GÖZDE OĞUZ
ABU KISHIK

TOWARDS SUSTAINABLE URBAN WATER AND WASTEWATER
MANAGEMENT MODEL FOR CITY OF NICOSIA

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A THESIS SUBMITTED TO THE INSTITUTE OF GRADUATE STUDIES
OF
NEAR EAST UNIVERSITY

By
GÖZDE OĞUZ ABU KISHIK

In Partial Fulfilment of the Requirements for the Degree of Master Science in Civil and Environmental Engineering

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Approval of Director of Institute of Graduate Studies

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We certify this thesis is satisfactory for the award of the degree of Masters of Science in Civil and Environmental Engineering

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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 requested by these rules and conduct, I have fully cited and referenced all material and results that are not original to this work.

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To my daughter...

ABSTRACT

Water is an essential element for the sustainable development of countries. It is the key to strengthening the resilience of the environment, the economy, and society. Rapid population growth, urbanization, climate change, and industrial activities all have an impact on the availability of water to meet the community's demand.

The development and implementation of Sustainable Urban Water and Wastewater Management is critical for the municipal economy, the benefits of society, and for environmental protection.

In this study, for sustainable urban water and wastewater management; foremost, the Sustainability Index for the city of Nicosia has been calculated into three sections: Central Nicosia, Hamitkoy/Mandres quarter, and Haspolat/Mia Milia quarter, according to the collected water consumption data, population, and structure of the regions. To develop a sustainable management system, future expected water deficits were estimated based on population projections until 2035 according to the generated scenario.

Possible additional supplies and technical alternatives have been evaluated for the long-term planning. These alternatives are weighted based on nine economic, environmental, and social indicators. To select the best additional alternative for management planning, multi-criteria decision-making methods are applied. The result indicates that the water management system for the city of Nicosia should include the renovation of the system, an additional water supply of treated water, and conservation actions should be taken into consideration to support the sustainability of the system in the economy, the environment, and social dimensions.

Keywords: Sustainable urban water and wastewater management; city of Nicosia; sustainability index; MCDM; sustainable management.

ÖZET

Su, ülkelerin sürdürülebilir kalkınması için vazgeçilmez bir unsurdur. Çevrenin, ekonominin ve toplumun direncini güçlendirmenin anahtarıdır. Hızlı nüfus artışı, kentleşme, iklim değişikliği ve endüstriyel faaliyetlerin tümü, toplumun talebini karşılamak için suyun mevcudiyeti üzerinde bir etkiye sahiptir.

Sürdürülebilir Kentsel Su ve Atıksu Yönetiminin geliştirilmesi ve uygulanması belediye ekonomisi, toplumun yararları ve çevrenin korunması için kritik öneme sahiptir.

Bu çalışmada sürdürülebilir kentsel su ve atık su yönetimi için; Öncelikle, Lefkoşa Şehri için sürdürülebilirlik endeksleri; mevcut su tüketim verileri, nüfus ve bölgelerin yapısına göre Merkez Lefkoşa, Hamitköy/Mandres mahallesi ve Haspolat/Mia Milia mahallesi olarak üç bölümde hesaplanmıştır. Sürdürülebilir bir yönetim sistemi geliştirmek için, oluşturulan senaryo ile 2035 yılına kadar nüfus tahminlerine dayalı olarak gelecekte beklenen su açıkları tahmin edilmiştir.

Uzun vadeli planlama için olası su kaynağı ve teknik alternatifler değerlendirilmiştir. Seçilen alternatifler, ekonomik, çevresel ve sosyal dokuz adet göstergeye göre değerlendirilmiştir. Yönetim planlamasında için en iyi alternatif ek su kaynağını seçmek için çok kriterli karar verme yöntemleri uygulanmıştır. Sonuç olarak, Lefkoşa şehri için su yönetimi, sistemin yenilenmesini, arıtılmış suyun ek su kaynağı olması ve suyun korunarak ekonominin, çevrenin ve sosyal boyutların desteklenerek korunmasını içermelidir.

Anahtar Kelimeler: Sürdürülebilir kentsel su ve atıksu yönetimi; Lefkoşa şehri; sürdürülebilirlik endeksi; MCDM; sürdürülebilir yönetim.

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AHP:	Analytic Hierarchy Process
BOD:	Biovhemical Oxygen Demand
CM:	Critic Method
COD:	Chemical oxygen Demand
CP:	Compromise Programming
EM:	Etrophy Method
EU:	European Commision
IWM:	Integrated Water Management
IWWM:	Integrated Water and Wastewater Management
MBR:	Membrane Bioreactor
MCDA:	Multi Criteria Decision Analysis
MCDM:	Multi Criteria Decision Method
MCM:	Million Cubic Meter
NC:	North Cyprus
NTM:	Nicosia Turkish Municipality
NWWTP:	New Wastewater Treatment Plant
Rel:	Reliability
Res:	Resilience
SAW:	Simple Additive Weighting
SI:	Sustainability Index
SUWM:	Sustainable Urban Water Management
SWUA:	Sustainable Water Use in Agriculture
TOPSIS:	Technique for Order Preference by Similarity to Ideal
TSS:	Total Suspended Soil
Vul:	Vulnerability
WDM:	Water Demand Management
WDS:	Water Distribution Systems
WPI:	Water Poverty Index
WWD:	Water Works Department
WWTP:	Wastewater Treatment Plant

CHAPTER 1

INTRODUCTION

1.1. General

Water is at the center of both health and hygiene, and the major source of energy in the world. It is critical for all living things. One of the primary issues of the Sustainable Development Goals is access to safe water resources (WHO, 2008).

The average volume of water on the planet, according to research and estimates, is 1.26 $x10^{21}$ liters. Around 97.5 percent of the total water is saline and the remaining 2.5 percent is freshwater, which is suitable for survival. However, only 1.3 percent of the freshwater we can reach is surface and groundwater. The remaining freshwater is contained in the glaciers and ice caps (Lal, 2015b). Because freshwater is a finite resource, good water management and reuse are critical for long-term water availability and well-being. Surface water and groundwater are critical resources that are linked to each other due to the hydrological cycle. Management plans should consider them all together (Winter et al., 1998).

Freshwater is used for domestic, industrial and agricultural activities. The limited amount of fresh water is a major challenge for many countries (Flörke et al., 2013). Also, climate change and an increasing population are exacerbating the pressure on water resources. (Haddeland et al.,2014). Cities are expanding as the urban population grows, and the demand for fresh water creates a significant gap in meeting daily needs (UN DESA, 2018).

Water scarcity is one of the major effects of climate change and it is a global issue that cities should have action to generate an adequate water management plan to adapt global warming trends to balance the use and supply of water (Mukheibir, 2010). Access to safe water is becoming increasingly difficult for most countries, and the effects of climate change vary in magnitude from region to region. Sustainable water management should be a major strategy for countries to adapt to the results of global warming (Mukheibir, 2010; Fan et al., 2017).

The scenarios by researchers predict that at the end of the 21st century, the urban population of the globe will grow 60 to 92 percent (Jiang, L. and O'Neill, 2017).

This trend has had a significant impact on the affordability of water in many countries. It is predicted that water use will increase by 80% by 2030 and water withdrawals will be between 50 to 250% by the 2050s (Florke et al., 2018). These approaches show that, to adapt to climate change and increasing population water issues, communities should take action. A rise in water supply raises the possibility of a water shortage and increased demand for groundwater resources (McDonald et al., 2014).

Groundwater is one of the most valuable sources of water for most countries to meet the demand of the population for daily use, agricultural, and industrial activities (Winter et al., 1998). However, proportionally to the increased population, more demand for groundwater resources causes serious problems with the quality and quantity because of over abstraction (Gokcekus et al. 1997; Hinrichsen and Tacio, 2002). Climate change is another serious subject that has effects on the quality, quantity and availability of global water resources (Bates et al., 2008).

The United Nations World Water Reports published in 2020 found that about 2.2 billion people of the global population lack a good water supply. Population growth in cities, combined with rapid urbanization, creates challenges and inadequacies in water supply. With the rapid expansion of cities and a decrease in precipitation due to global warming, it is estimated that useable water resources will be reduced by 10 percent or more by the year 2020 (UN, 2020).

Since the 1950s, increasing job opportunities with industrial developments, population migration trends and the transformation of the cities from rural to urban areas have occurred. The 2018 edition of the UN's world urban prospects report revision has found that 55% of the world's population lives in urban areas. By 2050, the population density is expected to reach 68 percent (UN, 2018).

Urbanization is a spatial movement trend of the population density from rural to urban areas. This transformation does not include only spatial movement, but also includes culture, behaviour, and lifestyle changes. It is a socio-economic challenge because economic developments are the source of urbanization. The growth of cities is linked to the economy, the environment, and society. Providing basic life standards for housing and meeting the demands of an overburdened population while maintaining the economy is a huge challenge that is mostly found in developing countries. If urbanization progress is well managed, it will be a benefit to development and minimize environmental degradation (UN, 2018).

On the other hand, rapid, unplanned and unmanaged urbanization may cause pressure on cities (Roberts, 2016). These pressures have a negative impact on available resources and existing infrastructure assets such as water, waste, and drainage systems in many ways. The expansion of cities has a high risk of resulting in insufficient water and sanitation. Rapid urbanization causes a slew of issues in low- and middle-income countries (Reymond et al, 2016).

Another consequence is water stress. The combination of high population density in the cities and climate change is exacerbating water stress (Mikovits, 2018). It is a factor that limits opportunities for development and directly lowers living standards. Water stress is not the only factor that impacts on life standards. Water supply, demand fulfillment, and sanitation are critical for citizens' health and wealth (Reymond et al, 2016). Some areas may face a lack of water and waste infrastructure as a result of the rapid increase in the population. Infrastructure is a significant and costly investment. It is very difficult to attract this investment in cities which are not ready to grow. On the other hand, already constructed infrastructure may need rehabilitation to meet the demand of the rapidly increasing population (Lienert et al., 2013).

Sustainable urban water management is one of the major topics that aims to utilize water to satisfy existing ecological, social, and economic requirements while protecting the potential to meet certain challenges of the future. It helps managers to examine the legislative boundaries of water use and take action against them to minimize possible water availability risks.

Managing urban water resources is one of the most critical points in the sustainability of the most precious and finite source of human life. One of the primary issues of the Sustainable Development Goals is access to safe water resources (WHO, 2008). Water resources are vulnerable and, in recent years, pressures on water resources have been increasing day by day with the increase in the population and the effect of climate changes. The effects cause serious problems with water resources, such as water scarcity, pollution, and salinity.

Water security is a key development concept that has received increased attention from policymakers since the year 2000. The concept of water security can be described as the availability and accessibility of water in terms of basic needs, agricultural development, environmental security, enforcement and risk management, and independence (Jensen and Wu, 2018). All water resources are linked to each other, and they have to be considered as a whole. The concept has a broad scope, ranging from human daily needs to global issues. Conservation of water has lately been of major significance to population growth and development strategies. To secure and manage water resources, many concepts have been developed over the years.

Since the 80s, the definition of integrated water management has been increased in focus. Over the years, terminologies and insights have been changed and the sustainable water resources concept, water security concept and adaptative water management concepts have come up. Sustainable water management was developed in the 1990's with the report of the Brundtland report. Climate change and population growth have serious consequences in countries that are unable to adopt or act on climate change and population growth. Also, it is a risk to have suitability in management and development of the cities. Most cities face significant challenges in providing safe drinking water to their citizens. Especially in cities located in arid regions or where the country's water resources are insufficient or unsafe. Water infrastructure systems and reuse of wastewater play an important role in the development and water abundance of cities (Khatri and Vairavamoorthy, 2008). Balancing the amount and supply of water is critical in city governance. Incorrect and inadequate water management strategies can cause serious gaps between water use and supply. As cities become more densely populated, it has become more difficult to provide safe water to citizens while balancing the amount of supply and demand for water.

Minimizing climate change effects and handling the uncertainties of the governance of water resources in a city requires sufficient and sustainable management. For success, all natural and recycled water resources should be considered together.

There are many ways to evaluate the sustainability of the existing system of urban water management. In water management, two major issues emerge: one is to protect available resources, and the other is to manage additional water resources in a sustainable manner.

1.2. Problem Description

Water scarcity is one of the major issues that small islands face due to many factors, such as climate change, economic developments, urbanization, improper irrigation methods, and the growth of the population. The island of Cyprus is a living example of the serious water scarcity issue over the last few decades.

For years, until 2015, Northern Cyprus's water demand was met solely by groundwater resources. Pollutants and seawater intrusion into aquifers are causing serious problems with water quality (Turker and Hansen, 2012; Gökcekus et al., 2018). In order to solve the water issues in North Cyprus, the water transfer project from Turkey has been implemented. The transferred water meets North Cyprus’s water demand.

Water transfer is purchased by municipalities and delivered to citizens. The management plan is critical for the preservation and conservation of this water, particularly for cities in North Cyprus that lack alternative water resources. The capital city of Nicosia is the most important example of a lack of secondary water supply resources.

The city of Nicosia is the most important region for North Cyprus's demographic and economic well-being. It is under the administration of the Nicosia Turkish Municipality

(NTM). With the addition of Hamitkoy/Mandres and Haspolat/Mia Milia residential areas to the borders of NTM, the city has experienced rapid unplanned urbanization and an increased population after 2010. Because workplaces are primarily concentrated in Nicosia, the city has a large population during working hours. The city continues to develop and expand. As a result, water consumption is rapidly increasing. Since the completion of the freshwater transfer project in 2017, the water demand has been met by this water. Depending on only one resource is not sustainable. This highlights the need for a water management plan to balance water use and define alternatives to keep the city's water program sustainable.

1.3. Aim of the Study

The main concept of this study is to develop a water management plan that will help with future decisions with respect to the three pillars of sustainability. In this study,

1) The existing situation has been analyzed with sustainability measures and regional investigations which used as an indicator for approaches such as regional structure, daily life conditions etc.

2) On the borders of Nicosia Turkish Municipality, alternative water-source solutions were investigated. These alternatives have been assessed in terms of their economic, environmental, and social benefits.

3) Future expected supply and demand deficits are evaluated regarding future population projections.

4) The most appropriate water management road map has been identified using a multi-criteria approach based on the three pillars of sustainability.

1.4. Scope of the Study

In this study, a sustainable model approach is intended for Nicosia, the capital city. Nicosia city has been evaluated in three sections: Region 1 Central Nicosia, Region 2 Hamitkoy/ Mandres quarter, and Region 3 Haspolat/ Mia Milia quarter. The regions are classified as water demand areas, and data is derived solely from total monthly distributed amounts. Due to the lack of separate data for domestic, industrial, and agricultural water consumption, demand has been estimated based on population projections, the structure of the region, industrial, and agricultural activity areas.

Four calculation stages are included in the approach to developing a sustainable water management plan. Firstly, supply and demand balance has been evaluated for the years between 2018-2020 and performance criteria and sustainability indexes calculated to have an idea of future plans and projects. Secondly, alternative water supply resources are investigated and multi-criteria decision methods are used to identify the performance of these alternatives based on economic, environmental and social criteria. The future expected deficit has then been estimated based on the generated scenario. Finally, scoring alternatives are assigned and checked to cover the deficit predictions according to their suitability for the region.

The study is presented in six chapters. Chapter-2 introduces a literature review of prevailing approaches to developing sustainable water management. Chapter-3 presents the study area. Chapter-4 explains the methodological framework of the study, including are discussed in Chapter -5. The recommendations and general conclusion of this study presented in Chapter-6.

CHAPTER 2

LITERATURE REVIEW

Water is a large-scale topic that has been studied on a wide range of topics and holds a prominent place in literature. While some researchers examined water in terms of natural resources, other researchers examined water use and its challenges.

Due to the increased water scarcity problem around the globe, awareness and studies on water management have increased in the last few decades. The majority of research and studies are focused on water resource management, integrated water and wastewater management, public education for efficient water use and integrated urban water management.

A sustainable urban water management (SUWM) plan aims to provide control and safety of water resources to balance water availability and meeting demand, quality and quantity, reducing damage risks to agriculture and infrastructure assets, recycling, sanitation and hygiene. The main framework of this thesis is comprised of these topics and management system evaluation methods. In this section, a literature review has been done on these subjects.

2.1. Domestic Water Demand Management

Water management plans have a strategic role in meeting the demands now and in the future to minimize the negative effects of water scarcity on the economy, society and the environment. A good management plan has benefits for all stakeholders and for future generations. The water management plan should be appropriate and adaptable. In other words, it should be sustainable.

There are various approaches to increasing the influence of water management and to achieving more beneficial results. One of the research approaches is to develop economic incentives, constitutional, political and public education while generating a strategy for a water management plan. A good strategic water management plan can be useful to reduce demand and provide efficient use of water. Improvements in efficient water consumption provide benefits for both the distributor and for domestic, agricultural and industrial users. Efficient use of water can help to save water. This has a positive impact on maintaining a balance between water supply and demand. Also provides economic benefits to stakeholders while also protecting the environment. Therefore, as was mentioned above in the approach of research, public education, economic incentives, legal and governmental regulations are implementation programs to proceed with strategic water demand management (Dziegielewski, 2003).

Public education is a critical component of achieving effective water conservation. Awareness of saving water will result in a reduction in consumption in households. There is a research study to quantify the influence of water saving on consumption beliefs. The research presents the Gold Coast Water Saver End Use study results. The study detected 132 households with a questionnaire survey and smart metering technology. Two factors, environmental attitudes and water saving awareness, have been identified in the study to determine their influences on water consumption. The confirmatory factor analysis and cluster analysis techniques are used for statistical studies and have been validated. As the result of the study, the propositions for environmentalists and water saving attitudes were analytically supported and, in addition to technical studies, educational programs are also highly recommended to achieve significant water saving in households (Willis et al., 2009).

The availability of water and how to manage demands are major concerns for the globe. In the management of water, some factors, such as climate change, rapid urbanization, pollution, and drought, are highlighted topics that accelerate the water gaps between supply and demand. The magnitude of the gap is a serious problem for the economic, political and environmental developments of many countries. In the case of current or future expected water scarcity issues, alternatives to water resources should be assessed. Lack of regulations, frameworks and economic plans are other subjects that support the needs of management. Managing water is a complex issue that may need to meet the requirements of rapid urbanisation and economic developments with limited sources. Water management applications focus on sustainable water services and water conservation with new technologies and products. The latest technologies are very effective in monitoring water use. Technological devices can determine the distribution of water and water loss in networks. Aside from technological alternatives, environmental education and economic alternatives such as taxes and regulatory frameworks are alternatives to roles in building water management. Various methods and approaches are used to determine the needs of a region during the planning of a management action to develop a management plan. One of the methods is the Delphi method. This method was used in the Caruaru municipality in Brazil. The aim of the study was to determine suitable measures to improve water availability in the region (Santana et al. 2019).

In general, WDM aims to increase the efficiency of available water in a balance of use and supply. There are several approaches and models used for these decisions. Establishing a management plan should focus on the regional climate, available resources and water consumption values to take a better approach. Furthermore, most studies focus on raising public awareness in order to increase the impact of water conservation.

2.2. Water Management for Differrent Sectors

Water consumption varies according to different sectors. It has been observed that water resources have the highest consumption in the agriculture sector. Aside from agriculture, the industry and tourism sectors consume a lot of water. As a result, integrated water management in these sectors benefits both the economic and environmental environments.

2.2.1. Water management evaluations in agriculture sector

Agriculture is the basis of the economy and of food security. In order to sustain agriculture, water resources should be used carefully and sustainability should be ensured. The use of water in agriculture varies with the development of countries. For irrigation purposes, developed countries consume approximately 60% of the available water, while developing countries consume approximately 90% (Adeyemi et al., 2017). Therefore, sustainable water use in agriculture (SWUA) has great importance around the globe. SWUA is one of the most international research topics (Velasco-Munoz et al., 2018b).

The increase in global irrigation water demand is proportional to the increase in the population. Changing standards and food patterns may help to increases the demand for water resources to satisfy the future expected water demand. The pathway has been studied by Fraiture and Wichelns, 2010.

The management objectives of the SWUA should be identified according to the country's development level. According to T. Russo et al., the objectives of SWUA in developed countries include water needed for crop productivity, environmental protection, and resource conservation, whereas in developing countries, these objectives include food security and increasing water productivity to supplement irrigation and rain.

Within the study, the water challenges have been analysed for the urban, agricultural and industrial sectors. Agricultural water demand challenges and solutions for developed and developing countries have been described. The cost of irrigation infrastructure and irresponsible consumption of limited water resources are highlighted challenges in developing countries. The rearrangement of prices and additional irrigation solutions such as rainwater harvesting are recommended solutions. Developed countries, on the other hand, face challenges to their agricultural water demand, such as the cost of technologies to improve water affordability (Russo et al., 2014).

Water is the most important element of agriculture and measures must be taken to preserve water availability. Especially in arid and semi-arid climates, it is necessary to develop an appropriate management plan for the regional situation. The prepared management plan should evaluate and include the use of new water meter technologies, new irrigation methods, reuse of treated waste water for irrigation, scientific investigations and training for farmers to reduce consumption.

2.3 Managing Water Under the Impact of Climate Change Studies

2.3.1 Climate change impacts

Based on the evidence, the globe has warmed by many degrees in the last several decades. According to the Inter-Governmental Panel on Climate Change report, it is expected that the world's surface temperature will keep increasing by between 1.1 to 6.4°C degrees Celsius until the end of the 21st century (IPCC, 2007). In recent decades, changes in the climate have caused impacts on natural and human systems on all continents and across the oceans. Climate change is evident in rising global temperatures, warming oceans, shrinking ice sheets, glacial retreat, decreased snow cover, rising sea levels, declining Arctic Sea ice, extreme events, and ocean acidification. (IPCC, 2007).

Global warming is a significant threat to survival on the earth. The warming of the planet has consequences that directly affect human life, with extreme changes in weather conditions, rising sea levels, droughts, flooding and many other impacts. These consequences have varying effects on all countries around the world. Some countries are experiencing water scarcity and extreme heat, while others are dealing with severe flooding and hurricanes as a result of extreme weather conditions. Predictions from research insist that the impacts of climate change will be severe in the future (EU, 2021).

The Mediterranean region's major significant consequences are reduced precipitation and warmer surface temperatures (and Lionello, 2008). Among climate change model scenarios, surface water runoff has been predicted to drop by 10 percent to 30 percent in the Mediterranean Region (Alexander et al., 2010). The Mediterranean region is the most vulnerable to climate change because of its location. There are several climate conditions surrounding the region. It is located between the conditions of the dry climate of Africa and the temperate climate of Europe. The interaction of these different climate conditions or any changes has effects on the Mediterranean region (Lionello et al., 2006a). With the implications of these features, models of climate changes show that the Mediterranean region is the 'hot spot' of the 21st century (Lionello and Scarascia, 2018). Climate change poses a potential risk to the environment and human life, influencing human health and well-being in a variety of ways. It undermines the basics of public health, such as safe drinking water, food supply and clean air. It also has the potential to lead to risk developments all over the world (WHO, 2008).Extreme weather events have had a significant impact on our water resources.Future projections and evidence indicate that increased evapotranspiration and precipitation water resources will deal with the negative effects of climate change in very complex ways (Lionello and Scarascia, 2018).Water access, as well as both short and long-term activities of water supply and sanitation, would be difficult for suppliers to provide (Alexander et al., 2010).

Climate change impacts on water resources have been experienced in the Mediterranean region for a few decades. In the region, water stress has increased with climate change and population growth (Chenoweth et. al., 2011). There is scientific research being conducted on the effects of climate change on the Mediterranean region's water resources. To predict the expected future water stresses on the regions, numerical models and simulations have been generated during the last few decades (Onol and Semazi, 2009) and have seen significant improvements over time.

In many studies, climate change in the Mediterranean region has been studied with high resolution models. High resolution climate change models are useful for future projections of countries to take precautions against the challenges of water resources management, agricultural activities and power supply applications (Onol and Semazi, 2009).

Models, simulations, and studies show that the precipitation pattern has changed and the surface temperature in the region has risen. These changes are contributing to the region's water stress.

2.3.2. Water management studies under the climate change impact

There is a strong relationship between climate change and water availability. Climate change has a significant impact on the quality and quantity of water. In many regions around the globe, management of water resources will be difficult due to severe climate change impacts on quantity and quality. Therefore, water management is very important for adaptation to climate change. There is a lot of research on water management in the context of climate change and adaptation.

Climate change is one of the major uncertainties of the future. Creating a strategic water management plan entails considering climate change adaptation options. Many different water resource management studies, such as Rogers, 1997; Lins and Stakhiv, 1998; Dessai and Van der Sluijs, 2007; Angel et al., 2010; Hall and Harvey, 2009, use future climate change predictions.

M. Haasnoot et al. (2011) and Stakhiv (2011) conducted studies on the development of water management strategies for the future of climate change. M. Haasnoot et al. (2011) discussed a transdisciplinary approach to unexpected events in the water and social systems. The study emphasizes that in the development of a water management plan, social responses to the variables of water systems should be included.

Another study, Poff et. al, (2016), worked on a paradigm for sustainable water management under future hydrological and climate uncertainities. The study's goal is to help decision-makers and planners work through complex problems in order to achieve sustainable water management in the face of uncertainty.

2.3.3. Sustainable urban water management approaches and methods

The definition of sustainable development was first introduced in the Brundtland Commission Report, which was also named Our Common Future, in 1987 (Brundtland, 1987). Combining economic, environmental and social criteria of sustainability with water management can help engineers, decision-makers and stakeholders to analyze the current water situation, focusing on the sustainability of water resources and management. (Loucks and Gladwell, 1999; Loucks et. al. 2000).

The subject of sustainable water management has been studied in many aspects, such as the management of water reserves due to regions, management in arid-semiarid climate conditions, country locations and structures, and policy and governmental evaluations. Apart from that, measuring the sustainability of water management has been scientifically calculated and approaches have been published.

Larsen and Gujer, (1997) identified four basic factors to discuss urban water management sustainability. Affordability, resources, local actions, and methods are determined by four basic principles and, generally, they are the majority of human-caused events. These principles gave directions to extract guidelines to determine options for future water management sustainability.

Compared to developed countries, developing countries have more challenges in the planning of sustainable urban water management. To achieve sustainability in developing countries, there are many factors that should be taken into consideration due to the region`s economic, social and environmental situation. A study by Asit K. Biswas, 1992, has identified the five major problems in developing countries that limit the application of engineers and decision-makers. The inadequate framework has been mentioned as the first factor that affects a water management plan. The rest of the factors are the balance in the framework is important to examine positive and negative impacts, the lack of appropriate guidelines and methods, the absence of enough knowledge, governmental constraints, and monitoring. In conclusion, the study highlights the importance of monitoring and evaluation. Monitoring and evaluation are essential and integrated with the plan to develop and keep the management plan sustainable (Biwas, 1992).

Managing water on islands has challenges due to the limited water reserves. Water scarcity is common on islands in the Mediterranean region with arid climates.There are articles about water management on islands. Kourtis et al. (2019) focused on water management on small islands, whereas I. Zacharias and T. Koussouris (2000) focused on sustainable water management on European islands.

To measure the sustainability of water management is another important topic that there are many efforts and approaches to define the most appropriate way to measure. In the context of this study, measuring sustainability is critical in order to be aware of current situations and plan for the future.

Water Distribution Systems (WDS) are an essential component of water management for suppliers and municipalities. Loucks (1997) has identified the importance of ensuring the system's sustainability now and in the future in order to meet social needs through a combination of ecology, hydrology, and the environment.To reduce risks and uncertainties, a quantitative measure of sustainability has also been proposed. The quantitative measure of sustainability (SI) depends on the satisfactory or unsatisfactory criteria, Reliability (Rel), Resiliance (Res) and Vulnerability (Vul) (Louck, 1997).

To define decisions for alternative solutions in the literature, multicriteria methods are used by researchers. MCDM is applied to many management studies De Marchi et al., 2000; Joubert et al., 2003; Zarghami et al.,2008, worked on urban water management, Flug et al., 2000; Srdjevic et al., 2004; Mahmoud & Garcia, 2000, studied water supply topics.

2.4. Water and Wastewater management studies in Cyprus

Cyprus is one of the Europe's most vulnerable region due to its scarcity of water resources. Small islands, such as Cyprus, are facing water scarcity issues as a result of population growth, climate change, and water resource management.

The island of Cyprus has been divided into the Republic of Cyprus (South Cyprus) and the Turkish Republic of Northern Cyprus (North Cyprus) since 1974. Both countries are suffering from water scarcity. In both countries, there are various literature studies on water and wastewater management. By using these studies, the gaps in the literature have been detected.

2.4.1. Water management studies in Cyprus

Gokcekus et. al. (2018), published an integrated water management plan strategy considering wastewater treatment in NC. The study focused on transport water from Turkey and defined essential factors for the IWM strategy.

Elkıran et al., (2019) focused on water management and water consumption trends in North Cyprus. The Blaney-Criddle method and statistical relationships were used in the study to evaluate water demand for domestic and agricultural uses from 2000 to 2012. The Nicosia/Lefkoşa main region was defined as having higher water consumption compared to the Kyrenia/Girne and Famagusta/Magosa regions due to the high population and agricultural water use. As a result, the authors recommend that the water budget be kept under control and the supply and demand be updated every 5 or 10 years.

Gokcekus et al. (2020), worked on the IWWM strategy to provide a foundation for a North Cyprus water action plan. Water demands for domestic, tourism, education, agriculture, and effluent use are all addressed in the strategy. In some regions of NC, water data was combined with water transfers from Turkey and from local resources. For the city of Nicosia, only the transfer of water was included. Following extensive research on NC water resources, the authors recommended the development of watersheets, waste and environmental management plans, and administrative frameworks, as well as the addition of effluent to the water budget.

Park (2020), recommends a strategic plan for a sustainable water management plan for Cyprus and describes the history and effects of water disputes, highlights the shortcomings of water management methods, and suggests alternative water catchment and distribution strategies for divided Cyprus. The author strongly recommends alternative water sources for sustainable water management, such as waste reuse, rainwater harvesting, desalination, and distribution system renovation.

Charalambous et. al. (2012), worked on urban water flow modeling for Limasol city of the Republic of Cyprus. The aim of the study is to develop a tool for monitoring losses, flows and inefficiencies of the system. As a result of the research, the highest losses were identified as surface water loss and, secondly, potable water leakage from distribution systems.

2.4.2. Wastewater management studies in Cyprus

Turker et. al. (2005), evaluated wastewater management in the main cities of NC. The municipalities are evaluated for their sewerage availability with the Prioritisation Method.

The method includes social and environmental health effects, the economic sustainability of municipalities, and sanitation.

Elkiran et. al. (2019), focused on the reuse of treated waste as an alternative water resource in North Cyprus. The MBR treatment plant in Nicosia is the largest WWTP in Northern Cyprus. In the article, the importance of the use of effluent water was highlighted due to the quality and amount of treated wastewater.

Bakir (2001) investigated the long-term sustainability of wastewater management for small-scale countries in the Middle East and North Africa suffering from severe water scarcity. The article presents a comprehensive waste management strategy for countries such as Cyprus, Jordan, Morocco, Tunisia, and Bahrain.The author suggests that wastewater be included in the water budget as a resource. In addition, the article mentions that efforts to combat pollution caused by wastewater should be considered.

2.5. Gaps in literature

During a review of the literature, it was observed that there are no articles that include a sustainability index for water resource management planning in North Cyprus. Aside from sustainability, resilience, reliability, vulnerability, and future projections are not included in North Cyprus's management planning.

CHAPTER 3

STUDY AREA

3.1. Introduction to study area

Nicosia City is located in the center of the island of Cyprus (See in Figure 3.1). The island is located in the Eastern Mediterranean region at 35.12 latitude and 33.49 longitude coordinates. Cyprus's climate is semi-arid, with mild, rainy winters and hot summers. (Oktay, 2002; Hadjinicolaou,).

The City is historically and politically significant. It was the first settlement area, and it has been the divided capital between the Republic of Cyprus and the Turkish Republic of North Cyprus since 1974. Topographically, the city is located on the flat and low plain surface of Cyprus island at 35° 10' north and 33° 21' east. The Mesaoria plain is a low-lying area between the Kyrenia and Trodos mountains at the north and south Cyprus, respectively.

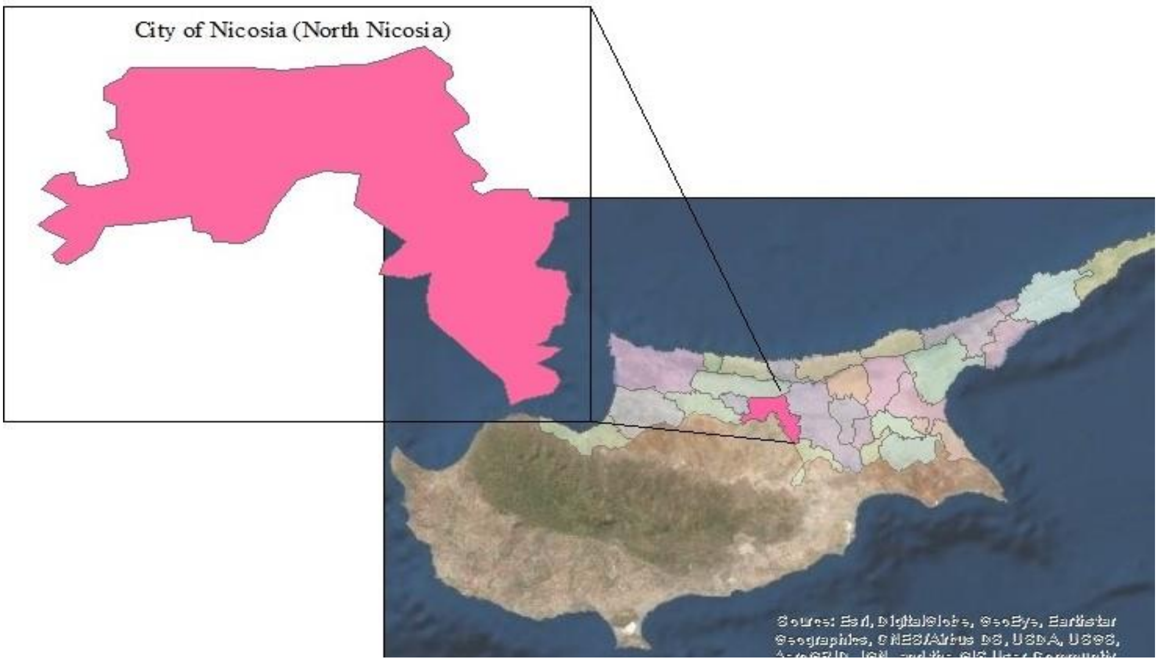

Figure 3. 1: Study area location (Google, n.d).

The topography of the island has an effect on its climate conditions. Summer temperatures in Cyprus's inland cities exceed 40 degrees Celsius. The Nicoisa district of North Cyprus has the highest annual temperatures, while the coastal areas are around 33ºC (Christos et. al. 2012).

Cyprus island is a vulnerable area. For the last decades, the impacts of climate change have been felt with a sudden and high percentage of rain, long and high temperature summers. Flooding and droughts have resulted from changes in climate patterns. The average temperature has risen over the last century, and the effects of climate change have been felt for several decades.

3.2. Urbanization and its impacts on Nicosia City

3.2.1. Urbanization of Nicosia City

Nicosia, the capital of Northern Cyprus, is located on the Nicosia District's border. Since the 1990s, there has been a significant increase in the population and unplanned urbanization (Charalambous et al., 2016) in the Nicosia district, according to the data. The city is particularly important for commercial purposes. As a result of job opportunities and more modern life possibilities, there has been a significant migration from rural areas to Nicosia. In figure 3.3, population projections for the districts of NC have been displayed. As can be seen from table 3.1 within Nicosia District borders, Nicosia City has the highest population. The growth rates due to the population increase between 2006-2020 are displayed in figure 3.4. Nicosia city experienced a 2,98%/year growth projected by the year 2020.

Within Nicosia's Turkish municipal borders, there are 81,893 inhabitants. Apart from the capital city of Nicosia, Louroujina/Akıncılar, Gerolakkos/Alayköy, Kioneli/Gönyeli and Kitrea/Değirmenlik municipalities are also connected to the Nicosia district. Considering the municipalities of the Nicosia district separately, Gönyeli has the highest population growth, which means the fastest increase in urbanization.

Capital Nicosia is governed by the Nicosia Turkish Municipality. Due to its central location and being the capital of the country, the region is a point of attraction in the country in terms of administration, education, trade and culture.

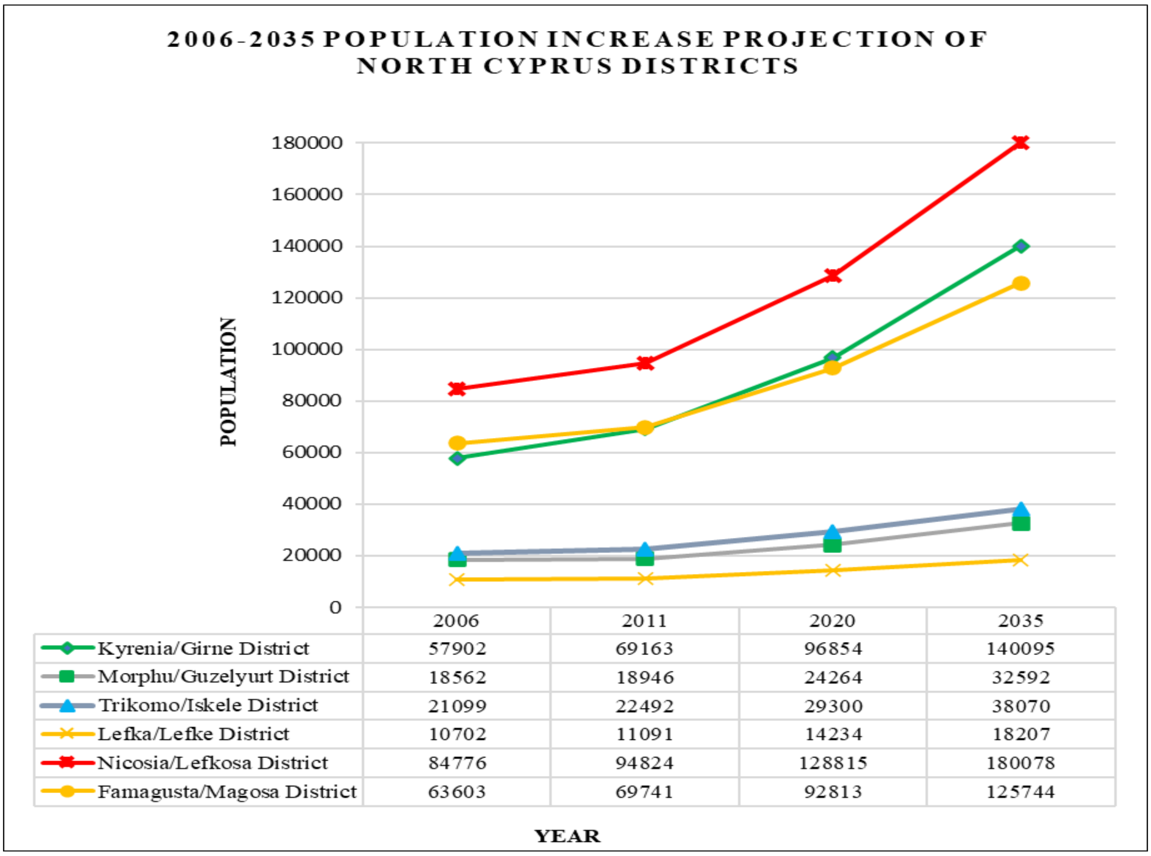

Figure 3.2: Population Increase projections of North Cyprus (TRNC, City planning Department).

Table 3.1: Population projections of Nicosia District (2006-2035) (TRNC, City planning Department).

POPULATION PROJECTIONS (YEAR 2006-2035)				
	2006	**2011**	**2020**	**2035**
Nicosia/ Lefkoşa	56883	61378	81839	112656
Kythrea/ Değirmenlik	11520	11895	15163	19100
Kioneli/Gönyeli	12393	17277	26197	41076
Gerolakkos/Alayköy	3478	3884	5189	6811
Louroujina/Akıncılar	462	390	426	433
Total	84776	94824	128814	180078

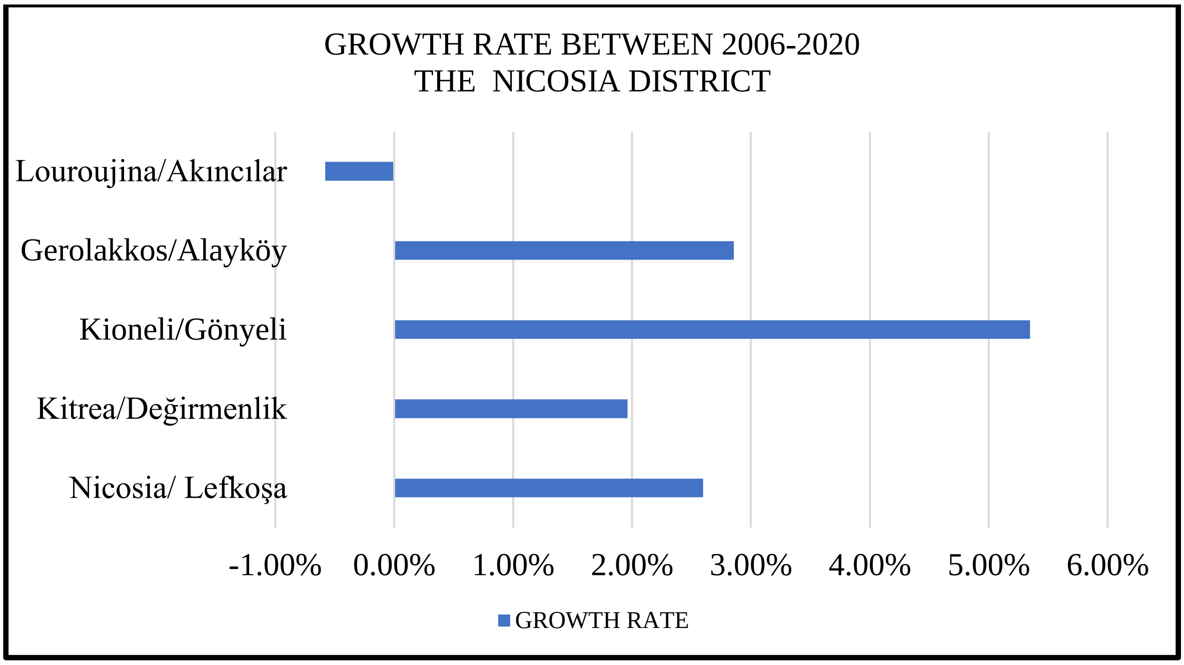

Figure 3.3: Growth Rate of Nicosia District between years 2006-2020 (TRNC, City planning Department).

The urbanization that started within the walled city of Nicosia has grown beyond the city walls over the years. In 2010, the total area of Nicosia city reached 92.8 km^2 with the addition of the Hamitköy/Mandres and Haspola/Mia Milia regions to the Nicosia Turkish Municipality districts.

a. Administrative quarters of Nicosia Turkish Municipality

Capital Nicosia has 25 quarters. 12 of these quarters are in the old walled city and 13 of them are outside. The walled city is the first urbanized area of Nicosia. As a result, it has a rich history as well as cultural ethics.The adaption needed to metropolitan city life has caused changes to the structure of the walled city to host most of the sectoral activities. How ever-changing lifestyles, adaptation to new living standards, overcapacity urbanization, and aging infrastructure have an impact on water and wastewater management.

Eleven of the quarters are outside of the walled city. They are newer settlements, but the water and wastewater infrastructure in some areas is as old as a walled city. The first comprehensive water and waste water infrastructure projects were built in the 1970s in Walled City and the Çağlayan quarter.

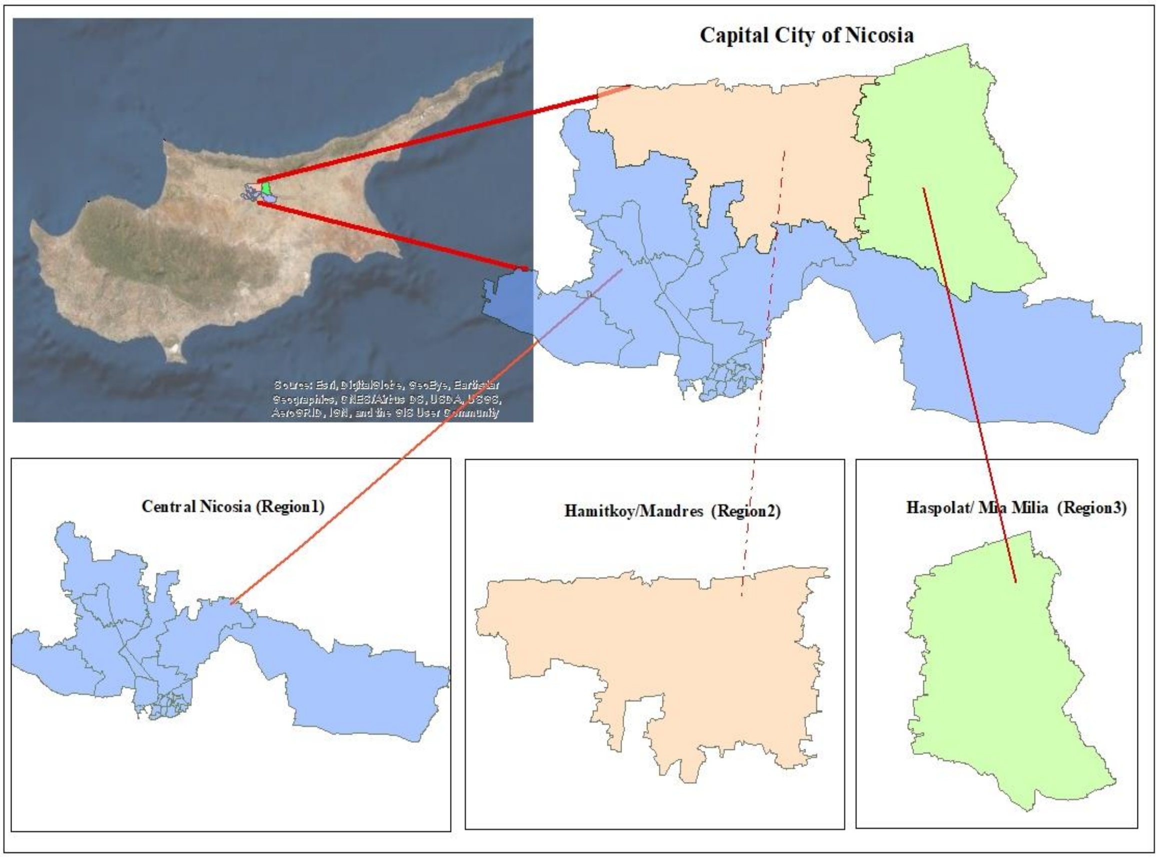

Figure 3. 4: Administrative borders of Nicosia Turkish Municipality (Google, n.d).

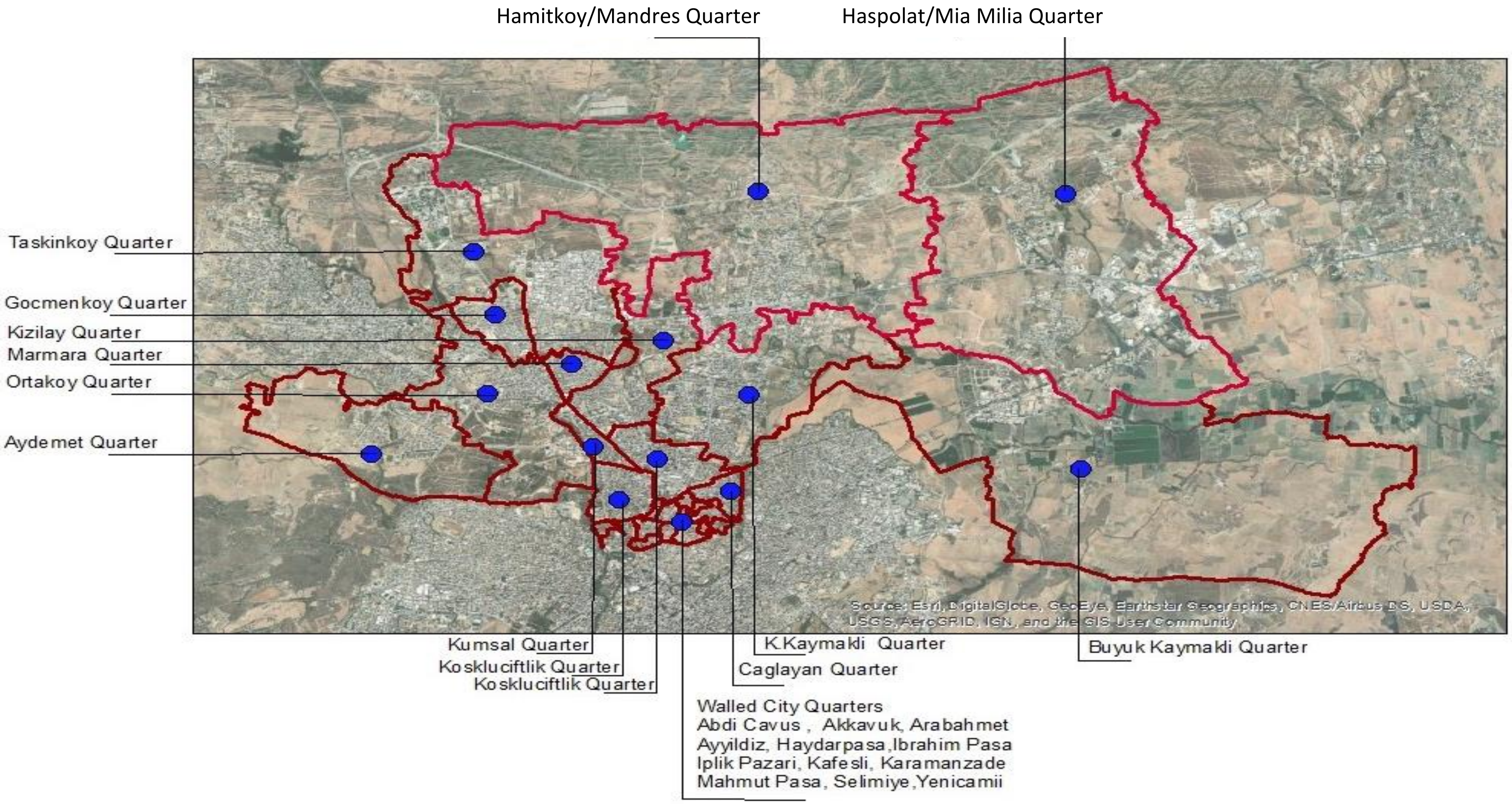

Figure 3. 5: Quarters of capital city of Nicosia (Google, n.d).

In this study, walled city and 11 quarters at the outside the walledcity are considered as the Central Nicosia/Lefkosa (Region 1) (see in figure 3.4). The area is a combination of 23 quarters and covers an area of 58 km^2. There are residential areas, governmental areas, educational institutions, and industrial zones in these areas shown in figure 3.6.

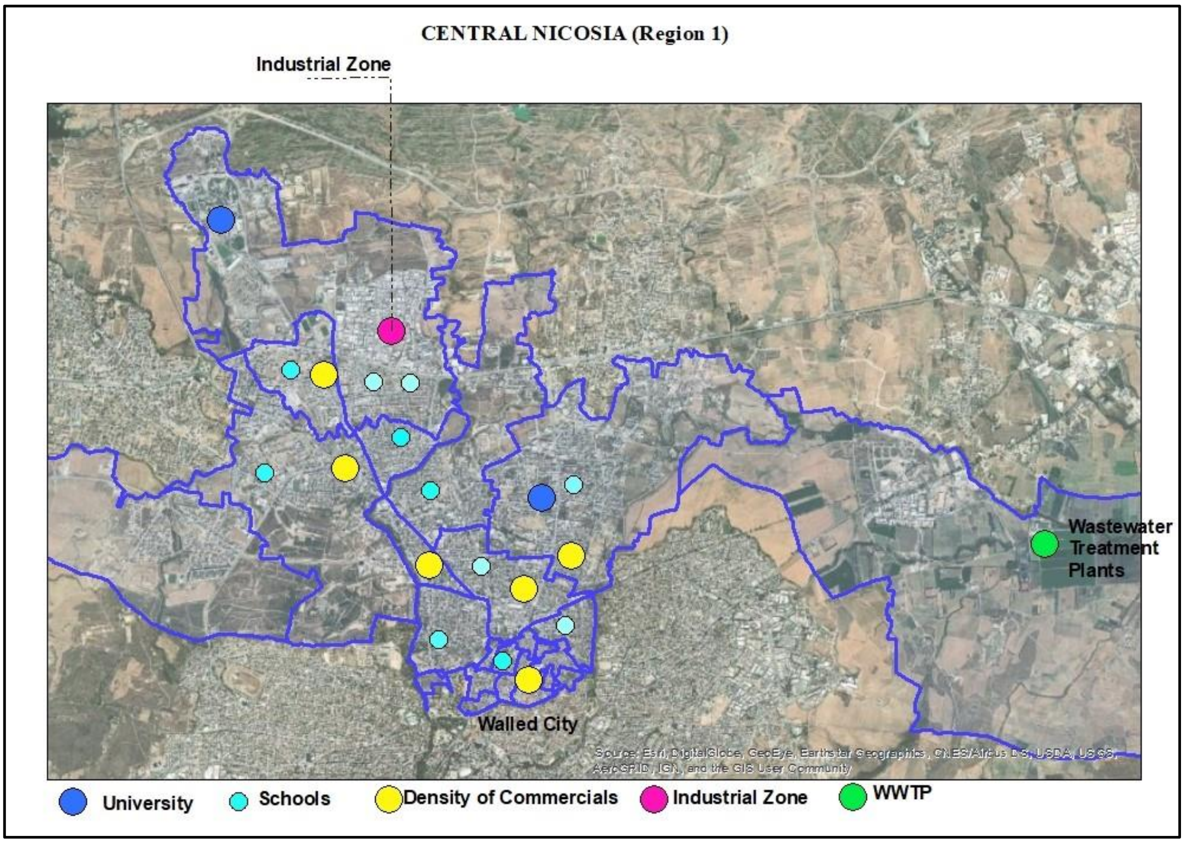

Figure 3.6: Central Nicosia (Region 1) borders (Google, n.d).

According to the 2006 census, the population of Central Nicosia was 49,868. The density of industrial, educational, and business centers in this region is a factor in the rapid progress of urbanization and the population. The projections show that the population in 2020 will be nearly 68,115 and in the year 2035, it is predicted to reach 92,593. The density of workplaces and educational institutions in this region significantly increases the daily population, with employees and students coming from outside of Nicosia.

Hamitkoy/Mandres (Region 2) is one of the quarters of Nicosia City. It was added to the districts of the city in 2010 with changed regulations. With these changes, the economic value of the region has been affected positively but has caused unplanned expansion and rapid urbanization.

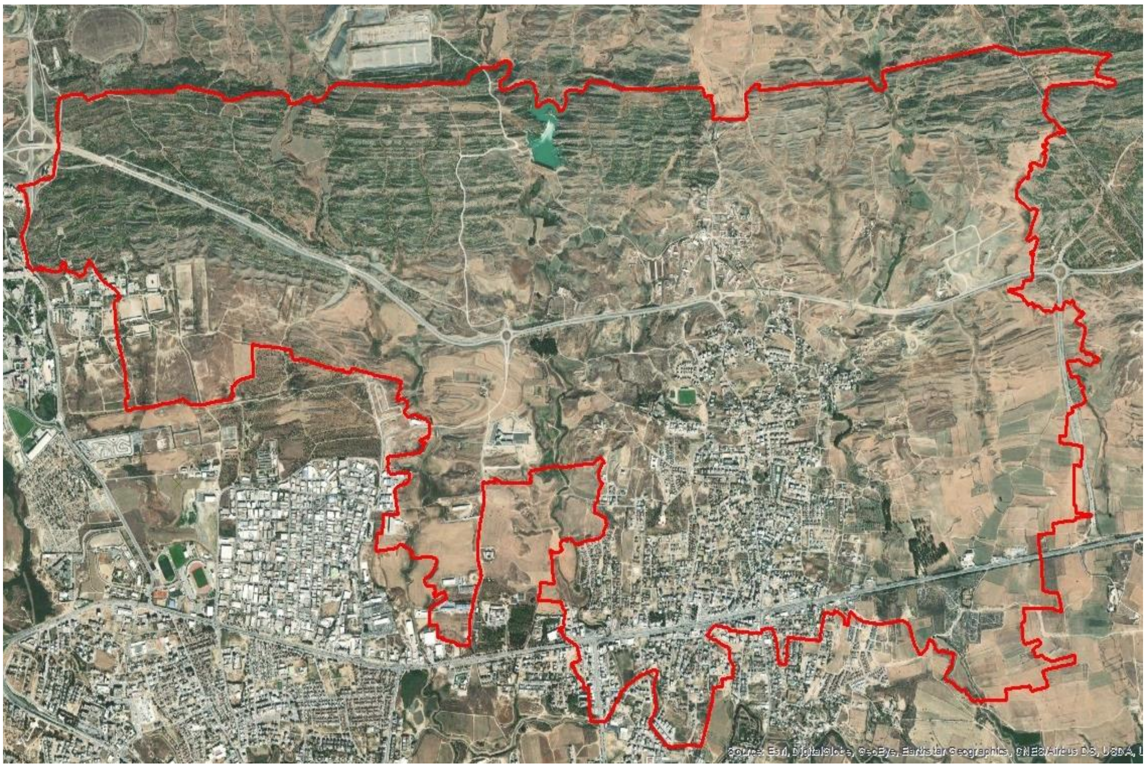

Figure 3.7: Hamitkoy/ Mandres quarter (Region 2) borders (Google, n.d).

The Hamitköy/Mandres quarter (Region 3) covers 17 km^2. Before 2010, agriculture and farming were the sources of income in the region. For the time being, farming is observed to be at a very low rate, and there is a high and steadily increasing density of residentials.The region's population is growing at the fastest rate.The population of Hamitkoy was 2,898 in 2006, but after the district changes, the population increased to 8,448 by 2020, and it is expected to reach 13,665 by 2035.

With regulatoin changes in 2010, the Nicosia city Haspolat/Mia Milia quarter was connected to the borders of NTM. Within the borders of the Haspolat region, there is a university, an industrial zone, residential, farming, and agricultural areas. The resident population of

Haspolat was 4,117 according to the 2006 census, and the residents' population has increased in the normal course since entering the governance of NTM.

The university, which has a capacity of 18,000 students and is located in the region, has had a significant impact on the Haspolat population.The industrial zone also has an effect on the daily population density.

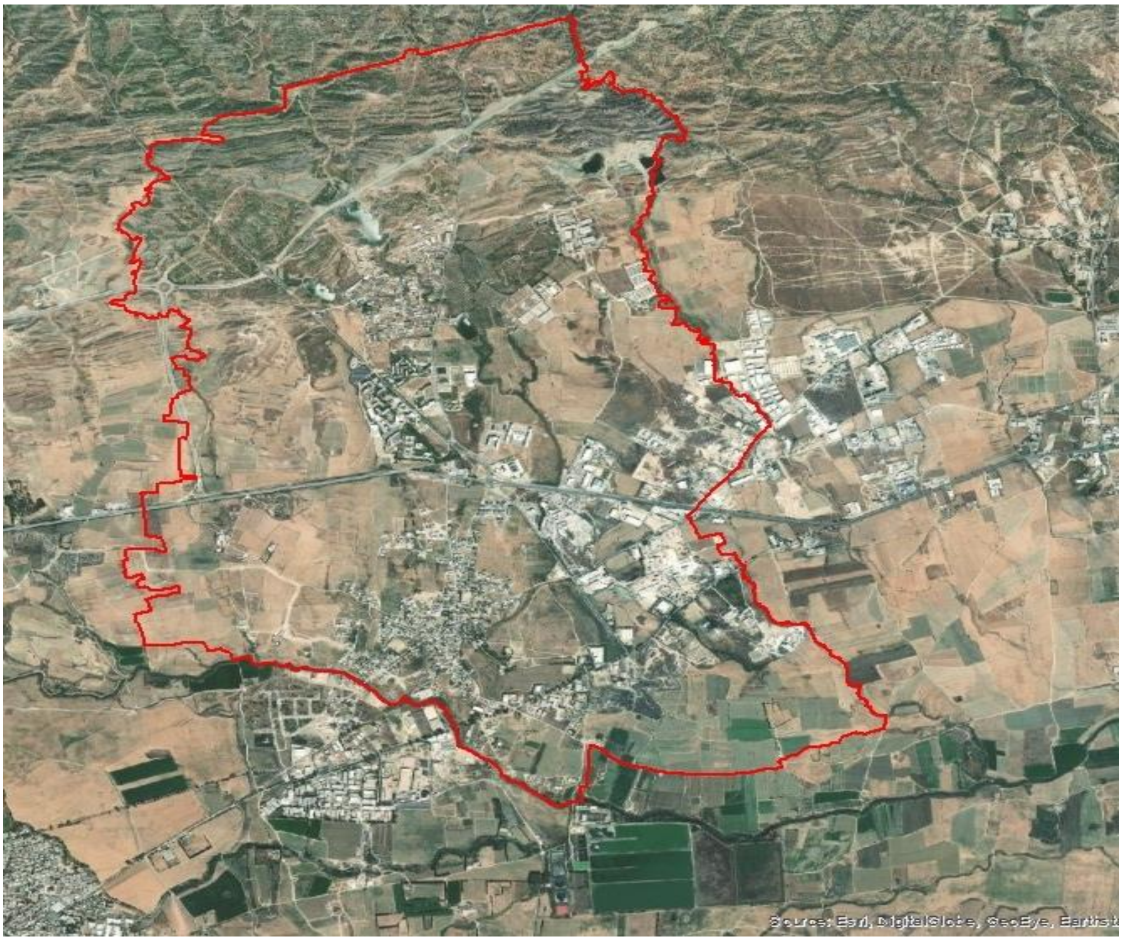

Figure 3.8: Haspolat/Mia Milia quarter (Region 3) borders (Google, n.d).

3.2.2. Impacts of Urbanization on North Nicosia

Increasing city population in relation to growing district areas creates a challenge for municipalities in providing services and has a negative impact on management costs. In particular, inadequences of the infrastructure assets as water, wastewater and drainage are main consequence of the rapid and unplanned urbanization. Infrastructure projects are expensive, and municipalities face challenges in implementing these investments within their own economies. Water scarcity is another result of cities' rapid expansion. Municipalities are in charge of water distribution to homes, and they will face water shortages in the coming years.

In the case of water issues, spatial developments in urban areas have an impact on both quantity and quality. Access to safe water is a global-scale, water-related issue. Many countries around the world are suffering by scarcity and contamination of their water resources. One of the reasons for both threats is associated with unpredicted population agglomerations and unmanaged land expansions (Brookshire and Whittington, 1993). It is inevitable that, unplanned processes for the development severe the water crisses. While cities are developing, many water -related problems occur. These problems has affects on the activities of environment, socieities, agriculture and industry. Apart from these unplanned developments, climate change also contributes to the increase in water issues.

The Nicosia Turkish Municipality has faced the challenges of rapid urbanization in the recent past. After the expansion of the borders, deficiencies in the sewerage, water and drainage systems have emerged. The growth of the service area has increased the operations and costs of the municipality.

Sewerage, water, and drainage system deficiencies are potential problems for the economy, the environment, and society. The most critical impact of rapid and unplanned urbanization is inadequate sewerage systems. The lack of sewerage system has created serious environmental and social health problems. In some areas of Nicosia, due to the impermiable soil, insufficient cesspools and septic tanks cause environmetal damages and problems for dwells and municipality.

After 2010, the percentage of available sewer assets decreased from 70% to 50% based on the district borders of the municipality. With the significant investments, the percentage of sewerage system assets covers 75% by 2020.

Water stress is another issue that rapid urbanization and inreased population cause deficiencies on the economy of municipality to meet demand. Also repairs, renovation and construction of new water distirbution systems are high cost implementations. Lack of the local water resources and and leakages on the system increases the cost of water supply for NTM.

Another water-related impact of unplanned urbanization is the inadequacy of drainage systems. With urbanization, most areas are covered with asphalt and concrete buildings. This action reduced the permeable soil areas for rainwater infiltration. Therefore, some areas experienced flooding as a result of a lack of available or insufficient drainage systems to carry runoff water.

3.3. Water resources of North Cyprus

Water scarcity is one of the most serious problems on most small islands (Falkland, 1999). Islands are isolated from the mainland and have very limited water resources available. Cyprus Island also presents an ongoing water challenge. Especially after the 1960's, with the expansion of agricultural activities, the demand for water has been increased (Gokcekus et. al., 1997). Between 1960 and 2017, groundwater resources were the major water supply to meet required water needs for all purposes (Gokcekus et al., 2018). The groundwater availability was depened on the precipitation (Elkiran and Ergil, 2006). Climate change has had a significant impact on precipitation over the last few decades (Sozen, 2017; TRNC, 2017). The drought of the 1970s exacerbated the water stress. The reduction of precipitation caused uncontrolled and excessive water extraction from the aquifers (Gokcekus et. al, 1997). Due to poor management, the aquifers are polluted and most of them have completed their service life.

North Cyprus has four main aquifers with the total capacity of 93.85 million m^3/year. These aquifers have supplied 90% of the water demand for many years (Gokmenoglu and Erduran, 2002).

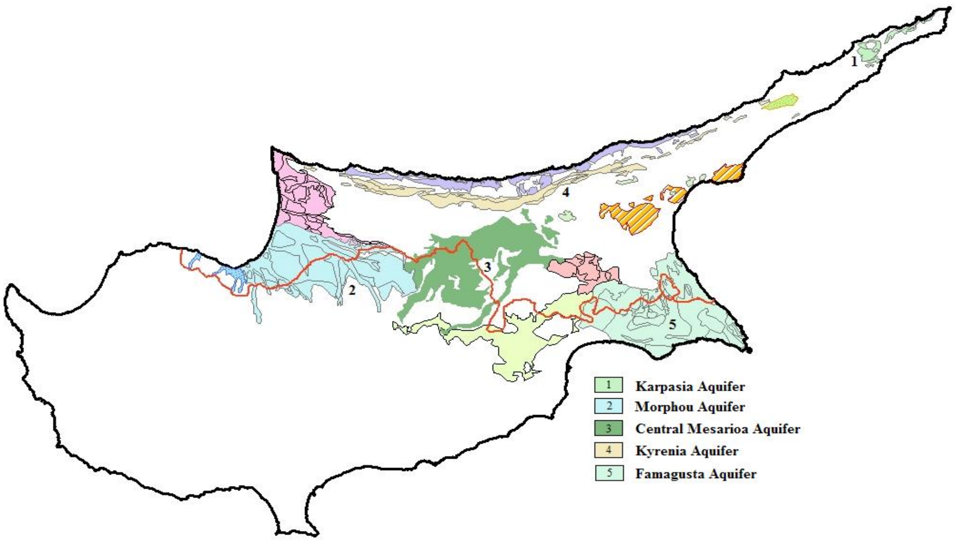

Figure 3.9: The Aquifers of North Cyprus (Turker and Hansen, 2012).

The decline of groundwater, pollution, and salt intrusion into aquifers have all posed serious challenges to North Cyprus's water management. To meet the needed demand and protect the depletion of the aquifers, many techniques and projects have been applied.

One of them was the construction of dams to conserve and utilize surface water. Between 1990 and 1997, 37 dams were built in North Cyprus (Konteatis, 1994). Between 1998 and 2002, another project was implemented to transport municipal water from Anamur (Turkey) to North Cyprus using water bags. It was expected that this project would transport 5 million cubic meters per year, but only 4.1 million cubic meters have been transported in the first five years.

The latest and most impressive transfer water project that supplies freshwater to the whole North Cyprus. The project is a milestone for water scarcity of NC. The Water transportation from Anamur (Turkey) to North Cyprus was designed to transfer 75 MCM of water to the Geçitköy Dam (North Cyprus) (Gokcekus et. al., 2018). Since the completion of the project, the transported water has been used mostly for municipal, agricultural and industrial purposes.

 In the city of Nicosia, 90% of its water demands were provided by the Güzelyurt aquifer until 2017. Currently, all water demand are met by high quaility tranfer water from Turkey.

3.3.1. Water Bodies within the Nicosia City Boundaries

a. Aquifer

The Central Mesaoria Aqifer is at the Nicosia District. The Aqufier expands from Nicosia to Serdarlı and it has diffuse pollution due to the urban, agricultural activities. The primary cause of urban pollution is a lack of sewerage systems. Waste collection in septic tanks and cesspools has the potential to pollute the groundwater. Also, the aquifer has specific pollution due to industrial wastewater and unsuitable wastewater treatment plant discharges (Turker and Hansen, 2012).

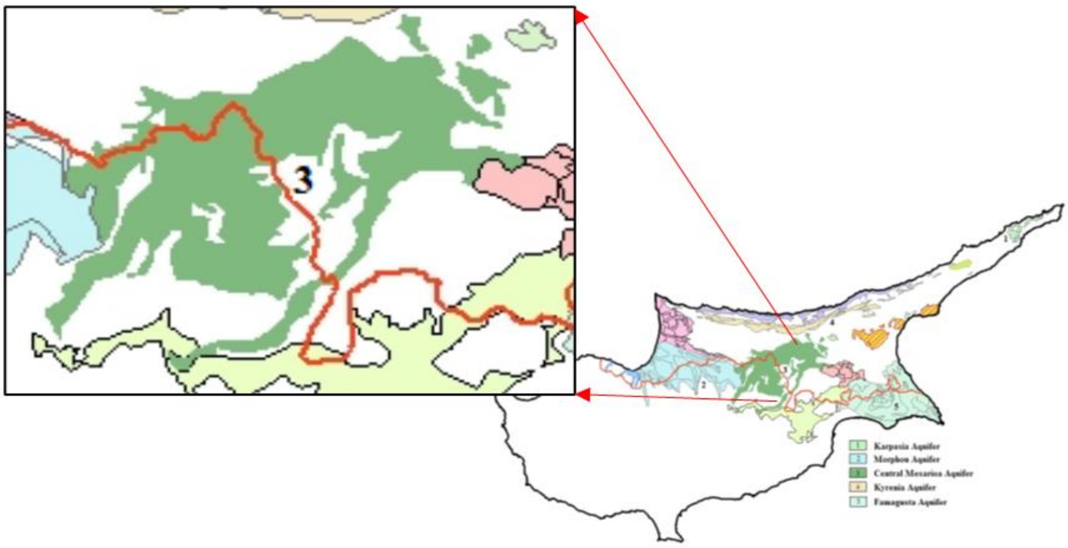

Figure 3. 10: Central masaoria aquifer. (Edited from Turker and Hansen, 2012)

b. Ponds

Within the boundaries of the city, there are two ponds in Hamitkoy/Mandres and Haspolat/ Mia Milia, which are under the control of the water works department (WWD) of the government. Hamitkoy/Mandres Baştanlıkdere earth pond has a 529.123 m^3 capacity. The pond’s fill rate depend on the surface water. The pond collects surface water and located at the northwestern part of Hamitköy/Mandres at 35° 14 "18.18 8" N and 33° 21 "48.086" E coordinates (TRNC Environment Law, 2014).

The dam was built in 1992 to provide 75 hectares of spring irrigation (Figure 3.10). According to the WWD’s datas the minimum full rate of the pond was %26 in Agust 2018. With the increase of rainfall in the following year, the full rate has been reached to 100%. These data’s indicates that the location of the pond is suitable to conserve water even during the dry summer months.

The Haspolat/Mia Milia Pond is located in the upper part of Haspolat/Mia Milia at 37° 14 " 42.58 N and 33° 24 49.925 E (TRNC Environ Law, 2007). The pond has a capacity of 117.390 m^3 (WWD, 2019).The pond was built for irrigation purposes in 1962 (Gokcekus et al., 1997). The data from WWD shows that from 2017 till December of 2018, the pond was dry. With the increased precipitation in 2019, the pond measured a 100% full rate (WWD, 2019). (Figure 3.11)

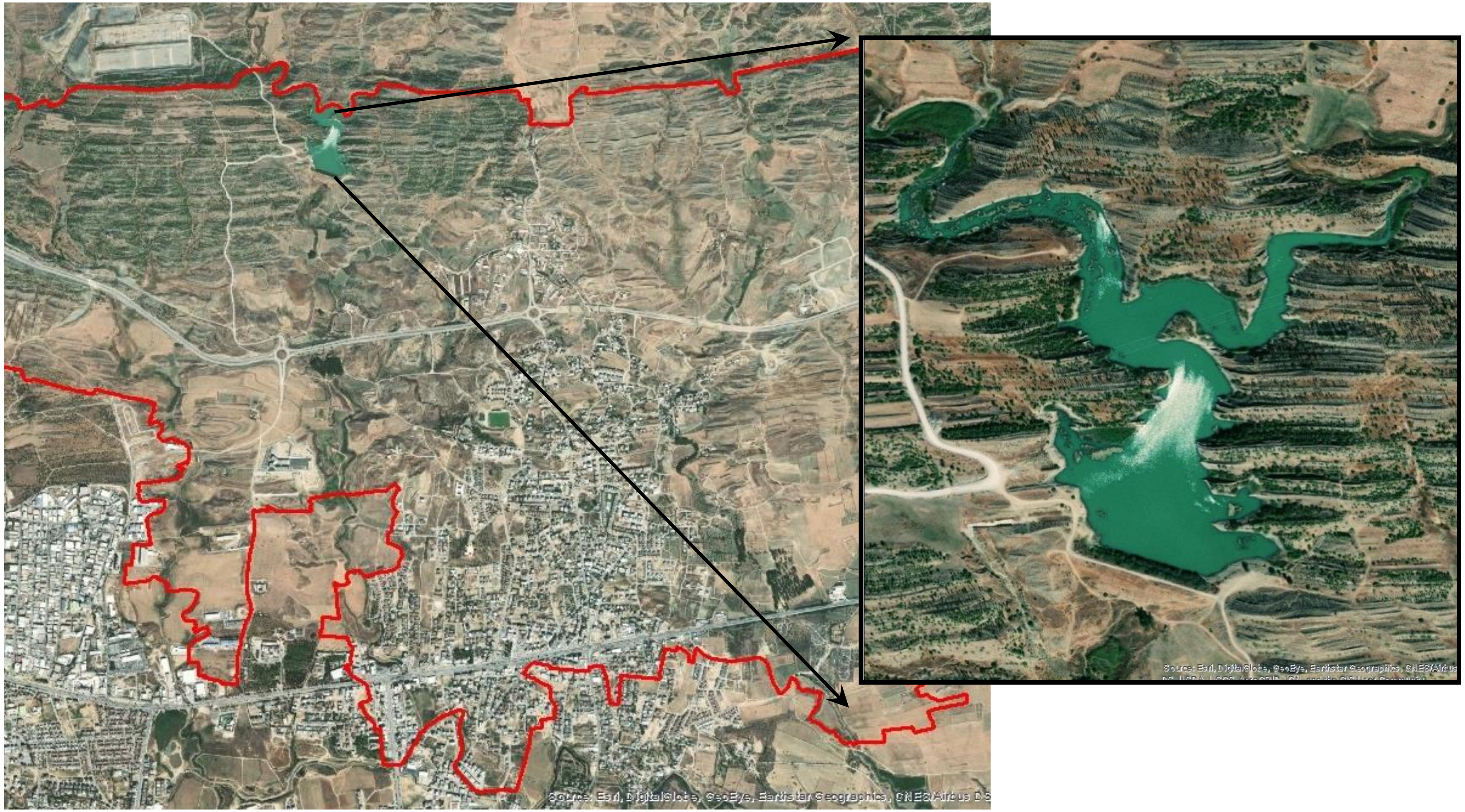

Figure 3. 11: Hamitkoy/Mandres Baştanlıkdere earth pond (Google, n.d).

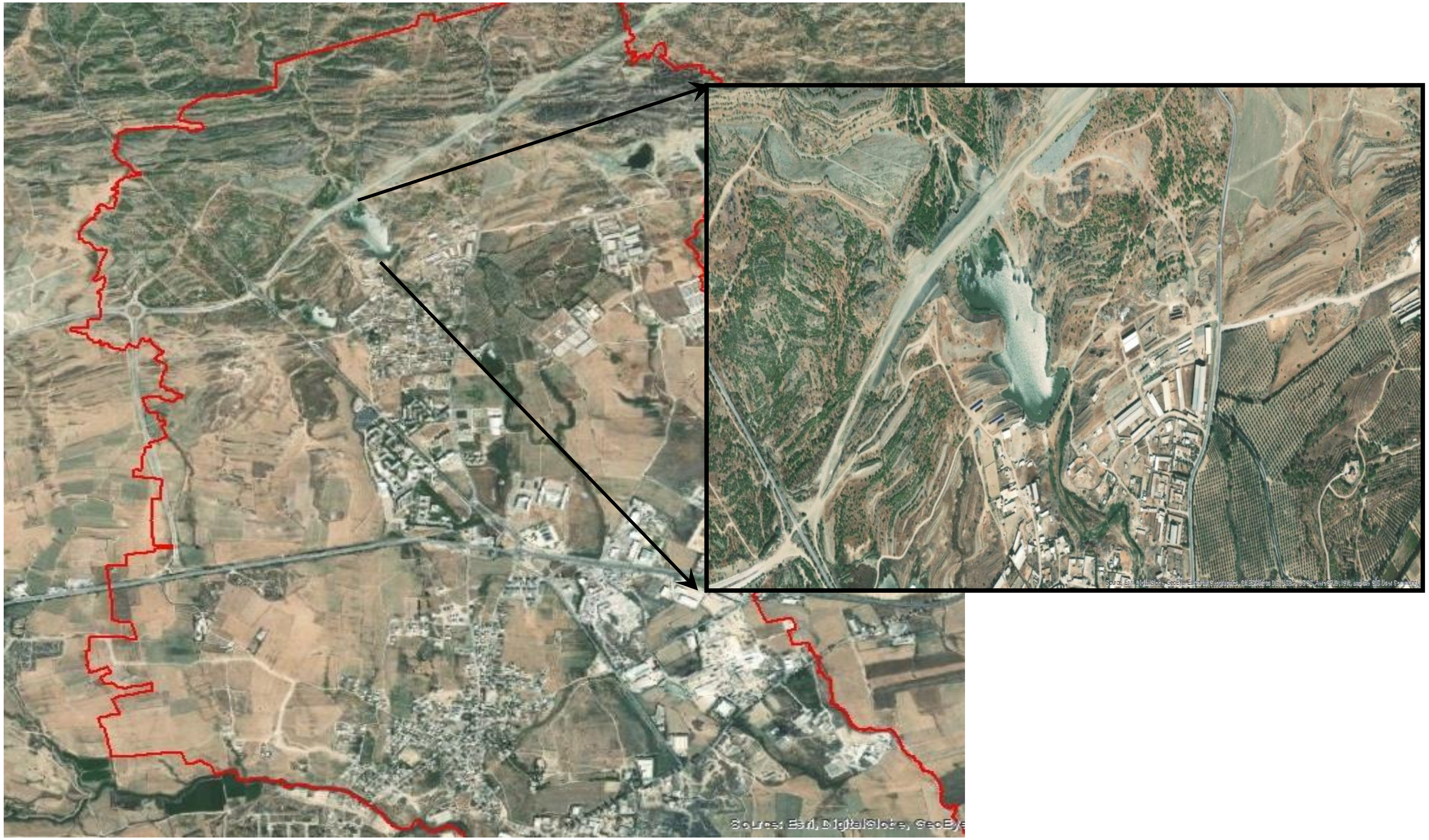

Figure 3. 12: Haspolat earth pond (Google, n.d).

c. River

The Trodos and Kyrenia Mountains are the starting points for the streams in Cyprus. The flow of the streams depends on the snow melting from the Trodos mountains and the rainfall. The Pedieos is the longest stream on the island with 100 km length. It begins from the Trodos mountains and passes through the central Mesaoria plain where Nicosia City is located. *Pedieos River* is non perennial but has importance for North Cypus that provides water to a large part of the city of Nicosia for agriculture activites.

Due to the overflooding of Pedios river, there have been many inundations in Nicosia since the 14th century. With the climate change effects flooding occurring more occasionally (Charalambous et al., 2016). In the north part of Cyprus, the pedieos river except runoff water from Trodos Mountains collects surface water, runoff from small streams, and effluent discharge from WWTP.

The rehabilitation of the pedios stream, which is home to various flora and fauna, is provided by the Nicosia Turkish Municipality's own efforts, but the absence of a flood management plan cannot prevent the illegal construction and discharge of pollutants into the stream.

d. Artificial Water Bodies

In North Cyprus there are six main wastwater treatment plants (WWTP) (Gokcekus et. al., 2019) except the small ones services for hotels and some building complexes. Within the boundaries and govern of Nicosia Turkish Municipality, there area 2 wastewater treatment plants. The old WWTP was Haspolat/MiaMilia treatment plant. The plant was build as bi-communal to serve Northern and Southern parts of Nicosia in 1970's. The Haspolat/Mia Milia Treatment Plant has been designed to operate with a lagoon system. Over the time, the plant has become insufficient in capacity and quality of treated water. Therefore, the largest treatment plant of NC has been built with advanced biological nutrient removal MBR system with 30,000m3/day treatment capasity (Gokcekus et. al., 2019). The old treatment plant (Hapolat/Miamilli WTP), currently operating for treatment of industrial wastewater.

The New Nicosia Waste Water Treatment Plant (NWWTP) is a bicommunal project that collects domestic waste from North Nicosia (30%) and South Nicosia (70%). The signed agreement between the two communities specifies a 30:70 ratio of effluent water distribution to the Turkish and Greek Cypriot communities, respectively. According to this agreement, approximately 3.3 MCM of effluent water per year can be reused for agricultural irrigation in North Cyprus.

There are agricultural fields for vegetables and fruits in the Haspolat region. Depending on the type of crop, approximately 500 hectares can be irrigated with this volume of effluent water. There are studies done by the EU and possible crop patterns have been determined regarding the available cultivated land, such as fodder crops (barley, wheat, sorghum and alfalfa), olive trees, date palms and pomegranate trees.

Effluent water is an important source for agriculture due to the possibility to recycle nutrients and water and thus reduces the costs of fertilisers for farmers.

The plant was built in accordance with EU standards and criteria. MBR system has a clear advantages that the quality of the effluent is proper to use for agriculture, aquifer recharge, recreation and process water for industry. Furthermore, the use of MBR reduces the land's footprint significantly. For example, the old Haspolat plant covers an area of 900.000 m^2, whereas the new plant only requires 35,000 m^2.

The laboratory results show that the NWWTP outlet water complied with the EU urban water treatment directive 91/271/EEC (Table 3.2).

Table 3. 2: Comparison of NWWTP Outlet Water Parameters 2020 and EU standards (Nicosia Turkish Municipality, 2021)

New Nicosia Waste Water Treatment Plant Outlet Water Parameters		
Parameters	New Nicosia Waste Water Treatment	EU Standards
BOD	4 mg/lt	25 mg/lt
COD	22 mg/lt	125 mg/lt
TSS	<5 mg/lt	35 mg/lt
Total Nitrogen	8,8 mg/lt	10 mg/lt
Total	0.5 mg/lt	1 mg/lt

Rather than being used for agriculture, effluent can be used for a variety of purposes, including toilet flashing in commercial buildings, forestry, fire protection, and landscaping.Unfortunately, due to public perceptions, the reuse of treated waste has been difficult.In order for the public to accept it, various awareness studies should be carried out and they should be endorsed by doctors and scientists.

Including effluent in the water budget has obvious benefits for all parties. The municipal budget and the agricultural sector will benefit from selling treated water at a lower price than potable water.

The treated wastewater from both plants is discharged to the Pedieos river and the water is pumped from the river by farmers into the agricultural fields located along the Pedeios River.

Figure 3. 13: Treatment Plants within NTM boundaries. Number1, old wastewater treatment plant . Number 2 , New wastewater treatment plant (Google, n.d).

3.4. Water Consumption of Nicosia City

Water consumption is described by several types of demand, and different sectors of society use water for various purposes, such as domestic, agricultural, and industrial uses (Gleick, 1996). Domestic consumption refers to a person's daily water requirements for basic needs such as cooking and household work. The consumption of water is the amount of water to meet the basic needs of an individual to survive.

According to the World Health Organization, a minimum of 50 to 100 liters per day of water is needed for a human to meet basic demands (WHO,2018). The amount of daily domestic water consumption per capita varies with daily life routine standards, seasons, technology, water welfare and the cost of water (White G.F. et al., 1972).

Municipal water distribution includes the daily demand for the public, as well as the need for the production of agriculture and industry. Municipal water also includes water needed for the landscape, facilities, and other public services. Therefore, the water consumption of a municipality covers all together. Meeting all the demand and ensuring the sustainability is serious responsiblity for the satisfaction. The water consumption purposes can change in a city. While some regions only need domestic water, some regions may use more water for agricultural activities. Aside from that, building structures can influence water consumption, such as residents with gardens who may use more water than a flat.

In Nicosia City, there are consumption purpose differences between the quarters due to the structures of the settlements. The Central Nicosia has been developed with more commecials and apartments at the center but the expantion to the west of the city is developing with more indivudual residentals with gardens. Furthermore, The demand character in Hamitköy and Haspolat is different than in Central Nicosia due to the agricultural activities in both regions.

Apart from the individuals and municipal basic water consumption, the leakages on the water systems increase the amount of water consumption and costs of water distributors. Until 2017, groundwater transfer from the Guzelyurt aquifer was the primary resource for

Nicosia's irrigation and municipal needs. Since the 1970s, the country has faced serious problems with groundwater quality and water scarcity. The water transfer project from Turkey is a new water resource that will meet the entire demand. All over North Cyprus, around 111,000 m^3/d municipal water is needed to meet demands in residental areas (Gokcekus et. al,2019). 21% of the total resident population in the country live in the city of Nicosia and the collected datas from water supplier shows that around 16,000 to 19,000 m^3/day water consumption occur which corresponding to 4,7 million m^3/year.

Currently, the transfer water from Turkey is the only source of water consumption in Nicosia.The water transfer is sufficient to meet the country's water needs.The management of water has great importance for sustainability and avoiding the cost of water for municipalities. Therefore, minimizing the water consume relatively cost on the municipality is important for sustainability.

The cracks and leakages on the water distribution systems are the major problems of the exceeding amount of water consume. Municipalities' water consumption costs can be reduced by determining and repairing the system. The accepted water loss in the world is less than 10% (AWWA, 1996), which technically cannot be avoided, but according to information obtained, the leakage into the system may reach 60% in some regions due to deteriorated pipe material that has reached the end of its economic life.Unavoidable water loss is economically accepted, but more than this amount should be controlled. A management plan has four components: leak detection, pressure and level control, faster response time for leak repair, maintenance, and rehabilitation, and ensuring the control and action of avoidable water losses (Thornton, 2008).

3.5. Water quality

The quality of the water is a major problem for the groundwater resources of North Cyprus. Over the years, the increase in agricultural activities and the population has caused more over-pumping of water from aquifers (Ergil, 2000). Increased demand for coastal aquifers has resulted in seawater intrusion, which is the major pollutant in the aquifers and has resulted in the depletion of North Cyprus's main freshwater aquifers. Inland aquifers are also depleted due to the over-extraction of water. The main pollutant of the inland aquifers is seepage of the soluble materials of geological formations, urban waste, and agricultural disinfestation activities (Turker and Hansen, 2012; Turker et. al., 2013,). Before transfer water from Turkey, the demand for Nicosia was supplied mainly by the Güzelyurt Aquifer. The salinity of the water from the aquifer was reported to be from 2,340 to 4,095 mg/L, between the years 2010 and 2016 in Nicosia City (Gokcekus et. al., 2018). Aquifer extraction has been reduced with the addition of new resource of transfer water from Turkey, which has a significant impact on rehabilitating local resources. Figure 3.13 represents the quality differences in the water in Nicosia City (Gokcekus et. al., 2018).

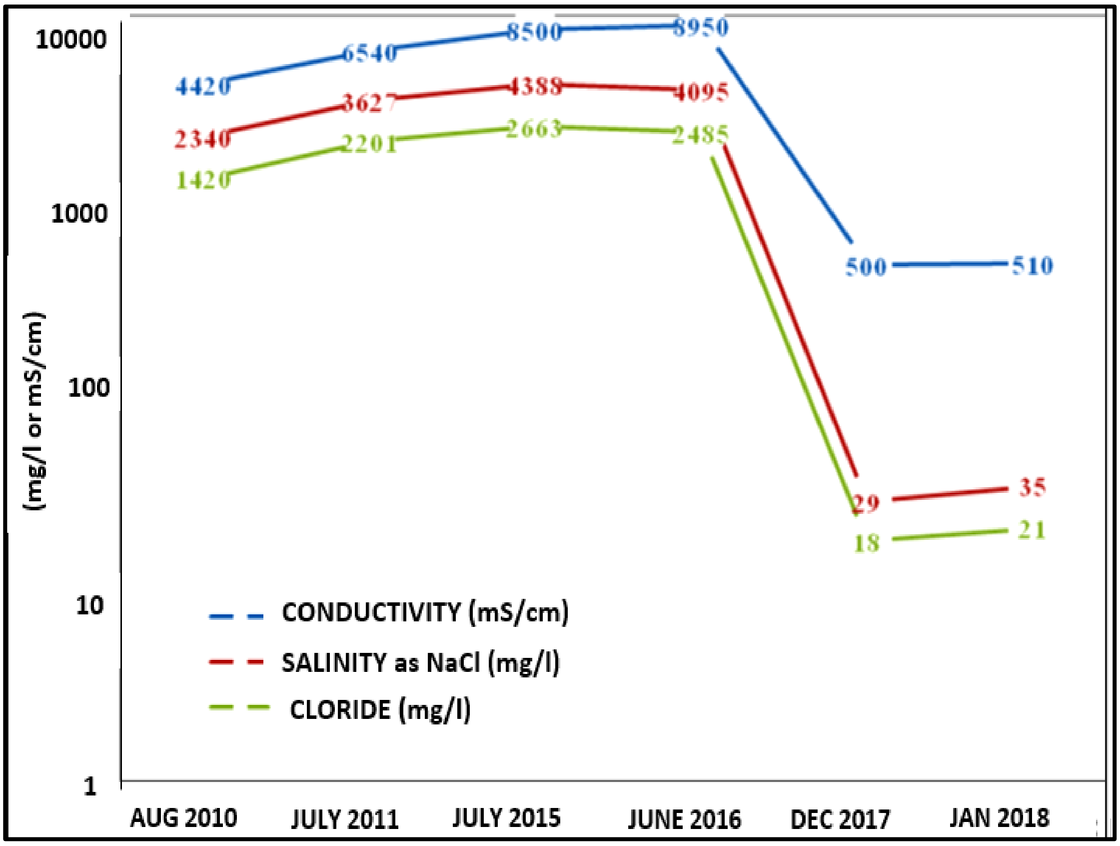

Figure 3.14: Water quality changes in Nicosia after the transportation of freshwater between 2010 to 2018 (Gokcekus et. al, 2018).

3.6. Data

Water consumption data was used to determine the sustainability of the current situation.The water consumption data is between the period of January 2018- December 2020. (Appendix

1). This period is after the transfer water supply. As mentioned above, in this study, according to the obtained data, Nicosia City water consumption was evaluated in three regions.

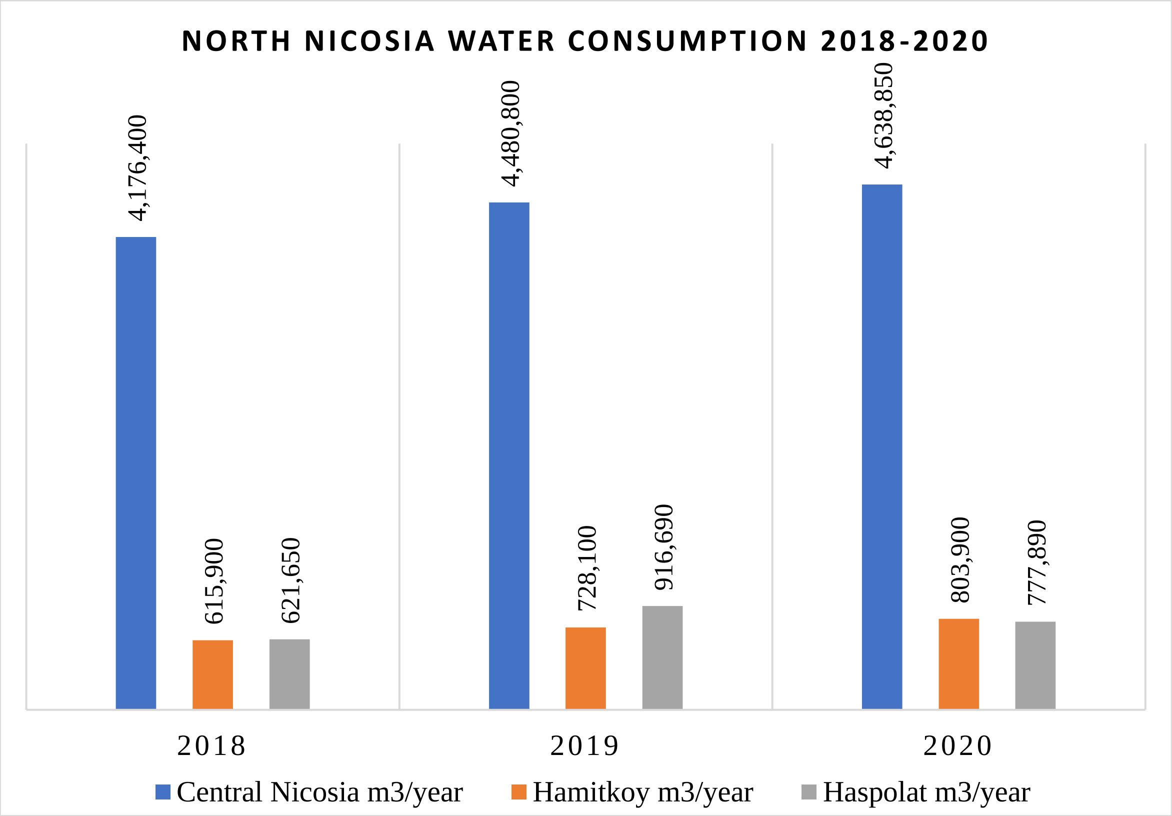

Figure 3.15: North Nicosia water consumption 2018 – 2020 (Nicosia Turkish Municipality, 2021)

The population projection data was obtained from the TRNC's City Planning Department. The last population census was in 2006 and calculations based on the population are made through projections (Appendix 2).

The current administrative Nicosia city map, local settlement distribution, industrial and agricultural activities have all been studied and used to determine the density and characteristics of the boundaries.

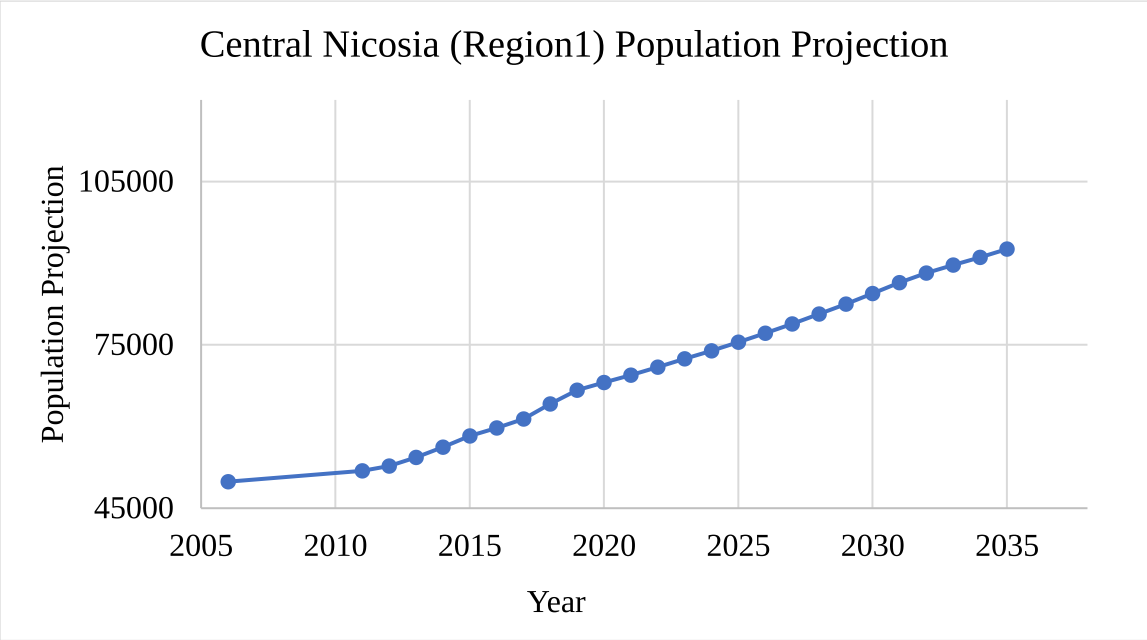

Figure 3.16: Central Nicosia (Region1) population projection.
(City Planning Department TRNC)

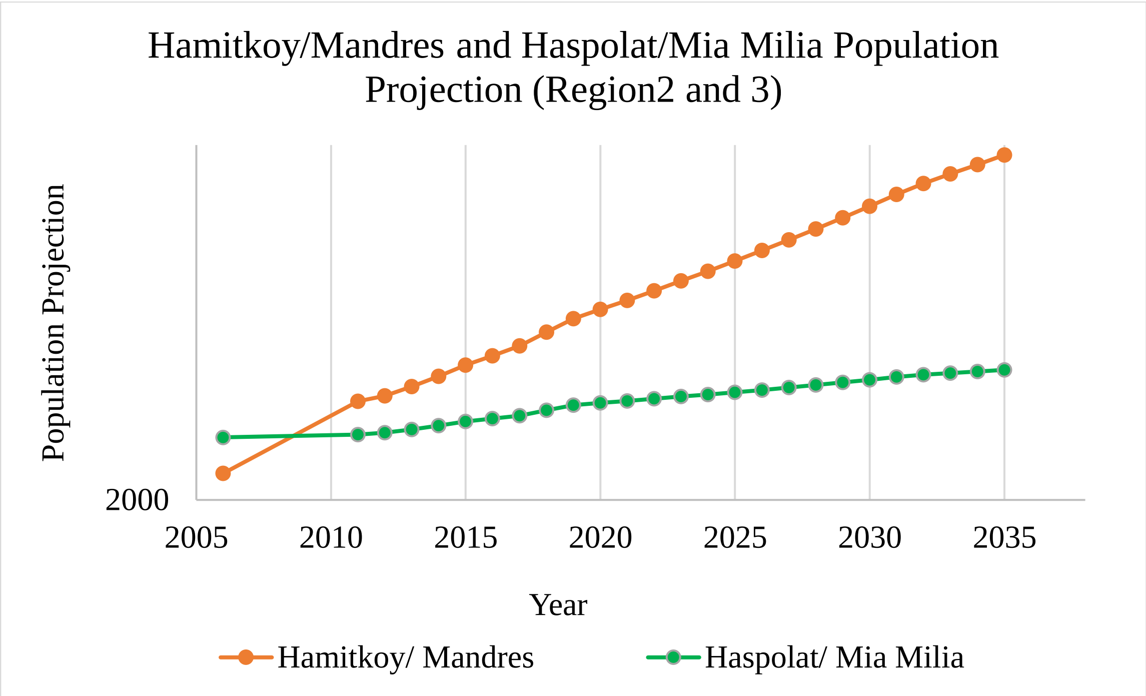

Figure 3.17: Hamitkoy/Mandres and Haspolat/ Mia Milia population projection.
(City Planning department TRNC).

CHAPTER 4

METHODOLOGY

The study was conducted to characterize the current sustainability performance of water distribution in Nicosia City to form the basis for a sustainable water management program (Sandoval et. al., 2011).

4.1. The Performance criterias and Sustaibanility Index Calculations

The performance criteria parameters are reliability, resiliance and vulnerability. In order to evaluate the management of water systems, these parameters are utilized. This new concept of the Sustainability Index (SI), measures the long-term viability of water policy from the perspectives of water supply and demand performance. Also, the sustainability index is a measure of the capacity of the system to decrease vulnerability (Sandoval et. al., 2011).

4.1.1. Reliability

Reliability quantifies the water demand probability that the water supply meets. (Hashimoto et al. 1982).

The calculation of reliability based on the time period **(t)** and deficits ($\boldsymbol{D_t^i}$)**.** For each time period ; (Loucks, 1997)

$\mathbf{D_t^i}$ is **positive** if $\boldsymbol{X^i_{Target,t}} > \boldsymbol{X^i_{supplied,t}}$ (4.1)

$\mathbf{D_t^i}$ is **zero** **if** $\boldsymbol{X^i_{Target,t}} = \boldsymbol{X^i_{supplied,t}}$ (4.2)

$$\mathbf{D_t^i} = \begin{cases} X^i_{Target,t} - X^i_{supplied,t} & \text{if } X^i_{Target,t} > X^i_{supplied,t} \\ 0 & \text{if } X^i_{Target,t} = X^i_{supplied,t} \end{cases} \quad (4.3)$$

Reliability (Rel^i) is quantified as the number times deficits occurs ($\boldsymbol{D_t^i = 0}$) with respect to the number of time (n)periods considered (n= months or years) (McMahon et al. 2006).

$$\mathbf{Rel^i} = \frac{\text{number of } D_t^i{=}0}{n} \tag{4.4}$$

4.1.2. Resilience

Resilience is the probability that a system recovers from deficits and failures. (Hashimoto et al. 1982).The most effective change in water resources is changing climate conditions. Therefore, water management policies must be able to adapt to changing climatic conditions. The ability of a system to adapt to potential changes is referred to as resilience (Res^i) (WHO, 2008). Res^i is a probability that depends on the number of successful periods following a failure period with respect to all failure periods.

$$\mathbf{Res}^i = \frac{\text{number of times } D_t^i \text{ follows } D_t^i{>}0}{\text{number of time } D_t^i{>}0 \ \mathit{occured}} \tag{4.5}$$

4.1.3. Vulnerability

The magnitude of the failure is described by vulnerability. Loucks and van Beek 2005, expressed the vulnerability of an average failure. It is an important criterion that water decision makers should be aware of how severe a failure may occur. (Hashimoto et al. 1982) The vulnerability (Vul^i) calculation depends on the sum of deficits, the number of time deficits occurring and the annual water demand for the ith water user.

$$\mathbf{Vul^i} = \frac{\sum_{t=0}^{t=n} D_t^i / \text{number of time } D_t^i{>}0 \text{ occurs}}{\text{Annual water demand}} \tag{4.6}$$

4.1.4. Sustainability Index

The Sustainability index (SI) is applied to water resource systems and is the performance indicator for water systems over long periods. Loucks (1997) has developed a conceptual approach to SI as a weighted combination of reliability, resiliance and vulnerability. These are measures of environmental, social and economic criteria.

The main concept of evaluating sustainability in terms of reliability, resiliance and vulnerability is to minimize risks and uncertainities to achieve sustainability. (Loucks, 1997).

The formula developed by Loucks (1997) consists of reliablity, resiliance, vulnerability and it is identified as follows:

$$SI^i = REL^i \text{ x } RES^i \text{x } (1 - VUL)^i \quad (4.7)$$

The formula of SI formula had modification by Sandoval-Solis et al. (2011) as follows;

$$SI^i = [REL^i \text{ x } RES^i \text{x } (1 - VUL)^i]^{1/3} \quad (4.8)$$

In this study modificated formula has been used to determine water management system of Nicosia City.

SI has characteristics as follows:

a) The value of SI is between 0 and 1
b) If any component of the SI is zero the SI is zero,

Calculation variables:

The target water demand in this study was calculated using the world's accepted minimum daily needed amount of 100 lt/day/capita.Each of North Nicosia City's quarters has been assessed based on the region's current and future population density and structure character.

To evaluate the SI index of the water distribution system, the components of reliability, resilience, and vulnerability have been calculated with the obtained data. The results of the calculation were used to evaluate the expected deficits in the water systems.

The results of the level of sustainability help to describe applicable and appropriate water management systems. Predicting the future expected deficits guides decision-makers to define whether alternative water resources will be needed to satisfy the demands.

The SI calculation results can be evaluated according to the ranges given in Table 4.1.

Table 4.1: SI range states

Range	State
0 to 0.25	Not acceptable
0.25 to 0.5	Moderate
0.5 to 0.75	Acceptable
0.75 to 1	Ideal

4.2. Modeling a sustainable Integrated Urban Water Management

The Sustainability index (SI) is a mechanism that promotes the concerted production and management of water, soil, and related resources in order to optimize economic and social wellbeing (Jonch-Clausen, 2004).

To identify the goals and criteria of a satisfying water framework, water management planning considers supply, demand, and alternative water resources.

This research focuses on developing an appropriate integrated water management plan for Nicosia City by defining a goal programming model.

4.2.1. Requirements

The first stage of planning water management is defining the fundamentals of the system. The fundamentals are:

a) Analysing the current capacity of the system.

b) Identifying potential future demand requirements.

d) Defining scenarios

c) Defining alternative water supply resources

e) Defining criteria and calculating the weights with selected methods. In this study, AHP, EM and CM methods were selected.

f) Alternatives are evaluated and ranked using selected MCDM methods. In this study, SAW and MCDA methods were selected.

4.2.2 . Explanation of selected methods.

The methods and processes for criteria weights and MCDM methods are explained below.

4.2.2.1) Defining Criteria Weights.

a) The Performance Matrix.

The performance matrix is the most important component of the decision-making process. The matrix consists of alternatives in the rows and criteria in the columns. The weight of the criteria influences the decision-making process.

Decision makers and professionals value the weight of the criteria in practice applied based on their own experiences.Using some of the various approaches is another way to assess the weight of the criteria.It is observed that to have a more accurate approach, previous studies have focused on the Analytic Hierarchy Process (AHP), the Entropy Method (EM), and the Critic Methods (CM). The weights of criteria in this study were calculated using the AHP, EP, and CP methods.Performance Matrix:

$$P = \begin{array}{c} \\ A_1 \\ A_2 \\ A_3 \\ \vdots \\ A_n \end{array} \begin{array}{c} \begin{array}{cccc} C_1 & C_2 & \cdots & C_m \end{array} \\ \begin{bmatrix} a_{11} & a_{12} & \cdots & a_{1m} \\ a_{21} & a_{22} & \cdots & a_{2m} \\ a_{31} & a_{32} & \cdots & a_{3m} \\ \vdots & \vdots & \vdots & \vdots \\ a_{41} & a_{42} & \cdots & a_{4m} \end{bmatrix} \end{array} \quad (4.9)$$

Where;

$A_1, A_2, A_3 ....A_n$; Alternatives

$C_1, C_2, C_3 ....C_n$; Criterias

$a_{11}, a_{21}, a_{31}.........a_{m1}$; Indicators

b) *Analytic Hierarchy Process (AHP)*

The AHP aproach is applied to compute the weights of the criteria.The method of AHP was developed by Thomas L. Saaty in the 1970s. The method has three parts. The goal or aim is to solve a problem. The possible solutions are called alternatives and criteria to evaluate possible alternatives. The steps of the AHP method are as below:

Step1: Developing a hierarchical structure. Define the decision problems and objectives, as well as the criteria and alternatives.

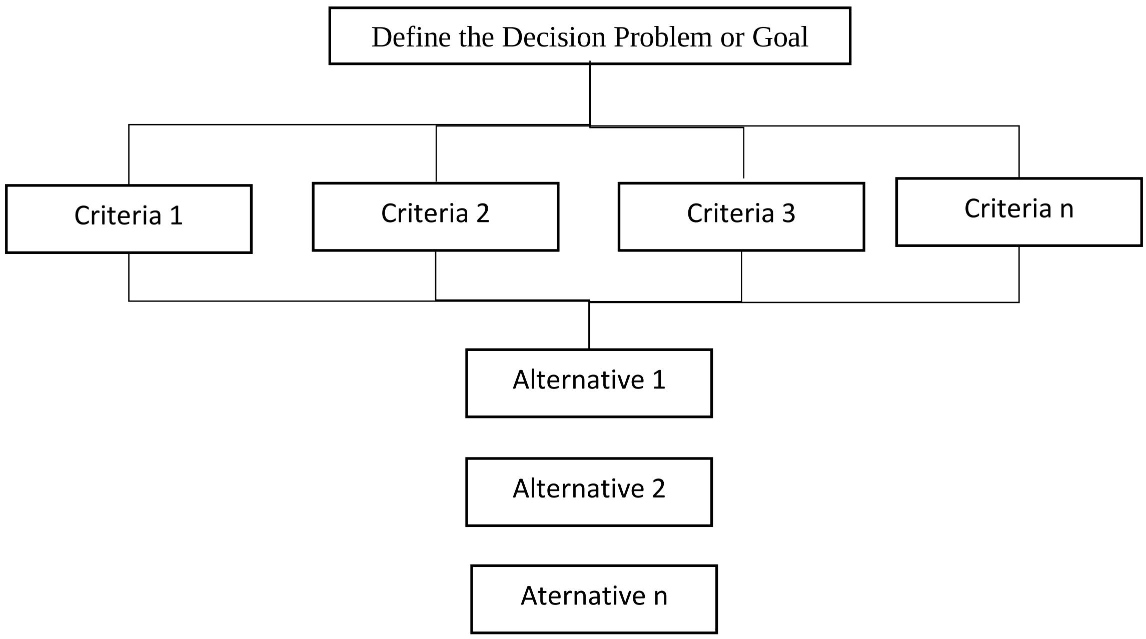

Figure 4. 1: Hierarchical structure of decision progress

Step 2: Determining the relative importance of the criteria with respect to the goal. Build a pair-wise comparison matrix according to the scales of relative importance developed by Thomas L. Saaty:

Table 4. 2: Relative importance ranges (Thomas L. Saaty, 1970)

Scale	Definition
1	Equal Importance
3	Moderate Importance
5	Strong Importance
7	Very Strong Importance
9	Extreme Importance
2,4,6,8	Intermediate Values
1/3,1/5,1/7,1/9	Values for Inverse Comparison

Pair-wise matrix:

$$PW = \begin{matrix} & C_1 & C_2 & \cdots & C_m \\ C_1 & 1 & p_{12} & \cdots & p_{1m} \\ C_2 & p_{21} & 1 & \cdots & p_{2m} \\ C_3 & p_{31} & p_{32} & \cdots & p_{3m} \\ \vdots & \vdots & \vdots & \vdots & \vdots \\ C_n & p_{41} & p_{42} & \cdots & 1 \end{matrix} \tag{4.10}$$

Step 3: Define normalised pair-wise matrix and define criteria weights.

Pair-wise matrix:

$$X = \begin{bmatrix} {}^{1}/_{\sum_{m=1}^{m} p_{m1}} & \cdots & \cdots & {}^{1}/_{\sum_{m=1}^{m} p_{tm}} \\ \vdots & & & \vdots \\ \vdots & & \ddots & \vdots \\ \vdots & & & \vdots \\ {}^{p_{m1}}/_{\sum_{m=1}^{m} p_{m1}} & \cdots & & {}^{1}/_{\sum_{m=1}^{m} p_{tm}} \end{bmatrix} \tag{4.11}$$

$$X = \begin{bmatrix} X_{11} & \cdots & \cdots & X_{1m} \\ \vdots & & & \vdots \\ \vdots & \ddots & & \vdots \\ \vdots & & & \vdots \\ X_{m1} & \cdots & & X_{mm} \end{bmatrix} \tag{4.12}$$

$$W = \frac{1}{m}\begin{bmatrix} \sum_{m=1}^{m} X_{11} \\ \vdots \\ \vdots \\ \vdots \\ \sum_{t=1}^{m} X_{mt} \end{bmatrix} = \begin{bmatrix} w_1 \\ w_2 \\ w_3 \\ \vdots \\ w_m \end{bmatrix} \quad (4.13)$$

The sum of criteria weights must be equal to 1.

Step 4: Consistency Ratio (CR) must be checked (Triantaphyllou, 2000) to verify the accuracy of given weights. If the approach is acceptable, the CR value must be smaller or equal to 10% (Triantaphyllou, 2000). CR is determined as in Eq (4.14).

$$CR = \frac{CI}{RI} \quad (4.14)$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \quad (4.15)$$

Where λ_{max} is average of W matrix and n is number of criterias. RI is average random consistency index that obtained from Table 4.3.

Table 4. 3: RI average random consistency

Criteria	1	2	3	4	5	6	7	8	9
RI	0	0	0.58	0.90	1.12	1.24	1.32	1.41	1.45

AHP method is very useful and simple method to find weights of criterias. In this study, AHP is one of the method used to define weights of criterias.

c) *Entropy Method (EM)*

The entropy method was developed by Shannon and Weaver in 1947. The method is known as a measure of uncertainty. The steps outlined below should be followed to determine the weights of criteria using the entropy method.

Step1: Normalising the performance matrix withEquation 4.16.

$$p_{ij}=\frac{a_{ij}}{\sum_{a}^{m} a_{ij}} \quad (4.16)$$

$$P=\begin{bmatrix} \frac{a_{11}}{\sum_{i=1}^{n} a_{11}} & \frac{a_{12}}{\sum_{i=1}^{n} a_{12}} & \cdots & \frac{a_{1m}}{\sum_{i=1}^{n} a_{1m}} \\ \frac{a_{21}}{\sum_{i=1}^{n} a_{21}} & \frac{a_{22}}{\sum_{i=1}^{n} a_{22}} & \cdots & \frac{a_{2m}}{\sum_{i=1}^{n} a_{2m}} \\ \frac{a_{31}}{\sum_{i=1}^{n} a_{31}} & \frac{a_{32}}{\sum_{i=1}^{n} a_{32}} & \cdots & \frac{a_{3m}}{\sum_{i=1}^{n} a_{3m}} \\ \vdots & \vdots & \vdots & \vdots \\ \frac{a_{n1}}{\sum_{i=1}^{n} a_{nm}} & \frac{a_{n2}}{\sum_{i=1}^{n} a_{n2}} & \cdots & \frac{a_{nm}}{\sum_{i=1}^{n} a_{nm}} \end{bmatrix} \quad (4.17)$$

$$P = \begin{bmatrix} p_{11} & p_{12} & \cdots & p_{1m} \\ p_{21} & p_{22} & \cdots & p_{2m} \\ p_{31} & p_{32} & \cdots & p_{3m} \\ \vdots & \vdots & \vdots & \vdots \\ p_{n1} & p_{n2} & \cdots & p_{nm} \end{bmatrix} \quad (4.18)$$

Step 2: Define entropy measure by eq..

$$E_j=-k \sum_{i=1}^{n} p_{ij} \ln p_{ij} \quad (4.19)$$

where k is consant that calculated with k=1/ln(n) and j=1,2,...m

Step 3: Defining weights of criterias based on entropy concept with Equation 4.20

$$w_j= \frac{1-E_j}{\sum_{i=1}^{n}(1-E_j)} \quad (4.20)$$

In this study, Entropy method is another method used to define weights of criterias.

d) *The Critic Method (CM)*

The critical method is the third method used to define the weights of the criteria in this study. Diakoulaki et al. proposed the method in 1995.The acronym 'CRICTIC' stands for 'Criteria Importance Through Inter Criteria Correlation' (Yilmaz and Harmancoglu, 2010).The critic method is used to detect the comparison between the criteria.

The following are the steps for determining weights or criteria using the critical method.

Step 1 : Normalizing the decision matrix with Equation 4.16

Step 2: Calculation of standard deviation (sj) for each criteria.

Step3: Determine the symmetric matrix of m x m with element rik which is the linear corellation coefficient between the vectors pi and pk.

Step 4: Calculating the magnitude of the conflict caused by correlation j in relation to the decision situation defined by the remaining criteria in Equation 4.21..

$$\sum_{i=1}^{m}(1 - r_{jk}) \qquad (4.21)$$

Step 5: Equation 4.22 used to define the amount of information in relation to each critera.

$$C_j = \sigma_j * \sum_{i=1}^{m}(1 - r_{jk}) \qquad (4.22)$$

Step 6: Determining the weights by Equation 4.23.

$$w_j = \frac{C_j}{\sum_{k=1}^{m} C_j} \qquad (4.23)$$

4.2.3. Evaluation and ranking of alternaties with *SAW* and *MCDA*

After calculation of criteria weights, there are several methods to evaluate alternatives for making optimal decisions. In literature, there are methods such as Simple Additive Weighting (SAW), Technique for Order Preference by Similarity to Ideal Solution (TOPSIS), Compromise Programming (CP), and Multi Criteria Decision Makin Analysis (MCDA).

In this study, SAW and MCDA methods were used to evaluate and compare alternatives with calculated criteria weights.

a) Simple Additive Weighting (SAW)

The SAW method is a multi-attribute process that was proposed by Fishburn in 1967. The system for this method evaluates the weighted sum of each alternative's performance and recommends the option with the highest score.(A Ibrahim1, 2018). The steps for SAW method calculations are as follows.

Step 1: Defining performance scores of alternatives and transforming attributes (aij) to a commensurable scale between 0 and 1 by diving attributes to max (aij) (Eq 4.24).

$$p_{ij}= \frac{a_{ij}}{\max(a_{ij})} \tag{4.24}$$

Step 2: To score alternatives equation 4.25 is used. In the equation, Wj represents criteria weights.

$$A_i= \sum_{j=1}^{m} w_j(p_{ij}) \tag{4.25}$$

In this study, three weighting methods are used as mentioned above and those results are applied to the SAW separately. The best scoring alternative is obtained as a result of this process.

b) Multi Criteria Decision Analysis (MCDA)

MCDA is a decision-making method that evaluates multiple contributing criteria. The method is an effective tool in water management research (Hajkowicz and Higgins, 2008). The first step of the decision-making process with MCDA starts with developing a performance matrix. The performance value of ith alternative to the jth criteria should be defined.

The second step is to describe the criteria as beneficial or non-beneficial. The aim of this process is to determine what is desired. After identifying the beneficial effects of each criteria on the decision procedure, the equations 4.26 and 4.27 are used to normalise the performance matrix.

$$\text{Non- Beneficial} =\frac{\min(a_{ij})}{a_{ij}} \tag{4.26}$$

$$\text{Beneficial}= \frac{a_{ij}}{\max(a_{ij})} \tag{4.27}$$

The final step of decision-making is assigning criteria weights to a decision matrix. The weights of criteria are calculated using three different methods as mentioned earlier and applied to the MCDA method separately to evaluate alternatives.

CHAPTER 5

RESULTS AND DISCUSSION

5.1. Comparison of Sustainability Indexes and Scoring methods

The methodolgy of this study for sustainability Index calculations followed from Louck (1997), Vieira et. al. (2018) and Aydin et. al (2014). Referance studies are similarly based on the water distibution to the system. Vieira et. al. (2018) focused on the demand and available water management of Verde Basin, Brazil. Sustainability Index was used to evaluate alternative plans for demand and supply balance under selected scenarios. The other followed methodology of Aydin et. al (2014), focused to determine sustainability of water distribution systems under pressure. Louck, (1997) identified the sustainability index and indicators. In this study, methodology and formulations in referance studies are used for approaches and performance calculations were computed to develop a sustainable management plan of Nicosia city between the predicted periods of 2021-2035. However, before generating a future water management road map, the performance analysis based on the existing data forms the basis of the management plan to give an opinion on the region's sustainability levels.

For the evalaution of the alternatives, the methodology followed from Yilmaz (2010). Criteria weighting methods of AHP, CM and EM are used same as the referance study. Yilmaz (2010), used TOPSIS and SAW methods for the scoring the alternatives differnet than referance study, for the scoring method MCDA and SAW methods are used.

5.2. Application of Selected Methods to Study Area

5.2.1. The Performance criterias and sustaibanility index calculations of Nicosia

Rel., Res., Vul. and SI values have been calculated for Central Nicosia, Hamitköy and Haspolat quarters. The water consumption values for the years 2018-2020 are a major input into the calculations. Average daily water consumption per capita has been calculated according to population estimates and supplied quantity.

Table 5.1: Nicosia City Water Consumption 2018-2020

Nicosia City Water Consumption (2018-2020)					
Years	**Consumption /Month (m^3)**	**Consumption /Day (m^3)**	**Population**	**m^3/cap./ day**	**lcd**
01.2018	417,500	13,917	81839	0.170	170
02.2018	358,800	11,960	81839	0.146	146
03.2018	369,100	12,303	81839	0.150	150
04.2018	467,300	15,577	81839	0.190	190
05.2018	469,400	15,647	81839	0.191	191
06.2018	448,800	14,960	81839	0.183	183
07.2018	451,000	15,033	81839	0.184	184
08.2018	510,100	17,003	81839	0.208	208
09.2018	480,800	16,027	81839	0.196	196
10.2018	487,500	16,250	81839	0.199	199
11.2018	452,600	15,087	81839	0.184	184
12.2018	424,900	14,163	81839	0.173	173
01.2019	417,300	13,910	83509	0.167	167
02.2019	439,200	14,640	83509	0.175	175
03.2019	404,500	13,483	83509	0.161	161
04.2019	479,300	15,977	83509	0.191	191
05.2019	474,500	15,817	83509	0.189	189
06.2019	557,100	18,570	83509	0.222	222
07.2019	533,700	17,790	83509	0.213	213
08.2019	537,600	17,920	83509	0.215	215
09.2019	553,800	18,460	83509	0.221	221
10.2019	520,700	17,357	83509	0.208	208
11.2019	495,600	16,520	83509	0.198	198
12.2019	486,100	16,203	83509	0.194	194
01.2020	407,400	13,580	85392	0.159	159
02.2020	431,300	14,377	85392	0.168	168
03.2020	443,900	14,797	85392	0.173	173
04.2020	487,800	16,260	85392	0.190	190
05.2020	524,100	17,470	85392	0.205	205
06.2020	617,700	20,590	85392	0.241	241
07.2020	620,250	20,675	85392	0.242	242
08.2020	611,300	20,377	85392	0.239	239
09.2020	546,300	18,210	85392	0.213	213
10.2020	331,400	11,047	85392	0.129	129
11.2020	515,100	17,170	85392	0.201	201
12.2020	411,600	13,720	85392	0.161	161
Total Cons.	17,185,350			**Average. lcd**	190

lcd: litter per capita per day **Cons.:** Consumption **Cap.:**Capita

Besides the water consumption data, regions were examined in detail as to their social life standards and regional structure. This data reflects an understanding of the various types of consumption, such as domestic, industrial, and agricultural. For each region, investigations and performance analysis carried out are presented as follows.

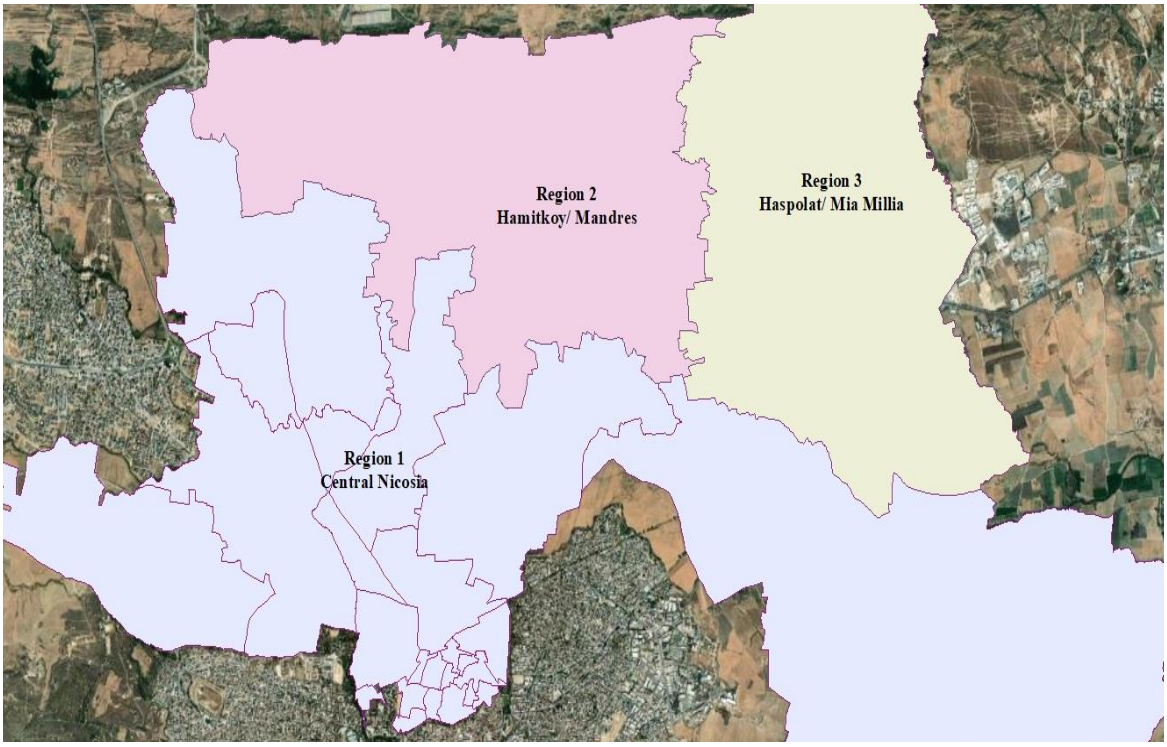

Figure 5.1: Regions of the study area.

a. Region 1. Central Nicosia:

Water consumption in central Nicosia is mostly for domestic and industrial/commercial use. Considering the structural and sociological conditions of the region, water consumption types percentages separated as %60 domestic use, %35 industrial, schools and commercial use, %5 municipal uses as irrigation of landscapes, parks.

According to the world standard water consumption per capita is between 50 to 100 lt/ day. This amount varies according to the standard of living, cultural habits and water availability.

Another factor that negatively affects the municipal water budget is leakages. The information obtained from the municipality indicates that there are 70% leakages because of the aged pipes in some specific areas. Leakages have been added to the calculations with respect to the problematic area's population.

Domestic water use for non-aged pipe areas is accepted as 110 lcd, including 10% leakage, in calculations to compare water management sustainability, and aged-pipe areas are accepted as 180 lcd (see Appendix 3). Based on the data obtained for the years between 2018-2020 and daily consumption estimations, the system performance analysis resulted as, Reliability of the system is calculated as 0.58 according to the supplied water amount. The reliability value is in the moderate range, indicating that the water demand is very well met. The value of resilience is 0.26, which is in the low range because, based on the estimated consumption, system recovery is difficult and may occur at the same rate as failure between the applied years. Depending on the deficits occurring in the system, the vulnerability is calculated as -0.00168. As a result, it is discovered that the system to which data is provided is extremely vulnerable. After calculation of performance criteria, the Sustainability Index has been calculated at 0.1556. As presented in Table 5.2, the value of SI is very low and not sustainable with the assigned target water demands.

Table 5.2: Central Nicosia Reliability, Resiliance, Vulnerability and Sustainability Index Calculatios According to Target Water Demand

Central Nicosia Rel, Res, Vul, SI Calculations		
Months	n	36
Deficit	Dt=0	21
Reliability	**Rel**	**0.583333333**
Dt Follows DT>0		4
	Dt>0	15
Resiliance	**Res**	**0.266666667**
Sum Dt		-117,257
Number Of Dt>0		15
Annual Water Demand		4,638,850
		-7817.163733
Vulnerabılıty	**Vul**	**-0.001685151**
Sustainability Index	**SI**	**0.155642885**

b. Region 2. Hamitkoy/Mandres Quarter:

Water consumption is mostly domestic in the region. The region has shown an increase in population in recent years and there are more dense houses with gardens. As a result, the percentages of water consumption types are as follows: 70% domestic, 15% agricultural, 5% municipal, and 10% leakage (Appendix 4).

In performance criteria and sustainability calculations, water consumption per person is accepted at 170lcd, and based on the data between 2018-2020, system performance criteria reliability, resilience, and vulnerability are calculated at 0.7222, 0.3636, and -0.0269 respectively (Table 5.3). As a result of performance calculations, data history gives an idea that supplied water and demand amounts are almost moderated according to the accepted consumption amounts. In the sustainability calculation, this approach is justified. The SI calculations yielded a result of 0.26, indicating that the system is moderated.

Table 5.3: Hamitköy Reliability, Resiliance, Vulnerability and Sustainability Index Calculations According to Target Water Demand

Hamitkoy/Mandres Quarter Rel, Res, Vul, SI Calculations		
Months	n	36
Deficit	Dt=0	26
Reliability	**Rel**	**0.72222222**
Dt Follows DT>0		4
	Dt>0	11
Resiliance	**Res**	**0.363636**
Sum Dt		-230,083
Number Of Dt>0		11
Annual Water Demand		803,900
		-20916.66
Vulnerabılıty	**Vul**	**-0.0260189**
Sustainability Index	**SI**	**0.269459**

c. Region-3 Haspolat Quarter,

Region 3 is less populated than other regions as a local settlement, but the university, industrial facilities and agricultural activities in the region increase the water consumption amounts. The percentages of water consumption types seperated as, domestic %55, agricultural, industrial and municipal uses %45 Consumption amounts due to the universities in the region, dormitory capacities, and the estimated daily student population are all included in Appendix 5.

In target water demand calculations, domestic use for the residential population is 150 lcd, dormitories 100 lcd, and daily student consumption 40 lcd accepted. According to performance criteria based on target supply amounts, the region may experience severe failures, increasing the region's vulnerability. Reliability and resilience of the system are at in the limits that in the future with the increase of population the region the amount of distributed water needs to be increased in accordance. The values obtained for reliability, resiliency, and vulnerability were 0.55, 0.25, and 0.0042, respectively. Based on the performance criteria, SI has been calculated as 0.138 in Table 5.4. Therefore, the result shows that the estimated target demand is not sustainable for the region.

Table 5. 4: Haspolat Reliability, Resiliance, Vulnerability and Sustainability Index Calculations According to Target Water Demand

Haspolat Rel, Res, Vul, SI Calculations		
Months	n	36
Deficit	Dt=0	20
Reliability	**Rel**	**0.555555556**
Dt Follows DT>0		4
	Dt>0	16
Resiliance	**Res**	**0.25**
Sum Dt		53,067
Number Of Dt>0		16
Annual Water Demand		777,890
		3316.693426
Vulnerabılıty	**Vul**	**0.004263705**
Sustainability Index	**SI**	**0.138296708**

5.3. Assiging Alternatives

After investigation and calculations of sustainability according to the estimated consumtions, the combination of social, environmental, and economic alternatives and criteria was evaluated to address a sustainable water management program.

The main idea behind this section of the research is to find the best solution to potential future water stress that will help to avoid economic conflicts, protect environmental health, and provide public benefits. A road map to evaluate alternatives can be applied in Nicosia city with steps as follows,

a) Analysing the system; the goal of analysing of the system is defining the current water supply system and available resources in use. In this study, Nicosia city water supply datas have been obtained from municipality.

b) Future demand need and developments are the center of water management plan. In this study, predicted future water consumption is calculated with respect to predicted population.

c) Defining scenarios to provide a framework for dealing with future water stress. The scenario was generated to evaluate the sustainability of water distribution if the water budget is kept constant, the same as the average annual average water use rate of 2020 and to predict when the regions will experience water scarcity with the expected population increases to develop a future sustainable water management plan. (Appendix 11,12,13)

d) Defining alternative water supply resources

This phase includes possible alternative water supply resources and generation of scenarios. The alternative water resources can be reuse of treated wastewater, groundwater exploitation, dams, irrigation systems, water transporting.

As a result, defining alternative water supplies can be beneficial in bridging the supply-demand gap. Possible alternatives in the district of Nicosia city have been investigated and identified in Table 5.5.

Table 5. 5: Possible Water Resource Alternatives

Alternatives	
Rehabilitation of Existing Hamitkoy pond and new system for consumption	A1
Rehabilitation of existing Haspolat pond and new system for consumption	A2
New reservoir for collection treated wastewater and surface water for irrigation	A3
Distribution of reuse water to city gardening and landscaping purpose	A4
New wells to extract groundwater	A5
Renewing system to prevent leakage	A6
Building storages for rain and surface water harvest	A7

e) Defining Criteria and weights

To measure the suitability and sustainability of the advised alternatives, nine criteria were determined as shown in Table 5.6. These criteria were selected to represent the three pillars of sustainability.

Table 5.6: Criterias

Criteria		Pillar
Implementation cost	C1	
Return period (months)	C2	Economic
Operation and Management Cost	C3	
Quality of water	C4	
Environmental Effects	C5	Environmental
Domestic Supply Rate	C6	
Reliability	C7	
Affordability	C8	Social
Benefits	C9	

The performance matrix was created during the decision-making process to select the best alternative for additive water resources. The most important component in determining the relative importance of criteria and goals is the performance matrix. Several elements of the performance matrix were developed following discussions with the Nicosia Municipality's water department.

The performance matrix is created first. To express the importance of some elements, linguistic terms are used. Table 5.8 displays the performance matrix. A conversion scale given in Table 5.7 is used to convert the elements expressed in linguistic terms into numbers Table 5.9 displays the converted performance matrix.

Table 5.7: Conversion scales used for performance matrix.

Performance	Scale
Very High	5
High	4
Medium	3
Low	2
Very low	1

Table 5.8: Performance Matrix

Performance Matrix										
		Economical			**Environmental**			**Social**		
		Implementation Cost (C1)	Return Period (Months) (C2)	Operation And Management Cost (C3)	Quality Of Water (C4)	Environmental Effects (C5)	Domestic Supply Rate (C6)	Reliability (C7)	Affordability (C8)	Benefits (C9)
Rehabilitation Of Existing Hamitköy Pond and New System for Consumption	A1	Very High	24	High	Medium	Very High	Medium	Medium	High	High
Rehabilitation Of Existing Haspolat Pond New System for Consumption	A2	Very High	24	High	Medium	Very High	Medium	Medium	High	High
New Reservoir for Collection Treated Wastewater and Surface Water for Irrigation Purpose	A3	Very High	24	Very High	High	Very High	High	Very High	Very High	Very High
Distribution Of Reuse Water to City Gardening and Landscaping Purpose	A4	High	15	High	High	Very High	High	Very High	Very High	Very High
New Wells to Extract Groundwater	A5	Medium	10	Low	Low	Very Low	Low	Low	Low	Very Low
Renewing System to Prevent Leakage	A6	High	24	Low	Very High	High	Very High	Very High	Very High	Very High
Building Storages for Rain and Surface Water Harvest	A7	Medium	12	Low	Medium	High	Medium	Medium	Medium	High

Table 5.9: Converted Performance Matrix

Performance Matrix (Converted to Numerical)										
		Economical			Environmental			Social		
		Implementation cost (C1)	Return period (months) (C2)	Operation and Management Cost (C3)	Quality of water (C4)	Environmental Effects (C5)	Domestic Supply Rate (C6)	Reliability (C7)	Affordability (C8)	Benefits (C9)
Rehabilitation of Existing Hamitköy pond and new system for consumption	A1	4	18	4	3	5	3	3	4	4
Rehabilitation of existing Haspolat pond new system for consumption	A2	4	18	4	3	5	3	3	4	4
New reservoir for collection treated wastewater and surface water for irrigation purpose	A3	5	36	5	4	5	4	5	5	5
Distribution of reuse water to city gardening and landscaping purpose	A4	4	15	4	4	5	4	5	5	5
New wells to extract groundwater	A5	2	10	2	2	1	2	2	2	1
Renewing system to prevent leakage	A6	4	18	2	5	4	5	5	5	5
Building storages for rain and surface water harvest	A7	3	12	2	3	4	3	3	3	4

Calculating criteria weights by using *Analytic Hierarchy Process (AHP), EM and CM methods:*

These three methods have been applied to the selected criteria to assign weight. The AHP method deals with a pair-wise matrix that is generated on the scale of relative importance given in table 4.1.

While proposing a project, implementation cost (C1) is a major element that effects the progress of the planning, but on the other hand, there are other elements that, after implementation, have more importance for the sustainability of the system, such as the return period (months) (C2), Operation and Management Cost (C3), and the Domestic Supply Rate (C4). These criteria are nearly as important as implementation cost (C1), and their relative importance is graded as '2' in table 4.1.

Following any project implementation, environmental effects such as water quality (C4) and environmental effects (C5) are more important than project implementation costs (C1). The relative importace between these crieterias assigned ‘3’.

Another important criterion to consider is the impact of a project on society after it has been implemented.The outcomes after implementation of a project, such as reliability (C7) and benefits (C9) are essentially more important than implementation cost (C1), and the relative importance between these criteria and C1 is graded as 3 and 5 respectively.

The most important pillar of an implemented project is when there will be a return from the project to meet the aims. As a result, the return period (months) (C2) is an important criterion that should be considered.As a return period, the Environmental Effects (C5) and Affordability (C8) of society have very similar relative importance, but in terms of sustainability, C5 and C8 have more magnitude than C2 as ‘2’.

Furthermore, water quality (C4), domestic supply rates (C6), reliability (C7), and benefits (C9) are required in environmental and social ways, and may have a greater impact on decision-making than C2.

After implementation, the third major project criterion is Operation and Management Cost (C3).Future expected costs should be considered when proposing a project in order to assess its sustainability.The relative importance of Return Period (months) (C2), quality of water (C4), affordability (C8), and benefits (C9) are necessary attributes that should be taken into account and, in terms of these attributes, may have a higher grade score than C2.

The quality of water (C4), Environmental Effects (C5), Domestic Supply Rate (C6), Reliability (C7), Affordability (C8) and Benefits (C9) are selected attributes that interact with the environmental and social pillars.

As a result of AHP calculations, the consistency of the criteria is satisfied (Table 5.10) and the assigned scores for the attributes show that the quality of water (C4), Environmental Effects (C5) and benefits (C9) have more weight than others. (Table 5.11)

Table 5.10 : Consistency Criteria

Measurement Of Inconsistency:	0.1242	
Random Index:	1.45	
Consistency Ratio:	0.0857	< **0.1**

Table 5. 11: Calculated Criteria Weights AHP Method

Calculated Criteria Weights AHP Method		
Criteria's		**Weights**
Implementation Cost	C1	0.040438822
Return Period (months)	C2	0.054635548
Operation and Management Cost	C3	0.045689034
Quality of Water	C4	0.240566971
Environmental Effects	C5	0.215727813
Domestic Supply Rate	C6	0.062992188
Reliability	C7	0.056488083
Affordability	C8	0.084000117
Benefits	C9	0.199461424

The weight is also calculated using the EM and CM methods (see Appendices G and H), and the results show that the C4, C5, and C9 attributes have higher weights than the others. The comparison weights obtained from these three methods are presented below.

Table 5.12: Weights of criterias

Criteria	Entropy Method	Critic Method	AHP method
	W_J	**W_J**	**W_J**
C1	0.063885705	0.149914219	0.040438822
C2	0.172659375	0.130794045	0.054635548
C3	0.134859126	0.157821938	0.045689034
C4	0.073285784	0.082698283	0.240566971
C5	0.148677789	0.106636172	0.215727813
C6	0.073285784	0.076200489	0.062992188
C7	0.104587712	0.108794054	0.056488083
C8	0.082105654	0.099350231	0.084000117
C9	0.146653071	0.087790568	0.199461424

Applying SAW and MCDA methods to evaluating Alternatives with weighted criterias:

SAW and MCDA methods have been applied to the performance matrix with weighted criteria (Appendix 9 and 10). The results of both methods show that the renewal system to prevent leakage (A6) receives the highest score, and the distribution of reused water for city gardening and landscaping purposes receives the second highest score (A4).

The third scoring alternative has differences between the methods. The SAW method indicates that Alternative A7 with respect to the EM and CM methods, Alternative A3 with AHP method scored third. On the other hand, the MCDA method scored A2, A7 and A3 using weighted criteria by methods EM, CM and AHP respectively.

The results of both multi-criteria decision methods are presented in Tables 5.10 and 5.11.

Table 5. 13: SAW Method Results

Alternatives		EM	Rank 1	CM	Rank 2	AHP	Rank 3
Rehabilitation of Existing Hamitköy pond and new system for consumption	A1	0.67767463	5	0.64349594	5	0.7319424	4
Rehabilitation of existing Haspolat pond new system for consumption	A2	0.67767463	5	0.64349594	5	0.7319424	4
New reservoir for collection treated wastewater and surface water for irrigation purpose	A3	0.72674035	4	0.68911619	4	**0.84815245**	**3**
Distribution of reuse water to city gardening and landscaping purpose	**A4**	**0.81376015**	**2**	**0.77075415**	**2**	**0.87801239**	**2**
New wells to extract groundwater	A5	0.56377635	7	0.62423277	7	0.4014202	7
Renewing system to prevent leakage	**A6**	**0.86158409**	**1**	**0.84558497**	**1**	**0.91235256**	**1**
Building storages for rain and surface water harvest	A7	**0.75755606**	**3**	**0.74252702**	**3**	0.71675768	6

Table 5. 14: MCDA Method Results

Alternatives		EM	Rank 1	CM	Rank 2	AHP	Rank 3
Rehabilitation of Existing Hamitköy pond and new system for consumption	A1	0.69233	6	0.66004	5	0.78006	5
Rehabilitation of existing Haspolat pond new system for consumption	A2	**0.72427**	**3**	0.66004	5	0.78006	5
New reservoir for collection treated wastewater and surface water for irrigation purpose	A3	0.71847	5	0.67258	4	**0.80004**	**3**
Distribution of reuse water to city gardening and landscaping purpose	**A4**	**0.80975**	**2**	**0.75421**	**2**	**0.82990**	**2**
New wells to extract groundwater	A5	0.49989	7	0.62423	7	0.40142	7
Renewing system to prevent leakage	**A6**	**0.82964**	**1**	**0.84558**	**1**	**0.91235**	**1**
Building storages for rain and surface water harvest	A7	0.71905	4	**0.74253**	**3**	0.71676	4

f) Defining expected future failures of water management with respect to the generated scenario

The study area has been subjected to a generated scenario.The water budget was kept constant in the scenario, and deficits were calculated with an increasing projected population as the first approach for each region. In this approach, the target water demand per capita is selected as demonstrated in chapter 5.1 for each region.

5.4. Evaluation of Results

The results of the performance criterias and sustainability index calculations with minimum levels of consumption per capita indicate that obtained sustainability in the related area is within low or not in sustinable limits. Hamitkoy/Mandres Region has higher SI index than Central Nicosia and Haspolat/ Mia Milia. The SI for the regions calculated as 0.269 for Hamitkoy, 0.155 for Central Nicosia and 0.138 for Haspolat region.

The results can be interpreted as water consumption is highly linked with the structure of the region. Since there are more residentals in the Hamitkoy/ Mandres region the water supply and demand is stable. On the other hand, Central Nicosia and Haspolat region except the residentals there are daily population increase due to the commercials, schools and other facilities. This flactuates the daily water supply amount.

The SI and performance criteria estimates give opinion that future increasing population or decrease of water quantity may cause serious deficits in the system. To meet future desired demand the water supply amout should increase. This is a challenge for the municipality to meet economically the water costs while preserving environment, sanitation needs and affordability of dwells.

To cover future expected deficits and conservation of water in this study several alternatives have been selected. These alternatives are evaluated and scored by MCDM methods to create a road map to a proper water management plan. This step is important for decision-makers to give directions to water suppliers to make the right investments and create organisations. As a result of scoring alternatives with respect to three pillars of sustainability, Alternative 6, Renewing system to prevent leakage has been ranked as first and Alternative 4, Distribution of reuse water to city gardening and landscaping purpose has been ranked as second. The evaluation results are very closed to each other. Therefore, these two alternatives should be taken in consideration to increase sustainability of water management plan.

Future possible deficit calculations were made based on the selected scenario for the management plan that this study aimed to create. Appendices K, L, and M present the expected deficits in regions 1, 2, and 3, respectively.

In Central Nicosia, based on the generated scenario and projected population, the future deficit in water demand expected occur in 2023 (Appendix 11). When failure occurs or before the second approach is to take action by scoring alternative A6, Renewing system to prevent leakage. This can result as saving a large amout of water. According to the scenario, after renewing the system, second deficit may occur in year 2029. To cover second deficit, water the reuse water can be added to water budget as secondary resource.

In Hamitkoy/Mandres Region, the result of the scenario is mor optimistic than other regions. According to generated scenario the first deficit of demand supply may occur in 2026. Inreasing water amout around %10 can provide the sustainability of system. After increasing water budget in 2030 second deficit may occur according to the population increase. In the region, Alternative 1, Rehabilitation of Existing Hamitköy pond and new system for consumption can be applied to the area and addition of reuse water can provide needed amount.

Haspolat/ Mia Milia Region has the worst case of water deficits. According to the scenario additional water resource of increase of water supply quatity inevitable. Reuse water and rehabilitaton of Haspolat pond are alternatives that can be added to water budget.

In order to develop a long-term management plan until 2035 for all regions, the alternative solutions can cover the deficitis.

Table 5.15 Expected deficits and assigning possible alternative for solution

Region	Expected Deficit Years	Detected problem	Structure of region	Solution	Possible Alternative
Region 1 Central Nicosia	2023	Leakage / aged pipes	Domestic+ Industrial	Changing aged pipes	A6
	2029			%10 Additional Resource	A4
Region 2 Hamitkoy/ Mandres	2026		Domestic+ Agricultural	%10 additional Resource	A1 A4
	2030		Domestic+ Agricultural	%20 Additional Resource	A4 A1 A7
Region 2 Haspolat/ Mia Milia	2021		Domestic+ Agricultural+ Industrıal	%10 Additional Resource	A2 A4
	2028		Domestic+ Agricultural+ Industrial	%20 Additional Resource	A2 A4 A3

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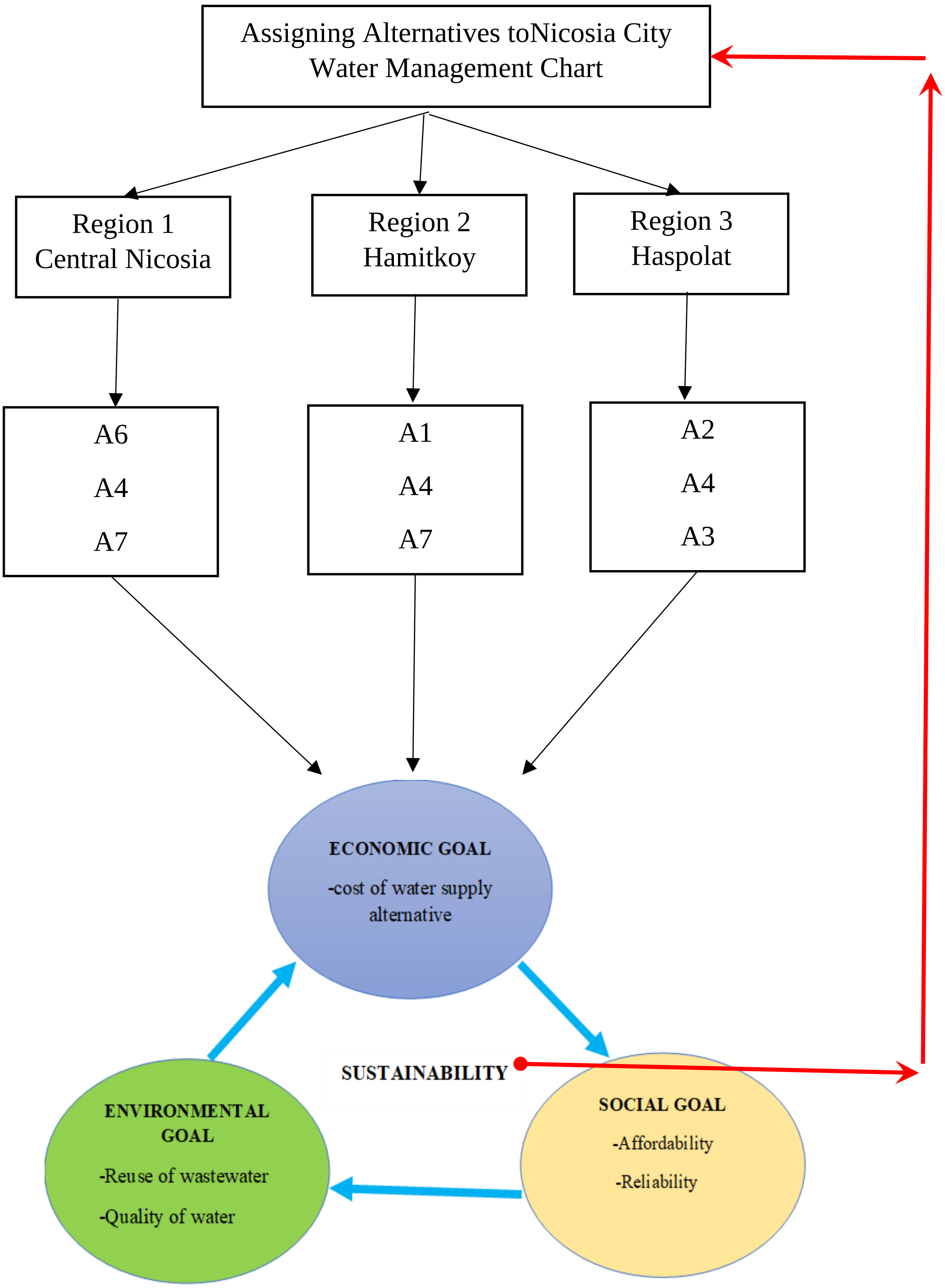

Figure 5.2: Assigning alternatives to Nicosia city water management chart

CHAPTER 6

CONCLUSION AND RECOMMENDATIONS

6.1 Conclusion

Water is the most critical element in life for living things, the sustainability of the environment, and the development of countries. Water management is difficult due to the uncertainties of climate change and an increasing population. Authorities have challenges to sustain water and wastewater needs for the city.

In this study, a road map to the sustainable urban water and wastewater management model for the city of Nicosia has been presented. The city has been evaluated under three regions. All regions are detailed based on the water consumption variants of domestic, agricultural, and industrial, as well as the life standrads of the people. For the years 2018-2020, the performance of these three regions reliability, resilience, vulnerability, and sustainability indices was identified. The result of these calculations reflects a possible water crisis.

The city of Nicosia dependi only on one water supply resource of transfer water from Turkey. This is not sustainable for water availability in the event of a defect or a water crisis at the point of transfer. New alternatives were defined using MCDM methods in terms of environmental protection, economic and social benefits indicators.

6.2 Recommendations

As a result of approaches and calculations, recommmendations for the road map to the sustainable urban water and wastewater management for city of Nicosia described below.

- Due to the future expected water crisis under the climate change effects and population increase, action plans should include all possible local and non local water resources.
- Aged pipes should renewed. Water demand and supply amounts should be monitored and leakage detection systems can be used for early detection of losses.

- Effluent water should be added to water budget. Effluent quality of NWWTP provides urban water treatment directive 91/271/EEC. It is suitable for agricultural purposes therefore, it can be sold for farmers with lower price than potable water. This may contribute economical advantage to municipal economy.
- Completion of all sewerage systems is important for environmental health and effluent producing.
- Effluent water can be distibuted to houses with piping systems for garden irrigation and house hold uses such as toilet flushing. Due to the fact that the pipe system is a costly investment, treated water is not distributed to the houses for the time being. However, although the implementation of this system is costly in the first place, it will provide gains for both dwells and municipalities in the following years.
- Conservation of effluent water is an advantage for agriculture in the dry seasons. The development of a new reservoir to collect treated wastewater could benefit agricultural activities in the Mesaoria plain.
- Another important water ealted issue is drainage systems for the cities. It is essential to have sufficient capacity of drainage system and ponds.
- Surface water can be added to water budget. The collected water in the available ponds of Hamitkoy/Mandres and Haspolat/Mia Milia with rehabilitation and treatment can be used.
- In conservation of water individuals has important role. Therefore educations, workshops can be helpfull to increase awarness of users. For example dwells can be encouraged for rainwater harvesting. It can be applied to houses with storage tanks to use for gardening.
- Laws and regulations should be generated to support water related management plans such as water and wastewater management, flood management.

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APPENDICES

Appendix 1: Water Consumption Amounts 2018-2020

Year	Central Nicosia m^3/month	Hamitkoy m^3/month	Haspolat m^3/month
01.2018	313,500	42,300	61,700
02.2018	286,400	41,700	30,700
03.2018	293,800	39,200	36,100
04.2018	351,400	53,300	62,600
05.2018	358,500	54,100	56,800
06.2018	388,500	56,700	3,600
07.2018	372,500	59,000	19,500
08.2018	390,400	65,100	54,600
09.2018	365,000	59,200	56,600
10.2018	366,200	54,700	83,980
11.2018	356,600	48,600	74,800
12.2018	333,600	42,000	80,670
01.2019	337,900	40,100	59,570
02.2019	322,300	50,800	109,380
03.2019	309,700	49,000	73,240
04.2019	359,800	67,300	77,510
05.2019	362,800	56,700	74,800
06.2019	413,900	73,600	85,070
07.2019	393,100	71,400	84,790
08.2019	418,700	68,100	60,890
09.2019	419,000	66,500	78,420
10.2019	393,000	63,000	75,890
11.2019	379,700	58,600	71,200
12.2019	370,900	63,000	65,930
01.2020	346,400	19,300	77,060
02.2020	325,900	57,900	74,110
03.2020	340,000	60,400	75,210
04.2020	376,900	58,700	69,510
05.2020	406,900	73,100	70,120
06.2020	471,300	90,500	82,640
07.2020	468,950	97,400	74,290
08.2020	466,600	93,400	74,530
09.2020	420,900	91,800	56,980
10.2020	272,900	48,700	34,380
11.2020	407,300	63,200	47,330
12.2020	334,800	49,500	41,730

Appendix 2: Population Projections 2006-2035

Years	Hamitkoy/ Mandres	Haspolat/ Mia Milia
2006	2898	4117
2011	5338	4204
2012	5519	4271
2013	5831	4380
2014	6182	4512
2015	6556	4654
2016	6869	4747
2017	7205	4850
2018	7677	5037
2019	8126	5203
2020	8445	5279
2021	8750	5342
2022	9077	5417
2023	9411	5495
2024	9735	5563
2025	10080	5640
2026	10431	5720
2027	10791	5801
2028	11160	5886
2029	11542	5974
2030	11931	6065
2031	12331	6160
2032	12702	6238
2033	13020	6290
2034	13341	6343
2035	13665	6398

Appendix 3: Central Nicosia Deficit Calculations Between 2018-2020

			%10 Leakage Area			%70 Leakage Area		Other Uses				
Year	**$W_{supplied}$ m^3/Month**	**P_1**	**W_{d1}**	**$W_{target1}$ m^3/Month**	**P_2**	**W_{d2}**	**$W_{target2}$ m^3 /Month**	**W_{inds}+ W_{school}+ $W_{com.}$ /Month**	**$W_{mun.}$ /Month (%5)**	**Total W_{target} m3/Month**	**$W_{deficit}$ M^3/Month**	**Deficit**
01.2018	313,500	46962	110	154,975	17200	180	92,880	78,375	15,675	341,905	28,405	False
02.2018	286,400	46962	110	154,975	17200	180	92,880	71,600	14,320	333,775	47,375	False
03.2018	293,800	46962	110	154,975	17200	180	92,880	73,450	14,690	335,995	42,195	False
04.2018	351,400	46962	110	154,975	17200	180	92,880	87,850	17,570	353,275	1,875	False
05.2018	358,500	46962	110	154,975	17200	180	92,880	89,625	17,925	355,405	-3,095	0
06.2018	388,500	46962	110	154,975	17200	180	92,880	97,125	19,425	364,405	-24,095	0
07.2018	372,500	46962	110	154,975	17200	180	92,880	93,125	18,625	359,605	-12,895	0
08.2018	390,400	46962	110	154,975	17200	180	92,880	97,600	19,520	364,975	-25,425	0
09.2018	365,000	46962	110	154,975	17200	180	92,880	91,250	18,250	357,355	-7,645	0
10.2018	366,200	46962	110	154,975	17200	180	92,880	91,550	18,310	357,715	-8,485	0
11.2018	356,600	46962	110	154,975	17200	180	92,880	89,150	17,830	354,835	-1,765	0
12.2018	333,600	46962	110	154,975	17200	180	92,880	83,400	16,680	347,935	14,335	False
01.2019	337,900	49312	110	162,730	17372	180	93,809	84,475	16,895	357,908	20,008	False
02.2019	322,300	49312	110	162,730	17372	180	93,809	80,575	16,115	353,228	30,928	False
03.2019	309,700	49312	110	162,730	17372	180	93,809	77,425	15,485	349,448	39,748	False
04.2019	359,800	49312	110	162,730	17372	180	93,809	89,950	17,990	364,478	4,678	False
05.2019	362,800	49312	110	162,730	17372	180	93,809	90,700	18,140	365,378	2,578	False
06.2019	413,900	49312	110	162,730	17372	180	93,809	103,475	20,695	380,708	-33,192	0
07.2019	393,100	49312	110	162,730	17372	180	93,809	98,275	19,655	374,468	-18,632	0
08.2019	418,700	49312	110	162,730	17372	180	93,809	104,675	20,935	382,148	-36,552	0
09.2019	419,000	49312	110	162,730	17372	180	93,809	104,750	20,950	382,238	-36,762	0

Appendix 3: Continue

10.2019	393,000	49312	110	162,730	17372	180	93,809	98,250	19,650	374,438	-18,562	0
11.2019	379,700	49312	110	162,730	17372	180	93,809	94,925	18,985	370,448	-9,252	0
12.2019	370,900	49312	110	162,730	17372	180	93,809	92,725	18,545	367,808	-3,092	0
01.2020	346,400	50656	110	167,165	17458	180	94,273	86,600	17,320	365,358	18,958	False
02.2020	325,900	50656	110	167,165	17458	180	94,273	81,475	16,295	359,208	33,308	False
03.2020	340,000	50656	110	167,165	17458	180	94,273	85,000	17,000	363,438	23,438	False
04.2020	376,900	50656	110	167,165	17458	180	94,273	94,225	18,845	374,508	-2,392	0
05.2020	406,900	50656	110	167,165	17458	180	94,273	101,725	20,345	383,508	-23,392	0
06.2020	471,300	50656	110	167,165	17458	180	94,273	117,825	23,565	402,828	-68,472	0
07.2020	468,950	50656	110	167,165	17458	180	94,273	117,238	23,448	402,123	-66,827	0
08.2020	466,600	50656	110	167,165	17458	180	94,273	116,650	23,330	401,418	-65,182	0
09.2020	420,900	50656	110	167,165	17458	180	94,273	105,225	21,045	387,708	-33,192	0
10.2020	272,900	50656	110	167,165	17458	180	94,273	68,225	13,645	343,308	70,408	False
11.2020	407,300	50656	110	167,165	17458	180	94,273	101,825	20,365	383,628	-23,672	0
12.2020	334,800	50656	110	167,165	17458	180	94,273	83,700	16,740	361,878	27,078	False
Total Cons.	13,296,050								**Total Deficit**		-117,257	

$W_{supplied}$: Supplied water amount **Pop. 1:** Estimated population (%10 leakage area) **Pop. 2:** Estimated population (%60 leakage area)

W_{d1}: Estimated daily water consumption per capita (%10 leakage area) **W_{d2}:** Estimated Daily water consumption per capita (%70 leakage area) **$W_{target1}$:** Target water demand (%10 leakage area)

W_{inds} : Industrial water demand **W_{school}:** Schools water demand

$W_{com.}$: Commercial water demand **W_{mun}:** Municipal use

Appendix 4 : Hamitkoy/Mandres Quarter Water Consumption 2018-2020

		Domestic %70			Other %30			Total		
Year	**$W_{supplied}$ /Month** [illegible]	**Pop. 1**	**W_d**	**$W_{target1}$ m3/Month**	**$W_{agr.}$/Month (%15)**	**$W_{mun.}$ /Month (%5)**	**Leakage m3/Month (%10)**	**Total W_{target} m3/Month**	**$W_{deficit}$ M^3/Month**	**Deficit**
01.2018	42,300	7677	170	39,154	6,345	2,115	4,230	51,844	9,544	False
02.2018	41,700	7677	170	39,154	6,255	2,085	4,170	47,494	5,794	False
03.2018	39,200	7677	170	39,154	5,880	1,960	3,920	46,994	7,794	False
04.2018	53,300	7677	170	39,154	7,995	2,665	5,330	49,814	-3,486	0
05.2018	54,100	7677	170	39,154	8,115	2,705	5,410	49,974	-4,126	0
06.2018	56,700	7677	170	39,154	8,505	2,835	5,670	50,494	-6,206	0
07.2018	59,000	7677	170	39,154	8,850	2,950	5,900	50,954	-8,046	0
08.2018	65,100	7677	170	39,154	9,765	3,255	6,510	52,174	-12,926	0
09.2018	59,200	7677	170	39,154	8,880	2,960	5,920	50,994	-8,206	0
10.2018	54,700	7677	170	39,154	8,205	2,735	5,470	50,094	-4,606	0
11.2018	48,600	7677	170	39,154	7,290	2,430	4,860	48,874	274	False
12.2018	42,000	7677	170	39,154	6,300	2,100	4,200	47,554	5,554	False
01.2019	40,100	8126	170	41,442	6,015	2,005	4,010	49,462	9,362	False
02.2019	50,800	8126	170	41,442	7,620	2,540	5,080	51,602	802	False
03.2019	49,000	8126	170	41,442	7,350	2,450	4,900	51,242	2,242	False
04.2019	67,300	8126	170	41,442	10,095	3,365	6,730	54,902	-12,398	0
05.2019	56,700	8126	170	41,442	8,505	2,835	5,670	52,782	-3,918	0
06.2019	73,600	8126	170	41,442	11,040	3,680	7,360	56,162	-17,438	0
07.2019	71,400	8126	170	41,442	10,710	3,570	7,140	55,722	-15,678	0
08.2019	68,100	8126	170	41,442	10,215	3,405	6,810	55,062	-13,038	0

Appendix 4: Continue

09.2019	66,500	8126	170	41,442	9,975	3,325	6,650	54,742	-11,758	0
10.2019	63,000	8126	170	41,442	9,450	3,150	6,300	54,042	-8,958	0
11.2019	58,600	8126	170	41,442	8,790	2,930	5,860	53,162	-5,438	0
12.2019	63,000	8126	170	41,442	9,450	3,150	6,300	54,042	-8,958	0
01.2020	19,300	8445	170	43,071	2,895	965	1,930	46,931	27,631	False
02.2020	57,900	8445	170	43,071	8,685	2,895	5,790	54,651	-3,249	0
03.2020	60,400	8445	170	43,071	9,060	3,020	6,040	55,151	-5,249	0
04.2020	58,700	8445	170	43,071	8,805	2,935	5,870	54,811	-3,889	0
05.2020	73,100	8445	170	43,071	10,965	3,655	7,310	57,691	-15,409	0
06.2020	90,500	8445	170	43,071	13,575	4,525	9,050	61,171	-29,329	0
07.2020	97,400	8445	170	43,071	14,610	4,870	9,740	62,551	-34,849	0
08.2020	93,400	8445	170	43,071	14,010	4,670	9,340	61,751	-31,649	0
09.2020	91,800	8445	170	43,071	13,770	4,590	9,180	61,431	-30,369	0
10.2020	48,700	8445	170	43,071	7,305	2,435	4,870	52,811	4,111	False
11.2020	63,200	8445	170	43,071	9,480	3,160	6,320	55,711	-7,489	0
12.2020	49,500	8445	170	43,071	7,425	2,475	4,950	52,971	3,471	False
Total Cons.	2,147,900						Total Deficit		-230,083	

$W_{supplied}$: Supplied water amount **Pop. 1:** Estimated population**W_{d1}: Estimated d**aily water consumption per capita

$W_{target1}$: Target water demand **W_{inds} :** Industrial water demand**W_{school}:** Schools water demand **$W_{com.}$:** Commercial water demand

W_{mun}: Municipal use

Appendix 5: Haspolat/Mia Milia Quarter Water Consumption 2018-2020

	Supplied						Domestic %60						Other %40			
Year	$W_{supplied}$ (m3) /mo	P_1	W_d(lt)	$W_{target1}$ m3/mo	$P_{Dor.}$	$W_{Dor.}$ (lt)	$W_{target2}$ m3/Mo	P_2 (%50 of Student	$W_{d.uni.}$ (lt)	$W_{target3}$ m3/mo	W_{inds} (%25)	$W_{mun.}$ (%5)	Leakage m3/mo (%10)	Total W_{target} m3/mo	$W_{deficit}$ m^3/mo	Deficit
1.2018	61,700	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	15,425	3,085	6,170	64,148	2,448	False
2.2018	30,700	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	7,675	1,535	3,070	51,748	21,048	False
3.2018	36,100	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	9,025	1,805	3,610	53,908	17,808	False
4.2018	62,600	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	15,650	3,130	6,260	64,508	1,908	False
5.2018	56,800	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	14,200	2,840	5,680	62,188	5,388	False
6.2018	3,600	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	900	180	360	40,908	37,308	False
7.2018	19,500	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	4,875	975	1,950	47,268	27,768	False
8.2018	54,600	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	13,650	2,730	5,460	61,308	6,708	False
9.2018	56,600	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	14,150	2,830	5,660	62,108	5,508	False
10.2018	83,980	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	20,995	4,199	8,398	73,060	-10,920	0
11.2018	74,800	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	18,700	3,740	7,480	69,388	-5,412	0
12.2018	80,670	5037	150	22,668	2,500	100	7,500	7,750	40	9,300	20,168	4,034	8,067	71,736	-8,934	0
1.2019	59,570	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	14,893	2,979	5,957	64,039	4,469	False
2.2019	109,380	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	27,345	5,469	10,938	83,963	-25,417	0
3.2019	73,240	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	18,310	3,662	7,324	69,507	-3,733	0
4.2019	77,510	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	19,378	3,876	7,751	71,215	-6,295	0
5.2019	74,800	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	18,700	3,740	7,480	70,131	-4,669	0
6.2019	85,070	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	21,268	4,254	8,507	74,239	-10,831	0
7.2019	84,790	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	21,198	4,240	8,479	74,127	-10,663	0
8.2019	60,890	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	15,223	3,045	6,089	64,567	3,677	False

Appendix 5: Continue

9.2019	78,420	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	19,605	3,921	7,842	71,579	-6,841	0
10.2019	75,890	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	18,973	3,795	7,589	70,567	-5,323	0
11.2019	71,200	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	17,800	3,560	7,120	68,691	-2,509	0
12.2019	65,930	5203	150	23,411	2,500	100	7,500	7,750	40	9,300	16,483	3,297	6,593	66,583	653	False
1.2020	77,060	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	19,265	3,853	7,706	71,378	-5,682	0
2.2020	74,110	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	18,528	3,706	7,411	70,198	-3,912	0
3.2020	75,210	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	18,803	3,761	7,521	70,638	-4,572	0
4.2020	69,510	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	17,378	3,476	6,951	68,358	-1,152	0
5.2020	70,120	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	17,530	3,506	7,012	68,602	-1,518	0
6.2020	82,640	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	20,660	4,132	8,264	73,610	-9,030	0
7.2020	74,290	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	18,573	3,715	7,429	70,270	-4,020	0
8.2020	74,530	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	18,633	3,727	7,453	70,366	-4,164	0
9.2020	56,980	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	14,245	2,849	5,698	63,346	6,366	False
10.2020	34,380	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	8,595	1,719	3,438	54,306	19,926	False
11.2020	47,330	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	11,833	2,367	4,733	59,486	12,156	False
12.2020	41,730	5279	150	23,754	2,500	100	7,500	7,750	40	9,300	10,433	2,087	4,173	57,246	15,516	False
Total Cons.	2,316,230											**Total Deficit**			53,067	

$\mathbf{W_{supplied}}$**:**Supplied water amount **P1:** Estimated population P2: Student population$\mathbf{W_{d1}}$**: Estimated d**aily water consumption per capita

$\mathbf{W_{target1}}$**:** Target water demand $\mathbf{W_{inds}}$ **:** Industrial water demand$\mathbf{W_{mun}}$**:** Municipal use$\mathbf{W_{com.}}$ **:** Commercial water demand

Appendix 6. : AHP Pair- Wise Comparison Matrix

	Implimentation cost (C1)	Return Period (months) (C2)	Operation and Managemet Cost (C3)	Quality of water (C4)	Environmental Effects (C5)	Domestic SupplyRate (C6)	Reliability (C7)	Affordability (C8)	Benefits (C9)	Normalized	Weights Matrix	C*W	□ max calc.
Implementation cost (C1)	1	1/2	1/2	1/3	1/3	1/2	1/3	1	1/5	0.46	0.0404	0.4169	10.3098
Return Period (months) (C2)	2	1	3	1/3	1/2	1/3	1/3	1/2	1/4	0.62	0.0546	0.5923	10.8414
Operation and Management Cost (C3)	2	1/3	1	1/5	1/6	1	1	1/2	1/4	0.52	0.0457	0.4402	9.6345
Quality of water (C4)	3	3	5	1	1	6	8	4	1	2.74	0.2406	2.3353	9.7074
Environmental Effects (C5)	3	2	6	1	1	5	6	3	1	2.46	0.2157	2.0664	9.5786
Domestic Supply Rate (C6)	2	3	1	1/6	1/5	1	1	1	1/4	0.72	0.0630	0.6271	9.9546
Reliability (C7)	3	3	1	1/8	1/6	1	1	1/2	1/5	0.64	0.0565	0.5983	10.5918
Affordability (C8)	1	2	2	1/4	1/3	1	2	1	1	0.96	0.0840	0.8326	9.9115
Benefits (C9)	5	4	4	1	1	4	5	1	1	2.27	0.1995	1.8777	9.4136
W_j	**0.0404**	**0.0546**	**0.0457**	**0.2406**	**0.2157**	**0.0630**	**0.0565**	**0.0840**	**0.1995**	11.38	AVERAGE		9.9937

Appendix 7: Ethropy Method Results

	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	0.153846	0.141732	0.173913	0.166667	0.172414	0.125	0.115385	0.142857	0.142857
A2	0.153846	0.141732	0.173913	0.166667	0.172414	0.125	0.115385	0.142857	0.142857
A3	0.192308	0.283465	0.217391	0.125	0.172414	0.166667	0.192308	0.178571	0.178571
A4	0.153846	0.11811	0.173913	0.125	0.172414	0.166667	0.192308	0.178571	0.178571
A5	0.076923	0.07874	0.086957	0.083333	0.034483	0.083333	0.076923	0.071429	0.035714
A6	0.153846	0.141732	0.086957	0.208333	0.137931	0.208333	0.192308	0.178571	0.178571
A7	0.115385	0.094488	0.086957	0.125	0.137931	0.125	0.115385	0.107143	0.142857
C_n*ln(C_n)	-0.28797	-0.27692	-0.30421	-0.29863	-0.30308	-0.25993	-0.24917	-0.27799	-0.27799
	-0.28797	-0.27692	-0.30421	-0.29863	-0.30308	-0.25993	-0.24917	-0.27799	-0.27799
	-0.31705	-0.35735	-0.33175	-0.25993	-0.30308	-0.29863	-0.31705	-0.30764	-0.30764
	-0.28797	-0.2523	-0.30421	-0.25993	-0.30308	-0.29863	-0.31705	-0.30764	-0.30764
	-0.1973	-0.20013	-0.21238	-0.20708	-0.11611	-0.20708	-0.1973	-0.1885	-0.11901
	-0.28797	-0.27692	-0.21238	-0.32679	-0.27324	-0.32679	-0.31705	-0.30764	-0.30764
	-0.24917	-0.22292	-0.21238	-0.25993	-0.27324	-0.25993	-0.24917	-0.23931	-0.27799
Sum	-1.9154	-1.86346	-1.88151	-1.91091	-1.87491	-1.91091	-1.89597	-1.9067	-1.87588
E_J	0.984322	0.957629	0.966906	0.982016	0.963514	0.982016	0.974334	0.979851	0.964011
1-E_J	0.015678	0.042371	0.033094	0.017984	0.036486	0.017984	0.025666	0.020149	0.035989
SUM (1-E_J)	0.2454								
W_j	**0.063886**	**0.172659**	**0.134859**	**0.073286**	**0.148678**	**0.073286**	**0.104588**	**0.082106**	**0.146653**

Appendix 8: Critic Method Results

		C1	C2	C3	C4	C5	C6	C7	C8	C9
	A1	0.67	0.31	0.67	0.33	0.00	0.67	0.67	0.33	0.25
	A2	0.67	0.31	0.67	0.33	0.00	0.67	0.67	0.33	0.25
	A3	1.00	1.00	1.00	0.67	0.00	0.33	0.00	0.00	0.00
	A4	0.67	0.19	0.67	0.67	0.00	0.33	0.00	0.00	0.00
	A5	0.00	0.00	0.00	1.00	1.00	1.00	1.00	1.00	1.00
	A6	0.67	0.31	0.00	0.00	0.25	0.00	0.00	0.00	0.00
	A7	0.33	0.08	0.00	0.67	0.25	0.67	0.67	0.67	0.25
Standard Deviation	σ	0.32	0.33	0.42	0.33	0.37	0.33	0.42	0.38	0.35
	C1	1	0.8310	0.778755	-0.5129891	-0.87208	-0.692535	-0.758786	-0.910465	-0.867
	C2	0.83106692	1	0.731230	-0.1522385	-0.5208	-0.4538431	-0.583642	-0.628759	-0.5411
	C3	0.77875498	0.7312	1	-0.0194624	-0.70064	-0.1556997	-0.378787	-0.575707	-0.470
	C4	-0.5129891	-0.152	-0.01946	1	0.533333	0.65	0.3892494	0.5916079	0.603
	C5	-0.8720816	-0.520	-0.70064	0.53333333	1	0.5333333	0.5708992	0.7888106	0.885
	C6	-0.692535	-0.453	-0.15569	0.65	0.53333	1	0.93419	0.887411	0.845
	C7	-0.7587869	-0.583	-0.37878	0.3892494	0.57089	0.9341987	1	0.921132	0.846
r_J	C8	-0.9104654	-0.628	-0.57570	0.59160797	0.78881	0.8874119	0.921132	1	0.918
	C9	-0.8672906	-0.541	-0.47006	0.60380736	0.88558	0.845330	0.846114	0.91855	1

APPENDIX 8- CONTINUE

											Sum
	C1	0	0.1689	0.221245	1.51298917	1.87208	1.6925353	1.7587869	1.9104654	1.867	11.004327
	C2	0.1689330	0	0.268769	1.15223852	1.52086	1.4538431	1.5836429	1.6287593	1.541	9.31818268
	C3	0.22124501	0.2687	0	1.01946247	1.70064	1.1556997	1.3787878	1.5757077	1.470	8.79038454
	C4	1.51298917	1.1522	1.019462	0	0.46666	0.35	0.6107505	0.4083920	0.396	5.91669202
$1\text{-}r_J$	C5	1.87208159	1.5208	1.700649	0.46666666	0	0.4666666	0.4291007	0.2111893	0.114	6.78163637
	C6	1.69253538	1.4538	1.155699	0.35	0.46666	0	0.0658012	0.1125880	0.154	5.45180397
	C7	1.75878691	1.5836	1.378787	0.61075052	0.42910	0.0658012	0	0.0788676	0.153	6.05962379
	C8	1.91046546	1.62875	1.575707	0.40839202	0.21118	0.112588	0.0788676	0	0.08	6.00741091
	C9	1.867290599	1.54113	1.4700634	0.396192636	0.11441	0.1546696	0.153885	0.081441	0	5.7790895

APPENDIX 8- CONTINUE

Quantity Of Information

σ	Sum	C_j	W_j
0.3170	11.004327	3.489067688	**0.14991422**
0.3266	9.3181827	3.044069347	**0.13079405**
0.4178	8.7903845	3.673110062	**0.15782194**
0.3253	5.916692	1.924700059	**0.08269828**
0.3659	6.7816364	2.481824787	**0.10663617**
0.3253	5.451804	1.773471965	**0.07620049**
0.4178	6.0596238	2.532046811	**0.10879405**
0.3849	6.0074109	2.312253538	**0.09935023**
0.3535	5.7790895	2.043216693	**0.08779057**

Appendix 9: Saw Method Results

PERFORMANCE MATRIX

	ECONOMICAL			ENVIRONMENTAL			SOCIAL		
	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	4	18	4	3	5	3	3	4	4
A2	4	18	4	3	5	3	3	4	4
A3	5	36	5	4	5	4	5	5	5
A4	4	15	4	4	5	4	5	5	5
A5	2	10	2	2	1	2	2	2	1
A6	4	18	2	5	4	5	5	5	5
A7	3	12	2	3	4	3	3	3	4
Selection of Min and max	2	10	2	5	5	5	5	5	5
A1	0.5	0.55556	0.5	0.6	1	0.6	0.6	0.8	0.8
A2	0.5	0.55556	0.5	0.6	1	0.6	0.6	0.8	0.8
A3	0.4	0.27778	0.4	0.8	1	0.8	1	1	1
A4	0.5	0.66667	0.5	0.8	1	0.8	1	1	1
A5	1	1	1	0.4	0.2	0.4	0.4	0.4	0.2
A6	0.5	0.55556	1	1	0.8	1	1	1	1
A7	0.66666667	0.83333	1	0.6	0.8	0.6	0.6	0.6	0.8
	0.5	0.55556	0.5	0.6	1	0.6	0.6	0.8	0.8

Appendix 10: MCDM Method Results

				Performance Matrix -Beneficial Decision					
	Non-Beneficial	Non-Beneficial	Non-Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial	Beneficial
	C1	C2	C3	C4	C5	C6	C7	C8	C9
A1	4	18	4	3	5	3	3	4	4
A2	4	18	4	3	5	3	3	4	4
A3	5	36	5	4	5	4	5	5	5
A4	4	15	4	4	5	4	5	5	5
A5	2	10	2	2	1	2	2	2	1
A6	4	18	2	5	4	5	5	5	5
A7	3	12	2	3	4	3	3	3	4
	2	10	2	5	5	5	5	5	5
Decision Matrix									
A1	0.50	0.56	0.50	0.60	1.00	0.60	0.60	0.80	0.80
A2	0.50	0.56	0.50	0.60	1.00	0.60	0.60	0.80	0.80
A3	0.40	0.28	0.40	0.80	1.00	0.80	1.00	1.00	1.00
A4	0.50	0.67	0.50	0.0	1.00	0.80	1.00	1.00	1.00
A5	1.00	1.00	1.00	0.40	0.20	0.40	0.40	0.40	0.20
A6	0.50	0.56	1.00	1.00	0.80	1.00	1.00	1.00	1.00
A7	0.67	0.83	1.00	0.60	0.80	0.60	0.60	0.60	0.80
EM - W_J	0.06388571	0.17266	0.134859	0.073285784	0.148678	0.07328578	0.1045877	0.0821057	0.146653
CM- W_J	0.14991422	0.13079	0.157822	0.082698283	0.106636	0.07620049	0.1087941	0.0993502	0.087791
AHP- W_J	0.04043882	0.05464	0.045689	0.240566971	0.215728	0.06299219	0.0564881	0.0840001	0.199461

Appendix 10: MCDM Method Results -Continue

Evaluation with Entropy Method Criteria Weights

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**Sum**
A1	0.03194285	0.09592188	0.067429563	0.04397147	0.148678	0.04397147	0.0627526	0.0656845	0.117322	0.67767463
A2	0.03194285	0.09592188	0.067429563	0.04397147	0.148678	0.04397147	0.0627526	0.0656845	0.117322	0.67767463
A3	0.02555428	0.04796094	0.053943651	0.058628627	0.148678	0.05862863	0.1045877	0.0821057	0.146653	0.72674035
A4	0.03194285	0.11510625	0.067429563	0.058628627	0.148678	0.05862863	0.1045877	0.0821057	0.146653	**0.81376015**
A5	0.06388571	0.17265938	0.134859126	0.029314313	0.029736	0.02931431	0.0418351	0.0328423	0.029331	0.56377635
A6	0.03194285	0.09592188	0.134859126	0.073285784	0.118942	0.07328578	0.1045877	0.0821057	0.146653	**0.86158409**
A7	0.04259047	0.14388281	0.134859126	0.04397147	0.118942	0.04397147	0.0627526	0.0492634	0.117322	0.75755606

Evaluation with Critic Method Criteria Weights

	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**Sum**
A1	0.07495711	0.07266336	0.078910969	0.04961897	0.106636	0.04572029	0.0652764	0.0794802	0.070232	0.64349594
A2	0.07495711	0.07266336	0.078910969	0.04961897	0.106636	0.04572029	0.0652764	0.0794802	0.070232	0.64349594
A3	0.05996569	0.03633168	0.063128775	0.066158626	0.106636	0.06096039	0.1087941	0.0993502	0.087791	0.68911619
A4	0.07495711	0.08719603	0.078910969	0.066158626	0.106636	0.06096039	0.1087941	0.0993502	0.087791	**0.77075415**
A5	0.14991422	0.13079405	0.157821938	0.033079313	0.021327	0.0304802	0.0435176	0.0397401	0.017558	0.62423277
A6	0.07495711	0.07266336	0.157821938	0.082698283	0.085309	0.07620049	0.1087941	0.0993502	0.087791	**0.84558497**
A7	0.09994281	0.10899504	0.157821938	0.04961897	0.085309	0.04572029	0.0652764	0.0596101	0.070232	**0.74252702**

Appendix 10: MCDM Method Results -Continue

Evaluation with AHP Method Criteria Weights										
	C1	**C2**	**C3**	**C4**	**C5**	**C6**	**C7**	**C8**	**C9**	**Sum**
A1	0.02021941	0.03035308	0.022844517	0.144340183	0.215728	0.03779531	0.0338928	0.0672001	0.159569	0.7319424
A2	0.02021941	0.03035308	0.022844517	0.144340183	0.215728	0.03779531	0.0338928	0.0672001	0.159569	0.7319424
A3	0.01617553	0.01517654	0.018275613	0.192453577	0.215728	0.05039375	0.0564881	0.0840001	0.199461	**0.8481524**
A4	0.02021941	0.0364237	0.022844517	0.192453577	0.215728	0.05039375	0.0564881	0.0840001	0.199461	**0.8780124**
A5	0.04043882	0.05463555	0.045689034	0.096226788	0.043146	0.02519688	0.0225952	0.0336	0.039892	0.4014202
A6	0.02021941	0.03035308	0.045689034	0.240566971	0.172582	0.06299219	0.0564881	0.0840001	0.199461	**0.9123526**
A7	0.02695921	0.04552962	0.045689034	0.144340183	0.172582	0.03779531	0.0338928	0.0504001	0.159569	0.7167577

Appendix 11: Central Nicosia Future Evaluation And Application of Alternatives

In central Nicosia, after 2023 with respect to the world standard water demand and population increase, fixing leakage will save water budget till 2029. After 2029 it is expected gap to occur. Minimum 10% addition of water needed.

Years	W_{Budget}	P_1	W_{d1}	Target $W_{demand1}$	P_2	W_{d2}	Target $W_{demand2}$	$W_{ind.}$+$W_{sch.}$+$W_{com.}$ (%25)	W_{mun}(%5)	Total Target W_{Demand}	Deficit	
2021	386,571	51871	110	171,174	17546	180	94,223	96,643	19,329	381,368	-5,203	0
2022	386,571	53263	110	175,768	17634	180	94,694	96,643	19,329	386,433	-137	0
2023	386,571	54714	110	180,556	17722	180	95,167	96,643	19,329	391,695	5,124	False
2024	**386,571**	**56077**	**110**	**185,054**	**17811**	**110**	**58,775**	**96,643**	**19,329**	**359,800**	**-26,770**	**0**
2025	386,571	57592	110	190,055	17900	110	59,069	96,643	19,329	365,095	-21,476	0
2026	386,571	59159	110	195,224	17989	110	59,364	96,643	19,329	370,560	-16,011	0
2027	386,571	60785	110	200,590	18079	110	59,661	96,643	19,329	376,222	-10,348	0
2028	386,571	62478	110	206,179	18170	110	59,960	96,643	19,329	382,110	-4,461	0
2029	**386,571**	**64253**	**110**	**212,034**	**18260**	**110**	**60,259**	**96,643**	**19,329**	**388,264**	**1,693**	**False**
2030	386,571	66084	110	218,077	18351	110	60,558	96,643	19,329	394,607	-30,621	0
2031	386,571	67986	110	224,354	18443	110	60,862	96,643	19,329	401,187	-24,041	0
2032	386,571	69684	110	229,957	18535	110	61,166	96,643	19,329	407,094	-18,134	0
2033	386,571	71021	110	234,369	18628	110	61,472	96,643	19,329	411,813	-13,415	0
2034	386,571	72386	110	238,874	18721	110	61,779	96,643	19,329	416,624	-8,604	0
2035	386,571	73778	110	243,467	18815	110	62,090	96,643	19,329	421,528	-3,700	0

Appendix 11: Central Nicosia Future Evaluation And Application of Alternatives

Years	**WB_{udget}**	**W_{budget}+ %10 increase of budget**	**P_1**	**W_{d1}**	**Target $W_{demand1}$**	**P_2**	**W_{d2}**	**Target $W_{demand2}$**	**$W_{ind.}$+$W_{sch.}$+$W_{com.}$ (%25)**	**W_{mun}(%5)**	**Total Target W_{Demand}**	**Deficit after %10 W_{budget} increase**	
2021	386,571		51871	110	171,174	17546	179	94,223	96,643	19,329	381,368		
2022	386,571		53263	110	175,768	17634	179	94,694	96,643	19,329	386,433		
2023	386,571		54714	110	180,556	17722	179	95,167	96,643	19,329	391,695		
2024	**386,571**		**56077**	**110**	**185,054**	**17811**	**110**	**58,775**	**96,643**	**19,329**	**359,800**		
2025	386,571		57592	110	190,055	17900	110	59,069	96,643	19,329	365,095		
2026	386,571		59159	110	195,224	17989	110	59,364	96,643	19,329	370,560		
2027	386,571		60785	110	200,590	18079	110	59,661	96,643	19,329	376,222		
2028	386,571		62478	110	206,179	18170	110	59,960	96,643	19,329	382,110	**%10 increase of**	
2029	**386,571**	**425,228**	**64253**	**110**	**212,034**	**18260**	**110**	**60,259**	**96,643**	**19,329**	**388,264**	**budget**	
2030	386,571	425,228	66084	110	218,077	18351	110	60,558	96,643	19,329	394,607	**-30,621**	**0**
2031	386,571	425,228	67986	110	224,354	18443	110	60,862	96,643	19,329	401,187	-24,041	0
2032	386,571	425,228	69684	110	229,957	18535	110	61,166	96,643	19,329	407,094	-18,134	0
2033	386,571	425,228	71021	110	234,369	18628	110	61,472	96,643	19,329	411,813	-13,415	0
2034	386,571	425,228	72386	110	238,874	18721	110	61,779	96,643	19,329	416,624	-8,604	0
2035	386,571	425,228	73778	110	243,467	18815	110	62,090	96,643	19,329	421,528	-3,700	0

Appendix 12 : Hamitkoy/ Mandres Future Evaluation And Application of Alternatives

Years	WB_{udget}	P_1	W_{d1}	Target $W_{demand1}$	$W_{ind.}+W_{sch.}+W_{com.}$ (%15)	W_{mun}(%5)	Leakage m^3/Month (%10)	Total Target W_{Demand}	Deficit	
2021	66,992	8750	150	39,373	10,049	3,350	6699.2	59,471	-7,521	0
2022	66,992	9077	150	40,845	10,049	3,350	6699.2	60,943	-6,049	0
2023	66,992	9411	150	42,351	10,049	3,350	6699.2	62,449	-4,543	0
2024	66,992	9735	150	43,809	10,049	3,350	6699.2	63,907	-3,085	0
2025	66,992	10080	150	45,358	10,049	3,350	6699.2	65,456	-1,536	0
2026	**66,992**	**10431**	**150**	**46,940**	**10,049**	**3,350**	**6699.2**	**67,037**	**45**	**False**
2027	66,992	10791	150	48,559	10,049	3,350	6699.2	68,657	-5,035	0
2028	66,992	11160	150	50,222	10,049	3,350	6699.2	70,319	-3,372	0
2029	66,992	11542	150	51,938	10,049	3,350	6699.2	72,035	-1,656	0
2030	**66,992**	**11931**	**150**	**53,689**	**10,049**	**3,350**	**6699.2**	**73,787**	**96**	**False**
2031	66,992	12331	150	55,490	10,049	3,350	6699.2	75,587	1,896	False
2032	66,992	12702	150	57,158	10,049	3,350	6699.2	77,256	3,564	False
2033	66,992	13020	150	58,591	10,049	3,350	6699.2	78,688	4,997	False
2034	66,992	13341	150	60,035	10,049	3,350	6699.2	80,133	6,442	False
2035	66,992	13665	150	61,492	10,049	3,350	6699.2	81,590	7,899	False

Appendix 12 : Hamitkoy/ Mandres Future Evaluation And Applicatıon of Alternatives- Continue

Years	WB_{udget}	W_{budget}+ %10 increase of budget	P_1	W_{d1}	Target $W_{demand1}$	$W_{ind.}$+$W_{sch.}$ +$W_{com.}$ (%15)	W_{mun}(%5)	Leakage m^3/Month (%10)	Total Target W_{Demand}	Deficit	Deficit * %10 W_{budget} increase	
2021	66,992		8750	150	39,373	10,049	3,350	6699.2	59,471	-7,521		
2022	66,992		9077	150	40,845	10,049	3,350	6699.2	60,943	-6,049		
2023	66,992		9411	150	42,351	10,049	3,350	6699.2	62,449	-4,543		
2024	66,992		9735	150	43,809	10,049	3,350	6699.2	63,907	-3,085		
2025	66,992		10080	150	45,358	10,049	3,350	6699.2	65,456	-1,536	%10 increase of	
2026	66,992		10431	150	46,940	10,049	3,350	6699.2	67,037	45	budget	
2027	66,992	73,691	10791	150	48,559	10,049	3,350	6699.2	68,657	1,665	-5,035	0
2028	66,992	73,691	11160	150	50,222	10,049	3,350	6699.2	70,319	3,327	-3,372	0
2029	66,992	73,691	11542	150	51,938	10,049	3,350	6699.2	72,035	5,043	-1,656	0
2030	66,992	73,691	11931	150	53,689	10,049	3,350	6699.2	73,787	6,795	96	False
2031	66,992	73,691	12331	150	55,490	10,049	3,350	6699.2	75,587	8,595	1,896	False
2032	66,992	73,691	12702	150	57,158	10,049	3,350	6699.2	77,256	10,264	3,564	False
2033	66,992	73,691	13020	150	58,591	10,049	3,350	6699.2	78,688	11,696	4,997	False
2034	66,992	73,691	13341	150	60,035	10,049	3,350	6699.2	80,133	13,141	6,442	False
2035	66,992	73,691	13665	150	61,492	10,049	3,350	6699.2	81,590	14,598	7,899	False

Appendix 12 : Hamitkoy/ Mandres Future Evaluation And Applicatıon of Alternatives- Continue

Years	**WB_{udget}**		**P_1**	**W_{d1}**	**Target $W_{demand1}$**	**$W_{ind.}$+$W_{sch.}$+$W_{com.}$ (%15)**	**W_{mun}(%5)**	**Leakage m³/Month (%10)**	**Total Target W_{Demand}**	**Deficit**	**Deficit after %20 W_{budget} increase**	
2021	66,992		8750	150	39,373	10,049	3,350	6699.2	59,471	-7,521		
2022	66,992		9077	150	40,845	10,049	3,350	6699.2	60,943	-6,049		
2023	66,992		9411	150	42,351	10,049	3,350	6699.2	62,449	-4,543		
2024	66,992		9735	150	43,809	10,049	3,350	6699.2	63,907	-3,085		
2025	66,992		10080	150	45,358	10,049	3,350	6699.2	65,456	-1,536		
2026	**66,992**		**10431**	**150**	**46,940**	**10,049**	**3,350**	**6699.2**	**67,037**	**45**		
2027	66,992		10791	150	48,559	10,049	3,350	6699.2	68,657	1,665		
2028	66,992		11160	150	50,222	10,049	3,350	6699.2	70,319	3,327		
2029	66,992		11542	150	51,938	10,049	3,350	6699.2	72,035	5,043		
2030	**66,992**		**11931**	**150**	**53,689**	**10,049**	**3,350**	**6699.2**	**73,787**	**6,795**	%20 W_{budget} increase	
2031	66,992	88429	12331	150	55,490	10,049	3,350	6699.2	75,587	8,595	-12,842	0
2032	66,992	88429	12702	150	57,158	10,049	3,350	6699.2	77,256	10,264	-11,174	0
2033	66,992	88429	13020	150	58,591	10,049	3,350	6699.2	78,688	11,696	-9,741	0
2034	66,992	88429	13341	150	60,035	10,049	3,350	6699.2	80,133	13,141	-8,296	0
2035	66,992	88429	13665	150	61,492	10,049	3,350	6699.2	81,590	14,598	-6,839	0

Appendix 13: Haspolat/ Mia Milia Future Evaluation And Application of Alternatives

Years	W_{Budget}	P_1	W_d(lt)	$W_{target1}$ m^3/mo	$P_{Dor.}$	$W_{Dor.}$ (lt)	$W_{target2}$ m3/Mo	P_2 (%50 of Student number)	$W_{d.uni.}$ (lt)	$W_{target3}$ m^3/mo	$W_{inds+}W_{agr}$ (%30)	$W_{mun.}$ (%5)	Leakage m^3/mo (%10)	Total W_{target} m3/mo	$W_{deficit}$ m^3/mo	Deficit
2021	64,824	5342	150	24,039	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	68,992	4,168	False
2022	64,824	5417	150	24,377	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,330	4,506	False
2023	64,824	5495	150	24,728	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,681	4,857	False
2024	64,824	5563	150	25,034	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,987	5,163	False
2025	64,824	5640	150	25,380	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	70,333	5,509	False
2026	64,824	5720	150	25,740	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	70,693	5,869	False
2027	64,824	5801	150	26,105	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	71,058	6,234	False
2028	64,824	5886	150	26,487	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	71,440	6,616	False
2029	64,824	5974	150	26,883	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	71,836	7,012	False
2030	64,824	6065	150	27,293	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	72,246	7,422	False
2031	64,824	6160	150	27,720	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	72,673	7,849	False
2032	64,824	6238	150	28,071	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,024	8,200	False
2033	64,824	6290	150	28,305	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,258	8,434	False
2034	64,824	6343	150	28,544	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,497	8,673	False
2035	64,824	6398	150	28,791	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,744	8,920	False

Appendix 13: Haspolat/ Mia Milia Future Evaluation And Application of Alternatives – Continue - %10 Water Budget Increase in 2021

Years	W_{Budget}	W_{budget}+ %10 increase of	P_1	W_d(lt)	$W_{target1}$ m^3/mo	$P_{Dor.}$	$W_{Dor.}$ (lt)	$W_{target2}$ m^3/Mo	P_2 (%50 of Student	$W_{d.uni.}$ (lt)	$W_{target3}$ m^3/mo	$W_{inds+}W_{agr}$ (%30)	$W_{mun.}$ (%5)	Leakage m3/mo (%10)	Total W_{target} m^3/mo	$W_{deficit}$ m^3/mo %10 incr.	Deficit
2021	**64,824**	**71,306**	**5342**	**150**	**24,039**	**2,500**	**100**	**6482.4**	**7,750**	**40**	**9300**	**19,447**	**3241.2**	**6482.4**	**68,992**	**-2,314**	**0**
2022	64,824	71,306	5417	150	24,377	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,330	-1,977	0
2023	64,824	71,306	5495	150	24,728	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,681	-1,626	0
2024	64,824	71,306	5563	150	25,034	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,987	-1,320	0
2025	64,824	71,306	5640	150	25,380	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	70,333	-973	0
2026	64,824	71,306	5720	150	25,740	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	70,693	-613	0
2027	64,824	71,306	5801	150	26,105	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	71,058	-249	0
2028	**64,824**	**71,306**	**5886**	**150**	**26,487**	**2,750**	**100**	**6482.4**	**7,750**	**40**	**9300**	**19,447**	**3241.2**	**6482.4**	**71,440**	**134**	**False**
2029	64,824	71,306	5974	150	26,883	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	71,836	530	False
2030	64,824	71,306	6065	150	27,293	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	72,246	939	False
2031	64,824	71,306	6160	150	27,720	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	72,673	1,367	False
2032	64,824	71,306	6238	150	28,071	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,024	1,718	False
2033	64,824	71,306	6290	150	28,305	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,258	1,952	False
2034	64,824	71,306	6343	150	28,544	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,497	2,190	False
2035	64,824	71,306	6398	150	28,791	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,744	2,438	False

Appendix 13: Haspolat/ Mia Milia Future Evaluation And Applıcatıon Of Alternative- Continue - %20 Water Budget Increase in 2028

Years	W_{Budget}	Wbudget+20%	P_1	W_d(lt)	$W_{target1}$ m3/mo	$P_{Dor.}$	$W_{Dor.}$ (lt)	$W_{target2}$ m3/Mo	P_2 (%50 of Student	$W_{d.uni.}$ (lt)	$W_{target3}$ m3/mo	$W_{inds+}W_{agr}$ (%30)	$W_{mun.}$ (%5)	Leakage m3/mo (%10)	Total W_{target} m3/mo	$W_{deficit}$ m^3/mo	%10 incr.
2021	64,824		5342	150	24,039	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	68,992		
2022	64,824		5417	150	24,377	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,330		
2023	64,824		5495	150	24,728	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,681		
2024	64,824		5563	150	25,034	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	69,987		
2025	64,824		5640	150	25,380	2,500	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	70,333		
2026	64,824		5720	150	25,740	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	70,693		
2027	64,824		5801	150	26,105	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	71,058		
2028	**64,824**	**77,789**	**5886**	**150**	**26,487**	**2,750**	**100**	**6482.4**	**7,750**	**40**	**9300**	**19,447**	**3241.2**	**6482.4**	**71,440**	**-6,349**	**0**
2029	64,824	77,789	5974	150	26,883	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	71,836	-5,953	0
2030	64,824	77,789	6065	150	27,293	2,750	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	72,246	-5,543	0
2031	64,824	77,789	6160	150	27,720	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	72,673	-5,116	0
2032	64,824	77,789	6238	150	28,071	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,024	-4,765	0
2033	64,824	77,789	6290	150	28,305	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,258	-4,531	0
2034	64,824	77,789	6343	150	28,544	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,497	-4,292	0
2035	64,824	77,789	6398	150	28,791	3,025	100	6482.4	7,750	40	9300	19,447	3241.2	6482.4	73,744	-4,045	0

Appendix 14: Similarity Check Results

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Appendix 15: Plagiarism and Ethical Rules Contract Form

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