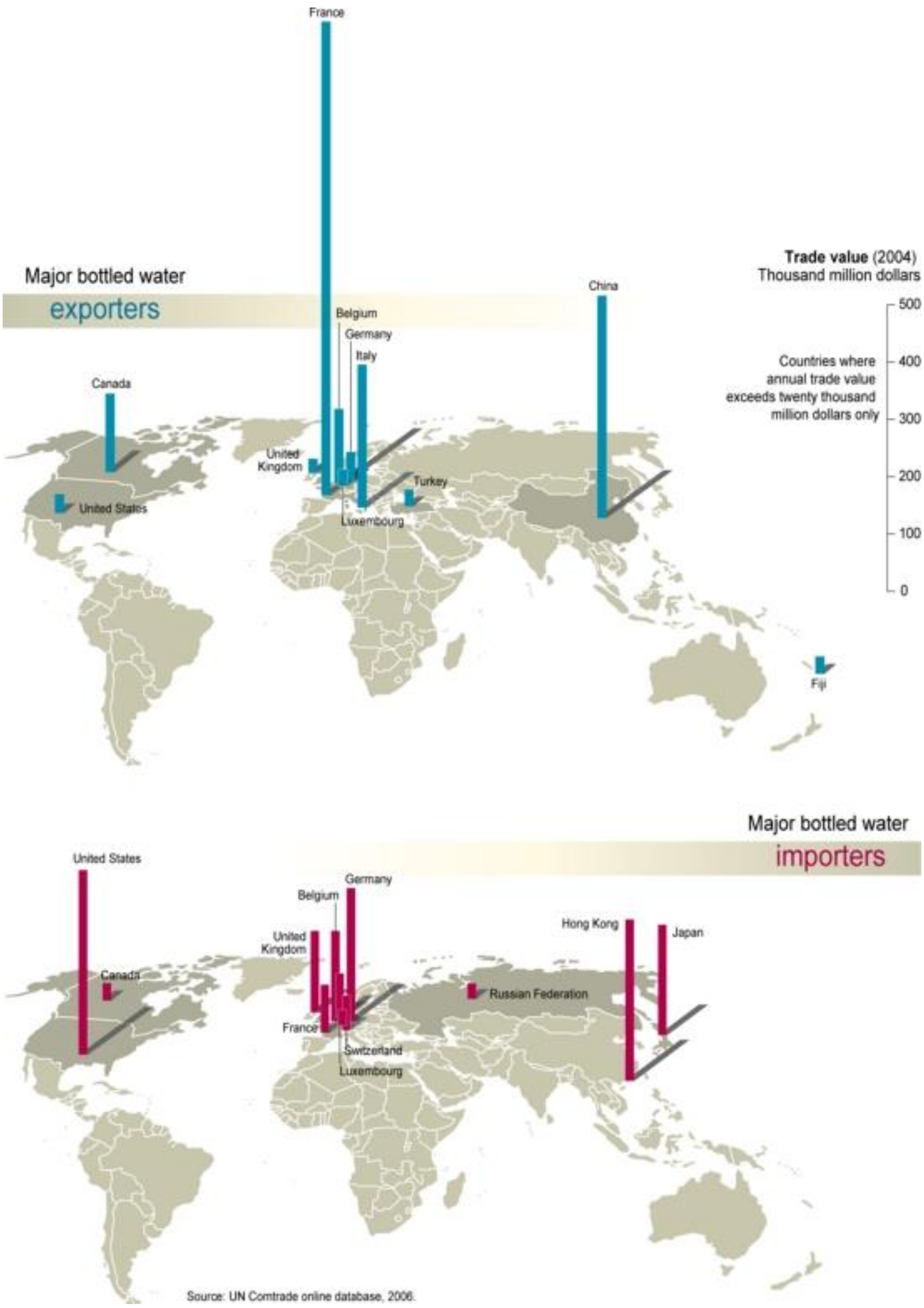
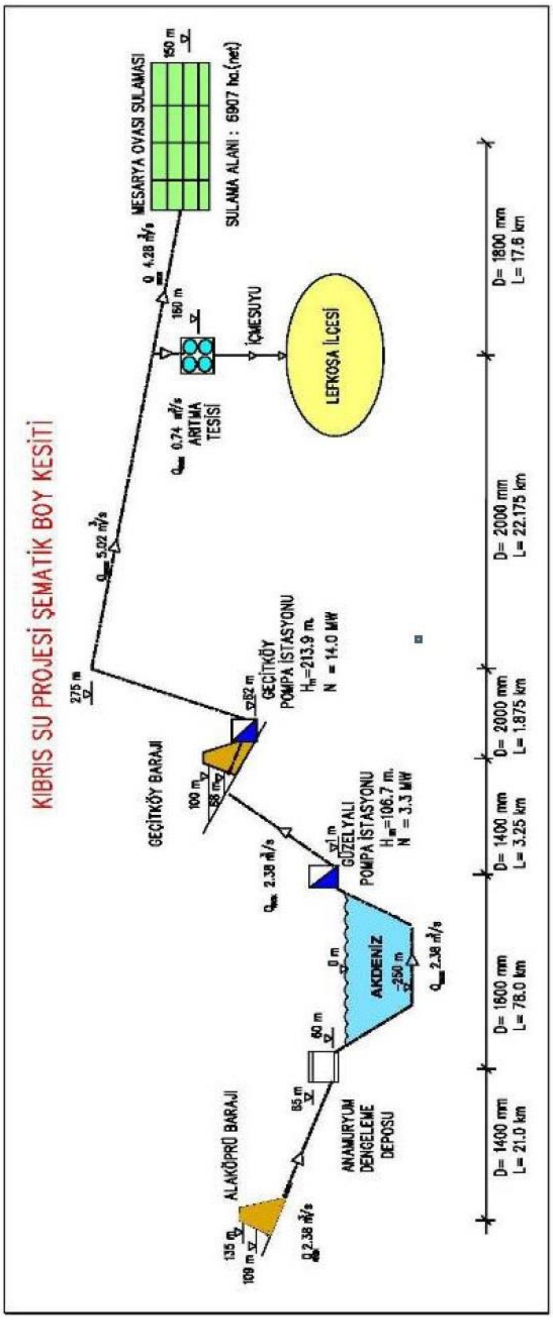
APPENDIX A

Figure A. 1 2004 UN Bottled Water Exporter and Importer Countries Map (Web 14)



APPENDIX B

Figure B. 1 Detailed schematic profile of the Turkey to North Cyprus bulk water transfer system (Ozdemir & Bostancı, 2007)



APPENDIX C

C.1 Exponential Projection

With this approach, population growth is assumed exponential and the Equation C.1 and C.2 are used.

$$P_t = P_o \times e^{r \times t} \tag{C.1}$$

$$r = \left(\frac{P_{\text{last population data}}}{P_{\text{initial population data}}}\right)^{1/n} - 1 \tag{C.2}$$

where,

P_o: Initial population

P_t: Population t years later,

r: Annual rate of growth,

e: Base of the natural logarithm

t: Projection time from now.

For Avşa Island, exponential projection of the population calculated for every 5 year is given in Table C.1.

Table C. 1 Exponential Population Projection of the Avşa Island

Year	Population
2016	3,041
2021	3,473
2026	3,967
2031	4,530
2036	5,174
2041	5,909
2046	6,749
2051	7,707

C.2 Geometric Projection

With this approach, population growth is assumed geometric and Equation C.3 and C.4 are used.

$$P_t = P_o \times (1+r)^t \tag{C.3}$$

$$r = \left(\frac{P_{\text{last population data}}}{P_{\text{initial population data}}}\right)^{1/n} - 1 \tag{C.4}$$

Table C. 2 Geometric Population Projection of the Avşa Island

Year	Population
2016	3,039
2021	3,465
2026	3,950
2031	4,504
2036	5,135
2041	5,854
2046	6,674
2051	7,609

C.3 Logarithmic Projection

With this approach, population growth is assumed logarithmic and the Equation C.5 and C.6 are used.

$$\ln P_t = \ln P_o + r \times t \tag{C.5}$$

$$r = \left(\frac{\ln P_{\text{last population data}}}{\ln P_{\text{initial population data}}}\right) / n \tag{C.6}$$

Table C. 3 Logarithmic Population Projection of the Avşa Island

Year	ln P_n	r × t	ln P_o+ r × t	Population
2016	7.97	0.05	8	3,039
2021	7.97	0.18	8	3,465
2026	7.97	0.31	8	3,950
2031	7.97	0.45	8	4,504
2036	7.97	0.58	9	5,135
2041	7.97	0.71	9	5,854
2046	7.97	0.84	9	6,674
2051	7.97	0.97	9	7,609

C.4 Linear Projection

With this approach, population growth is assumed linear and the Equation C.7 and C.8 are used.

$$P_t = P_o + r \times t \quad (C.7)$$

$$r = \frac{(P_{\text{last population data}} - P_{\text{initial population data}})}{(t_{\text{time of the last population data}} - t_{\text{time of the initial population data}})} \quad (C.8)$$

Table C. 4 Linear Population Projection of the Avşa Island

Year	Population
2016	2,969
2021	3,182
2026	3,395
2031	3,608
2036	3,821
2041	4,033
2046	4,246
2051	4,459

C.5 Least Squares Fitting Projection

With this approach, population growth over years is assumed stochastic. Population projection is calculated based on the unknown parameters calculated from past years of population, the Equation C.9, Equation C.10 and Equation C.11 are used.

$$Y=M\times X+b \quad (C.9)$$

$$M=\frac{(\sum x_i\times\sum y_i)/n-\sum(x_i\times y_i))}{(\sum x_i\times\sum x_i)/n-\sum x_i^2} \quad (C.10)$$

$$b=\frac{\sum x_i^2\times\sum_i y_i-\sum x_i\sum(x_i\times y_i)}{n\times\sum x_i^2-(\sum x_i)^2} \quad (C.11)$$

Y: Projected population

X: Projection time from the start date of the data to projection date

M: Unknown parameters

b: Unknown parameters

x_i: Time Period from the start date of the data to date of the population data

y_i: Population data

n: Number of population data

Table C. 5 Past Years Calculation Table

Year	**t - $t_{initial}$ (x_i)**	**Population (y_i)**	**$x_i \times y_i$**	**x_i^2**
1965	0	798	0	0
1970	5	777	3,885	25
1975	10	994	9,940	100
1980	15	1,228	18,420	225
1985	20	1,319	26,380	400
1990	25	2,617	65,425	625
2000	35	2,611	91,385	1,225
2007	42	1,969	82,698	1,764
2008	43	2,661	114,423	1,849
2009	44	2,613	114,972	1,936
2010	45	2,602	117,090	2,025
2011	46	2,559	117,714	2,116
2012	47	2,527	118,769	2,209
2013	48	2,500	120,000	2,304
2014	49	2,884	141,316	2,401
Total	474	30,659	1,142,417	19,204

$$M=\frac{(\left(\frac{474\times30.659}{15}\right)-1.142.417)}{(\frac{(474^2)}{15}-19.204)}=41.08 \quad (C.12)$$

$$b=\frac{19.204\times 30.659-474\times 1.142.417}{15\times 19.204-474^2}=746 \quad (C.13)$$

$$Y=41.08\times X+746 \quad (C.14)$$

Table C. 6 Least Squares Fitting Population Projection of the Avşa Island

Year	Population
2016	2,841
2021	3,047
2026	3,252
2031	3,457
2036	3,663
2041	3,868
2046	4,074
2051	4,279

C.6 Iller Bank Projection

Iller Bank is a special-budget joint-stock company with subject to the provisions of private law and has legal personality, working as development and investment bank. It was founded at 11th of June, 1933 to finance reconstruction activities of municipalities. In Iller Bank's infrastructure investment specifications; population projection method called Iller Bank Population Projection is stated. It is actually geometrical projection but r is calculated based on first and the last population data. On the other hand, in Iller Bank Projection annual rate of growth is calculated in three different ways. Firstly, annual rate of growth is calculated for each consecutive years and average of those calculated annual rate of growth values are taken. Secondly, annual rate of growth is calculated for the range of each year and last year. Then average of those calculated annual rate of growth values are taken. Finally, r is calculated for the first year to each year. Then average of those calculated r values are taken.

$$P_t=P_o\times(1+r)^n \quad (C.15)$$

$$r=\left(\left(\frac{P_t}{P_o}\right)^{1/a}\right)-1 \quad (C.16)$$

$$r = \left(\frac{P_{last}}{P_{initial}}\right)^{1/n} - 1 \quad (C.17)$$

Based on consecutive years, population growth rates are given in Table C.7 and by using average of those calculated population growth rate, calculated population projections are given in Table C.8.

Table C. 7 Annual rate of growth for each time period

Year	r (Increment Coefficient)
1970-1965	-0.00532
1975-1970	0.05049
1980-1975	0.04319
1985-1980	0.01440
1990-1985	0.14686
2007-1990	-0.01660
2008-2007	0.35145
2009-2008	-0.01804
2010-2009	-0.00421
2011-2010	-0.01653
2012-2011	-0.01250
2013-2012	-0.01068
2014-2013	0.15360
Average Population Growth Rate	0.05201

Table C. 8 Iller Bank Population Projection of the Avşa Island based on consecutive years

Year	Population
2016	3,192
2021	4,113
2026	5,299
2031	6,828
2036	8,799
2041	11,337
2046	14,609
2051	18,824

Based on last year, population growth rates are given in Table C.9 and by using average of those calculated population growth rate, calculated population projections are given in Table C.10.

Table C. 9 Annual rate of growth for each time interval

Year	**r (Increment Coefficient)**
1965-2014	0.02657
1970-2014	0.03026
1975-2014	0.02769
1980-2014	0.02543
1985-2014	0.02734
1990-2014	0.00406
2007-2014	0.05604
2008-2014	0.01350
2009-2014	0.01993
2010-2014	0.02606
2011-2014	0.04066
2012-2014	0.06830
2013-2014	0.15360
Average Population Growth Rate	**0.03996**

Table C. 10 Iller Bank Population Projection of the Avşa Island based on last years

Year	**Population**
2016	3,119
2021	3,794
2026	4,615
2031	5,614
2036	6,829
2041	8,306
2046	10,104
2051	12,290

Based on initial year, population growth rates are given in Table C.11 and by using average of those calculated population growth rate, calculated population projections are given in Table C.12.

Table C. 11 Annual rate of growth for each time interval

Year	r (Increment Coefficient)
1980-1970	-0.00532
1965-1975	0.02221
1990-1980	0.02915
1965-1985	0.02544
2008-1990	0.04865
1965-2007	0.02174
2010-2008	0.02840
1965-2009	0.02732
2012-2010	0.02661
1965-2011	0.02566
2014-2012	0.02483
1965-2013	0.02408
1965-2014	0.02657
Average Population Growth Rate	**0.02503**

Table C. 12 Iller Bank Population Projection of the Avşa Island based on initial year

Year	Population
2016	3,030
2021	3,429
2026	3,880
2031	4,390
2036	4,968
2041	5,621
2046	6,361
2051	7,198

APPENDIX D

During the preparation of the bill of quantities, published unit prices of Turkey are used. In all those bill of quantities table, pose number is given for each unit price of each item so by using those codes, It can be determined which unit price belongs to which state institution of Turkey.

Table D. 1 BoQ of the Well Construction

No	Pose No	Item Description	Unit	Quantitiy	Published Unit Price	Cost (TL)
Water Supply System Alternatives for Avsa Island - Alternative 1						
Well Construction Cost						
1	PAÇAL-K	Wide Excavation	m^3	150	25.00 TL	3,750.00 TL
2	14.1713	Soil Backfilling	m^3	20	10.78 TL	215.60 TL
3	Y.16.050/01	C8/10 Concrete Casting	m^3	3.5	132.81 TL	464.84 TL
4	Y.16.050/03	C16/20 Concrete Casting	m^3	14	144.88 TL	2,028.32 TL
5	Y.17.136	Blokage with Stone	Each	6	48.35 TL	290.10 TL
6	Y.18.001/C15	Masonary	m^2	20	30.14 TL	602.80 TL
7	19.022/İB-1	Insulation Against Water (2 Layer)	m^2	25	65.53 TL	1,638.25 TL
8	Y.21.001/01	Formwork Installation	m^2	70	11.78 TL	824.60 TL
9	Y.21.050/C01	Under-Formwork Scaffolding (0.00-4.00 m)	m^3	60	4.59 TL	275.40 TL
10	Y.21.051/C01	Scafolding for Plastering (0.00-51.50 m)	m^2	70	4.83 TL	338.10 TL
11	Y.21.051/C03	Scafolding for Plastering (0.00-21.50 m)	m^3	30	4.21 TL	126.30 TL
12	Y.23.014	8-12 mm Steel Bar	ton	0.5	1,972.66 TL	986.33 TL
13	Y.22.009	Wooden Door	m^2	2	88.36 TL	176.72 TL
14	Y.23.152	Manufacturing and Assembling of Steel Doors and Windows	kg	300	6.33 TL	1,899.00 TL
15	Y.23.176	Manufacturing and Assembling of Various Steel Works	kg	200	5.88 TL	1,176.00 TL
16	23.260/İB-1	Wire Fence With Reinforced Concrete Poles	m	100	99.84 TL	9,984.00 TL
17	Y.25.002/01	Steel Painting, 2 Layer	m^2	20	8.65 TL	173.00 TL
18	04.506/A1A	Wall Painting	m^2	90	6.50 TL	585.00 TL
19	Y.25.003/12	Lime Whitewashing for Interior Wall, 3 layer	m^2	2	2.48 TL	4.96 TL
20	04.398/007	Patterned Tile, Any Color (20x20 cm)	m^2	10	31.50 TL	315.00 TL
21	Y.26.006/303	1. Quality White Ceramic Tiles, (20x25cm) or (20x30cm)	m^2	60	33.53 TL	2,011.80 TL
22	Y.27.501/08	350 Dose Plastering	m^2	160	13.94 TL	2,230.40 TL
23	Y.27.501/03	Lime-Cement Plastering	m^2	25	19.45 TL	486.25 TL
24	Y.27.581	Leveling	m^2	25	9.95 TL	248.75 TL
25	27.582/1	Casting Screed with Steel Trowel	m^2	25	8.06 TL	201.50 TL
26	Y.28.645/C01	Installation of double glazed window unit, 3+3 mm steel thickness and 12 mm intermediate gap	m^2	2	49.25 TL	98.50 TL
27	A01	Wide type recessed interior door lock	Each	1	8.88 TL	8.88 TL
28	A07	Surface Mount Rim Lock for Outdoor	Each	2	29.44 TL	58.88 TL
29	B01	Espagnolette (Locking Device)	Each	3	10.38 TL	31.14 TL
30	ÖZEL	Well Pump	Each	1	15,000.00 TL	15,000.00 TL
31	B03	Vasistas For Doors	Each	3	9.38 TL	28.14 TL
32	30-15-8802/1	Water Drilling, Diameter 12 1/4"	m	30	425.04 TL	12,751.20 TL
Sub Total						**59,009.76 TL**
Unforeseen Expenses						**10,990.24 TL**
Total						**70,000.00 TL**
Transportation (%20)						**7,000.00 TL**
Water Well Construction Cost (1 Piece)						**77,000.00 TL**
Water Well Construction Cost (6 Piece)						**462,000.00 TL**

Table D. 2 BoQ of the Pipeline Between Wells and Pump Station

Water Supply System Alternatives for Avsa Island - Alternative 1						
Construction Cost of the Pipeline Between Wells and Pump Station in Canakkale, 225 PN10 HDPE						
No	Pose No	Item Description	Unit	Quantitiy	Published Unit Price	Cost (TL)
1	14.16003	Trench Excavation without Trench Shoring, 0-2 m	m^3	552.35	11.25 TL	6,213.94 TL
2	14.17	Soil Backfilling	m^3	404.88	11.44 TL	4,631.86 TL
3	15.140/İB-8	Sand Gravel Backfilling	m^3	134.75	15.30 TL	2,061.68 TL
4	36.08911	Ø 225 HDPE Pipe Installation	m	500	5.27 TL	2,635.00 TL
5	36.02111	Ø 225 HDPE Welding	Each	63	66.21 TL	4,171.23 TL
6	36.04763	Ø 225 HDPE Pipe Cutting	Each	7	13.34 TL	93.38 TL
7	36.11319	225/45 HDPE Elbow	Each	1	98.63 TL	98.63 TL
8	36.11321	225/90 HDPE Elbow	Each	1	81.75 TL	81.75 TL
9	36.00513	Ø 225 Welding with Flange	Each	2	54.07 TL	108.14 TL
10	04.768/8E-06A	Ø 225 PE Pipe Price ND10	m	550	51.25 TL	28,187.50 TL
Sub-Total						**48,283.11 TL**
Unforeseen Expenses						**11,716.89 TL**
Total						**60,000.00 TL**
Transportation (%20)						**12,000.00 TL**
Cost of the Pipeline Between Wells and Water Storage Facility in Balıkesir						**72,000.00 TL**

Table D. 3 BoQ of the Pump Station and Water Storage Facility in Çanakkale

Water Supply System Alternatives for Avsa Island - Alternative 1						
Pump Station and 500 m3 Capacity of Water Storage Facility in Canakkale						
No	**Pose No**	**Item Description**	**Unit**	**Quantitiy**	**Published Unit Price**	**Cost (TL)**
1	14.160001	Wide Excavation	575	m^3	9.85 TL	5,663.75 TL
2	14.16003	Trench Excavation without Trench Shoring, 0-2 m	159.33	m^3	11.25 TL	1,792.50 TL
3	14.16004	Foundation Excavation without Trench Shoring, 0-2 m	500	m^3	12.78 TL	6,390.00 TL
4	14.160041	Foundation Excavation without Trench Shoring, 2-3 m	833.33	m^3	13.14 TL	10,950.00 TL
5	14.160042	Foundation Excavation without Trench Shoring, 3-4 m	416.67	m^3	13.50 TL	5,625.00 TL
6	KGM/3605/A2	200 mm Diameter of PVC Drainage Pipe	150	m^3	23.11 TL	3,466.50 TL
7	Y.21.001/02	Smooth Surface Formwork and Reinforced Concrete	38.67	m^3	36.24 TL	1,401.28 TL
8	14.1713	Backfilling of the Wall Foundations	810	m^3	10.78 TL	8,731.80 TL
9	14.1717	Backfilling the Standart Backfilling Material	332.67	m^3	25.16 TL	8,369.89 TL
10	15.140/İB-1	Foundation and Trench Backfilling With Stabilized Backfilling Material	242.33	m^3	15.52 TL	3,761.01 TL
11	Y.16.050/01	C8/10 Concrete Casting	44	m^3	137.78 TL	6,062.32 TL
12	Y.16.050/06	C30/37 Concrete Casting	276.33	m^3	165.03 TL	45,603.29 TL
13	Y.17.136	Blokage with Stone	8	m^3	56.58 TL	452.64 TL
14	18.500/İB-11	Expansion Joint in Concrete Wall, 1 Quality	251	m	32.92 TL	8,262.92 TL
15	18.500/İB-17	Expansion Joint in Concrete Slab, DO (25/5) Type, 1 Quality	90	m	38.70 TL	3,483.00 TL
16	18.500/İB-21	Expansion Joint in Concrete Slab, A (25/8) Type, PVC Gasket	30	m	66.82 TL	2,004.60 TL
17	Y.18.462/013	Insulation Against Water	816.67	m^2	16.36 TL	13,360.67 TL
18	Y.19.056/001	Thermal Insulation	164	m^2	12.13 TL	1,989.32 TL
19	Y..21.001/02	Wood Formwork Installation	175.33	m^2	36.24 TL	6,354.08 TL
20	Y..21.001/03	Plywood Formwork Installation	633	m^2	26.99 TL	17,084.67 TL
21	Y.21.050/C11	Under-formwork scaffolding (0.00-4.00 m)	1461.67	m^3	4.78 TL	6,986.77 TL
22	Y.21.050/C12	Under-formwork scaffolding (4.01-6.00 m)	1252.67	m^3	5.55 TL	6,952.30 TL
23	Y.21.050/C13	Under-formwork scaffolding (6.01-8.00 m)	877	m^3	6.33 TL	5,551.41 TL
24	Y.21.051/C11	Scafolding for Wall Plastering	296.67	m^3	7.95 TL	2,358.50 TL
25	Y.21.051/C13	Scafolding for Ceiling Plastering	1793.33	m^3	6.45 TL	11,567.00 TL
26	Y.23.014	8-12 mm Steel Bar	9.33	ton	1,807.64 TL	16,871.31 TL
27	Y.23.015	14-26 mm Steel Bar	25.67	ton	1,751.08 TL	44,944.39 TL
28	Y.23.152	Manufacturing and assembling of steel doors and windows	366.67	kg	7.23 TL	2,651.00 TL
29	Y.23.176	Manufacturing and assembling of various steel works	157.33	kg	6.64 TL	1,044.69 TL
30	Y.23.220	Manufacturing and Installation of the Fences By Welding the Pipes	153.33	kg	6.69 TL	1,025.80 TL
31	23.260/İB-1	Wire Fence With 2.63 m Height of Reinforced Concrete Poles	125	m	119.95 TL	14,993.75 TL
32	24.061	PVC Type Storm Water Pipes,100 mm Diameter	12	m	12.85 TL	154.20 TL
33	Y.25.002/02	Painting the Steel Product	21.67	m^2	19.26 TL	417.36 TL
34	Y.25.004/02	Painting the Concrete Surface	902.67	m^2	19.56 TL	17,656.23 TL
35	Y.26.005/302	White Ceramic Tile	116.67	m^2	32.13 TL	3,748.61 TL
36	Y.27.581	Leveling Wtith 200 dose of Cement	59	m^2	12.21 TL	720.39 TL
37	Y.27.576	Mozaic Parapet Installation	16.67	m^2	192.71 TL	3,212.48 TL
38	Y.27.583	Casting Screed with Steel Trowel on Concrete Surface	501.33	m^2	14.24 TL	7,138.94 TL
Sub-Total						**308,804.36 TL**
Unforeseen Expenses						**41,195.64 TL**
Total						**350,000.00 TL**
Transportation (%20)						**70,000.00 TL**
Pump Station and 500 m3 Capacity of Water Storage Facility in Canakkale						**420,000.00 TL**

Table D. 4 BoQ of the Pipeline Between Pump Station and Water Storage Facility in Çanakkale

Water Supply System Alternatives for Avsa Island - Alternative 1						
Construction Cost of the Pipeline Between Pump Station and Water Storage Facility, 560 PN16 HDPE						
No	**Pose No**	**Item Description**	**Unit**	**Quantitiy**	**Published Unit Price**	**Cost (TL)**
1	14.16003	Trench Excavation without Trench Shoring, 0-2 m	m^3	5,580.00	11.25 TL	62,775.00 TL
2	14.17	Trench Backfilling	m^3	4,032.97	11.44 TL	46,137.20 TL
3	15.140/İB-8	Sand-Gravel Backfilling	m^3	808.5	15.30 TL	12,370.05 TL
4	36.0892	Ø 560 HDPE Pipe Installation	m	3,000.00	18.66 TL	55,980.00 TL
5	36.0212	Ø 560 HDPE Pipe Welding	Each	376	74.37 TL	27,963.12 TL
6	36.04772	Ø 560 HDPE Pipe Cutting	Each	47	40.69 TL	1,912.43 TL
7	36.11337	560/45 HDPE Elbow	Each	8	970.25 TL	7,762.00 TL
8	36.11338	560/90 HDPE Elbow	Each	4	1,067.25 TL	4,269.00 TL
9	36.0052	Ø 550 Welding with Flange	Each	6	173.16 TL	1,038.96 TL
10	04.768/8G-11A	Ø 560 PE Pipe Price ND16	m	3,300.00	477.50 TL	1,575,750.00 TL
Sub-Total						**1,795,957.76 TL**
Unforeseen Expenses						**104,042.24 TL**
Total						**1,900,000.00 TL**
Transportation (%20)						**380,000.00 TL**
Construction Cost of the Pipeline Between TO1 and TO2, 560 PN16 HDPE						**2,280,000.00 TL**

Table D. 5 BoQ of the Pipeline Between Water Storage Facility and Karabiga Valve Chamber

Water Supply System Alternatives for Avsa Island - Alternative 1						
Construction Cost of the Pipeline Between Water Storage Facility and Karabiga Valve Chamber, 560 PN16 HDPE						
No	**Pose No**	**Item Description**	**Unit**	**Quantitiy**	**Published Unit Price**	**Cost (TL)**
1	14.16003	Trench Excavation without Trench Shoring, 0-2 m	m^3	27,900.00	11.25 TL	313,875.00 TL
2	14.17	Trench Bacfillling	m^3	20,164.86	11.44 TL	230,686.00 TL
3	15.140/İB-8	Sand Gravel Backfilling	m^3	4,042.50	15.30 TL	61,850.25 TL
4	36.0892	Ø 560 HDPE Pipe Installation	m	15,000.00	18.66 TL	279,900.00 TL
5	36.0212	Ø 560 HDPE Pipe Welding	Each	1,876	74.37 TL	139,518.12 TL
6	36.04772	Ø 560 HDPE Pipe Cutting	Each	234	40.69 TL	9,521.46 TL
7	36.11337	560/45 HDPE Elbow	Each	26	970.25 TL	25,226.50 TL
8	36.11338	560/90 HDPE Elbow	Each	14	1,067.25 TL	14,941.50 TL
9	36.0052	Ø 550 Welding with Flange	Each	12	173.16 TL	2,077.92 TL
10	04.768/8G-11A	Ø 560 PE Pipe Price ND16	m	16,500.00	477.50 TL	7,878,750.00 TL
Sub-Total						**8,956,346.75 TL**
Unforeseen Expenses						**343,653.25 TL**
Total						**9,300,000.00 TL**
Transportation (%20)						**1,860,000.00 TL**
Construction Cost of the Pipeline Between TO2 and VO1, 560 PN16 HDPE						**11,160,000.00 TL**

Table D. 6 BoQ of the Sea Pass Over Pipeline

Water Supply System Alternatives for Avsa Island - Alternative 1						
Construction Cost of the Sea Pass, 560 PN16 HDPE						
No	**Pose No**	**Item Description**	**Unit**	**Quantitiy**	**Published Unit Price**	**Cost (TL)**
1	14.1600300	Trench Excavation without Trench Shoring, 0-2 m	m^3	500.00	41.65 TL	20,825.00 TL
2	15.140/İB8	Sand Gravel Backfilling	m^3	0.000	11.27 TL	0.00 TL
3	14.1714	Soil Backfilling	m^3	0.000	12.88 TL	0.00 TL
4	15.024/ÖBF-1	Excavation Under Water in Any Depth	m^3	0.000	97.78 TL	0.00 TL
5	15.151/ÖBF-2	Backfilling Underwater	m^3	0.000	31.83 TL	0.00 TL
6	16.103/ÖBF-3	Assembling of the Bouy in any Depth	Each	0	111.34 TL	0.00 TL
7	16.103/ÖBF-4	Assembling of the Concrete Block, Concrete Clamp, Duffisor Pipe Under WaterIn Any Depth	Each	0	324.70 TL	0.00 TL
8	23.167/ÖBF-5	Production of the Buoy with Solar FlashLight from 10mm HDPE Material	Each	0	36,465.00 TL	0.00 TL
9	ÖBF-1	Hydraulic Test of the 560 mm Diameter Pipe in Land Before Installation	m	19,000.00	18.61 TL	353,590.00 TL
10	ÖBF-2	Installation of the 560 mm Diameter Pipe Under Water	m	19,000.00	484.29 TL	9,201,510.00 TL
11	ÖBF-3	Flange Connection of the 560 mm Diameter Pipe Under Water	m	19,000.00	361.63 TL	6,870,970.00 TL
12	ÖBF-4	Hydraulic Test After Installation of the 560 mm Diameter Pipe Under Water	m	19,000.00	26.38 TL	501,220.00 TL
13	ÖBF-7	Gabion Block Manufacturing and Assembling (5.00x2.00x1.00)	Each	0	1,020.74 TL	0.00 TL
14	ÖBF-8	Gabion Block Manufacturing and Assembling (5,00x2,00x0,75)	Each	0	757.75 TL	0.00 TL
15	ÖBF-9	Gabion Block Manufacturing and Assembling (5,00x2,00x0,50)	Each	0	591.11 TL	0.00 TL
16	Y.16.050/05	C 25/30 Concrete Casting	m^3	0.000	144.34 TL	0.00 TL
17	Y.21.001/02	Wood Formwork Installation	m^2	0.00	27.14 TL	0.00 TL
18	Y.23.014	8-12 mm Steel Bar	ton	0.000	1,905.86 TL	0.00 TL
19	04.768/GE11A	F 560 mm. PN16 HDPE Pipe Price	m	19,000.00	477.50 TL	9,072,500.00 TL
Sub-Total						**26,020,615 TL**
Transportation and Unforeseen Expenses						**31,979,385 TL**
Total						**58,000,000 TL**

Table D. 7 BoQ of the Pipeline Between Avşa Valve Chamber and Avşa Water Storage Facility

Water Supply System Alternatives for Avsa Island - Alternative 1						
Construction Cost of the Pipeline Between Avsa Valve Chamber and Avşa Water Storage Facility, 560 PN16						
No	**Pose No**	**Item Description**	**Unit**	**Quantitiy**	**Published Unit Price**	**Cost (TL)**
1	14.160030	Shoring, 0-2 m	m^3	5,580.000	11.25 TL	62,775.00 TL
2	14.1700	Trench Backfilling	m^3	4,032.972	11.44 TL	46,137.20 TL
3	15.140/İB-8	Sand Gravel Backfilling	m^3	808.500	15.30 TL	12,370.05 TL
4	36.08920	Ø 560 HDPE Pipe Installation	m	3,000.00	18.66 TL	55,980.00 TL
5	36.02120	Ø 560 HDPE Pipe Welding	Each	376	74.37 TL	27,963.12 TL
6	36.04772	Ø 560 HDPE Pipe Cutting	Each	47	40.69 TL	1,912.43 TL
7	36.11337	560/45 HDPE Elbow	Each	25	970.25 TL	24,256.25 TL
8	36.11338	560/90 HDPE Elbow	Each	16	1,067.25 TL	17,076 TL
9	36.00520	Ø 550 Pipe Welding With Flange	Each	12	173.16 TL	2,077.92 TL
10	04.768/8G-11A	Ø 560 PE Pipe Price ND16	m	3,300.00	477.5 TL	1,575,750 TL
Sub-Total						**1,826,297.97 TL**
Unforseen						**173,702.03 TL**
Total						**2,000,000 TL**
Transportation (%20)						**400,000 TL**
Construction Cost of the Pipeline Between VO2 and Water Storage Facility in Avsa, 560 PN16 HDPE						**2,400,000 TL**

APPENDIX E

Table E. 1 BoQ of the Tanker Connection Offshore Pipes

Water Supply System Alternatives for Avsa Island - Alternative 2						
Construction Cost of the Tanker Connection Offshore Pipes, 560 PN16 HDPE						
No	**Pose No**	**Item Description**	**Unit**	**Quantitiy**	**Published Unit Price**	**Cost (TL)**
1	14.1600300	Trench Excavation without Trench Shoring, 0-2 m	m^3	500.00	41.65 TL	20,825.00 TL
2	15.140/İB8	Sand Gravel Backfilling	m^3	580.000	11.27 TL	6,536.60 TL
3	14.1714	Soil Backfilling	m^3	1,903.000	12.88 TL	24,510.64 TL
4	15.024/ÖBF-1	Excavation Under Water in Any Depth	m^3	17,186.000	97.78 TL	1,680,447.08 TL
5	15.151/ÖBF-2	Backfilling Underwater	m^3	10,777.000	31.83 TL	343,031.91 TL
6	16.103/ÖBF-3	Assembling of the Bouy in any Depth	Each	14	111.34 TL	1,558.76 TL
7	16.103/ÖBF-4	Assembling of the Concrete Block, Concrete Clamp, Duffisor Pipe Under WaterIn Any Depth	Each	499	324.70 TL	162,025.30 TL
8	23.167/ÖBF-5	Production of the Buoy with Solar FlashLight from 10mm HDPE Material	Each	14	36,465 TL	510,510.00 TL
9	ÖBF-1	Hydraulic Test of the 560 mm Diameter Pipe in Land Before Installation	m	3,000.00	18.61 TL	55,830.00 TL
10	ÖBF-2	Installation of the 560 mm Diameter Pipe Under Water	m	3,000.00	484.29 TL	1,452,870.00 TL
11	ÖBF-3	Flange Connection of the 560 mm Diameter Pipe Under Water	m	3,000.00	361.63 TL	1,084,890.00 TL
12	ÖBF-4	Hydraulic Test After Installation of the 560 mm Diameter Pipe Under Water	m	3,000.00	26.38 TL	79,140.00 TL
13	ÖBF-7	Gabion Block Manufacturing and Assembling (5.00x2.00x1.00)	Each	294	1,020.74 TL	300,097.56 TL
14	ÖBF-8	Gabion Block Manufacturing and Assembling (5,00x2,00x0,75)	Each	1019	757.75 TL	772,147.25 TL
15	ÖBF-9	Gabion Block Manufacturing and Assembling (5,00x2,00x0,50)	Each	71	591.11 TL	41,968.81 TL
16	Y.16.050/05	C 25/30 Concrete Casting	m^3	124.000	144.34 TL	17,898.16 TL
17	Y.21.001/02	Wood Formwork Installation	m^2	615.00	27.14 TL	16,691.1 TL
18	Y.23.014	8-12 mm Steel Bar	ton	16.000	1,905.86 TL	30,493.76 TL
19	04.768/GE11A	560 mm. PN16 HDPE Pipe Price	m	3,000.00	477.50 TL	1,432,500 TL
Sub-Total						**8,033,971.93 TL**
Transportation and Unforeseen Expenses						**1,466,028.07 TL**
Total						**9,500,000.00 TL**

Table E. 2 BoQ of the Pump Station In the Avşa Shore

Water Supply System Alternatives for Avsa Island - Alternative 2						
Pump Station Near the Avsa Shore						
No	Pose No	Item Description	Unit	Quantitiy	Published Unit Price	Cost (TL)
1	14.160001	Wide Excavation	300.00	m^3	9.85 TL	2,955.00 TL
2	14.160030	Trench Excavation without Trench Shoring, 0-2 m	80.00	m^3	11.25 TL	900.00 TL
3	14.160040	Foundation Excavation without Trench Shoring, 0-2 m	250.00	m^3	12.78 TL	3,195.00 TL
4	14.160041	Foundation Excavation without Trench Shoring, 2-3 m	400.00	m^3	13.14 TL	5,256.00 TL
5	14.160042	Foundation Excavation without Trench Shoring, 3-4 m	200.00	m^3	13.5 TL	2,700.00 TL
6	KGM/3605/A2	200 mm Diameter of PVC Drainage Pipe	75.00	m^3	23.11 TL	1,733.25 TL
7	Y.21.001/02	Smooth Surface Formwork and Reinforced Concrete	20.00	m^3	36.24 TL	724.80 TL
8	14.1713	Backfilling of the Wall Foundations	400.00	m^3	10.78 TL	4,312.00 TL
9	14.1717	Backfilling the Standart Backfilling Material	160.00	m^3	25.16 TL	4,025.60 TL
10	15.140/İB-1	Foundation and Trench Backfilling With Stabilized Backfilling Material	120.00	m^3	15.52 TL	1,862.40 TL
11	Y.16.050/01	C8/10 Concrete Casting	20.00	m^3	137.78 TL	2,755.60 TL
12	Y.16.050/06	C30/37 Concrete Casting	200.00	m^3	165.03 TL	33,006.00 TL
13	Y.17.136	Blokage with Stone	4.00	m^3	56.58 TL	226.32 TL
14	18.500/İB-11	Expansion Joint in Concrete Wall, 1 Quality	120.00	m	32.92 TL	3,950.40 TL
15	18.500/İB-17	Expansion Joint in Concrete Slab, DO (25/5) Type, 1 Quality	45.00	m	38.7 TL	1,741.50 TL
16	18.500/İB-21	Expansion Joint in Concrete Slab, A (25/8) Type, PVC Gasket	15.00	m	66.82 TL	1,002.30 TL
17	Y.18.462/013	Insulation Against Water	400.00	m^2	16.36 TL	6,544.00 TL
18	Y.19.056/001	Thermal Insulation	80.00	m^2	12.13 TL	970.40 TL
19	Y..21.001/02	Wood Formwork Installation	80.00	m^2	36.24 TL	2,899.20 TL
20	Y..21.001/03	Plywood Formwork Installation	300.00	m^2	26.99 TL	8,097.00 TL
21	Y.21.050/C11	Under-formwork scaffolding (0.00-4.00 m)	750.00	m^3	4.78 TL	3,585.00 TL
22	Y.21.050/C12	Under-formwork scaffolding (4.01-6.00 m)	600.00	m^3	5.55 TL	3,330.00 TL
23	Y.21.050/C13	Under-formwork scaffolding (6.01-8.00 m)	450.00	m^3	6.33 TL	2,848.50 TL
24	Y.21.051/C11	Scafolding for Wall Plastering	150.00	m^3	7.95 TL	1,192.50 TL
25	Y.21.051/C13	Scafolding for Ceiling Plastering	800.00	m^3	6.45 TL	5,160.00 TL
26	Y.23.014	8-12 mm Steel Bar	4.50	ton	1,807.64 TL	8,134.38 TL
27	Y.23.015	14-26 mm Steel Bar	16.00	ton	1,751.08 TL	28,017.28 TL
28	Y.23.152	Manufacturing and assembling of steel doors and windows	180.00	kg	7.23 TL	1,301.40 TL
29	Y.23.176	Manufacturing and assembling of various steel works	80.00	kg	6.64 TL	531.20 TL
30	Y.23.220	Manufacturing and Installation of the Fences By Welding the Pipes	80.00	kg	6.69 TL	535.20 TL
31	23.260/İB-1	Wire Fence With 2.63 m Height of Reinforced Concrete Poles	60.00	m	119.95 TL	7,197.00 TL
32	24.061	PVC Type Storm Water Pipes,100 mm Diameter	6.00	m	12.85 TL	77.10 TL
33	Y.25.002/02	Painting the Steel Product	10.00	m^2	19.26 TL	192.60 TL
34	Y.25.004/02	Painting the Concrete Surface	450.00	m^2	19.56 TL	8,802.00 TL
35	Y.26.005/302	White Ceramic Tile	60.00	m^2	32.13 TL	1,927.80 TL
36	Y.27.581	Leveling Wtith 200 dose of Cement	30.00	m^2	12.21 TL	366.30 TL
37	Y.27.576	Mozaic Parapet Installation	8.00	m^2	192.71 TL	1,541.68 TL
38	Y.27.583	Casting Screed with Steel Trowel on Concrete Surface	250.00	m^2	14.24 TL	3,560.00 TL
Sub-Total						167,156.71 TL
Unforeseen Expenses						32,843.29 TL
Total						200,000.00 TL
Transportation (%20)						40,000.00 TL
Pump Station Near the Avsa Shore						240,000.00 TL