

SUSTAINABLE WATER MANAGEMENT FOR THE FUTURE AT SARITEPE-
KILYOS CAMPUS OF BOGAZICI UNIVERSITY

by

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ABSTRACT

SUSTAINABLE WATER MANAGEMENT FOR THE FUTURE AT SARITEPE- KILYOS CAMPUS OF BOGAZICI UNIVERSITY

Recently, sustainability of water resources gained a lot of attention due to the lack of the resources, overpopulation and over industrialization throughout the world. In this regard, universities give support to their students, providing a more livable environment by taking environmentally friendly and economically practical precautions. Considering sustainability concept, Saritepe-Kilyos campus at Bogazici University in Turkey is one of the pioneers in developing a sustainable campus. It has a current population of 1500 which is a growing trend. Moreover, the water demand of the campus is supplied by groundwater and water tankers from ISKI. Therefore, increase in population, reduction in the level of groundwater and economic problems associated with the water tankers led to the water challenges in terms of quantity and sustainability on this campus. The aim of this study is to analyze the state of current and future water management of the Saritepe-Kilyos campus in terms of sustainability and recommend feasible and sustainable water practices to achieve a more sustainable campus by 2030. Both water and wastewater cycles in Saritepe-Kilyos campus have been studied to achieve the most applicable solutions. Based on the type of water and wastewater resources, different and feasible green infrastructure systems including usage of graywater systems, effective use of potable water of the existing buildings, collection of rainwater, desalination, preservation and improvement of groundwater resource and installation of water meters were introduced and proposed to overcome the water shortage on the campus and to improve the campus in terms of water sustainability by 2030.

ÖZET

BOĞAZİÇİ ÜNİVERSİTESİ'NİN KİLYOS KAMPÜSÜ'NDE GELECEKTE SÜRDÜRÜLEBİLİR SU YÖNETİMİ

Son yıllarda, su kaynaklarının sürdürülebilirliği dünyadaki doğal kaynakların yetersizliği, hızlı nüfus artışı ve sanayileşme nedeniyle dikkat çeken bir konu haline gelmiştir. Bu konuda üniversiteler, çevre dostu ve ekonomik açıdan uygulanabilir tedbirler alarak daha yaşanabilir bir çevre yaratmak için öğrencilerine destek olmaktadır. Sürdürülebilirlik kavramı göz önünde bulundurulduğunda, Boğaziçi Üniversitesi'nin Sarıtepe-Kilyos kampüsü sürdürülebilir bir kampüs olma yolunda Türkiye'de başı çekmektedir. Şu anki nüfusu 1500 olan Sarıtepe-Kilyos kampüsü gün geçtikçe büyüyen bir kampüstür. Buna ek olarak, kampüsün su ihtiyacı İSKİ'den temin edilen su tankları ve yeraltı suyu sayesinde karşılanmaktadır. Bu nedenle kampusun nüfusundaki artış, yeraltı suyu seviyesindeki azalmaya ve su tankerlerinden kaynaklı ekonomik problemler kampüste suyun miktarı ve sürdürülebilirliği açısından sorunlara yol açmıştır. Bu tezin amacı, Sarıtepe-Kilyos kampüsünün mevcut ve gelecekteki su yönetimini sürdürülebilirlik açısından analiz etmek ve 2030 yılına kadar sürdürülebilir bir kampus sağlamak için uygulanabilir ve sürdürülebilir su yöntemleri önermektir. Sarıtepe-Kilyos kampüsündeki su ve atık su döngüsü en cazip çözümleri elde etmek için incelenmiştir. Kampüsteki su probleminin üstesinden gelinmesi ve kampüsteki su sürdürülebilirliğinin 2030 yılına kadar geliştirilebilmesi amacıyla, su ve atık su kaynakları göz önünde bulundurularak, gri su sistemlerinin kullanımı, mevcut binalarda içme suyunun etkin kullanımı, yağmur suyu toplama sistemi, desalinasyon, yer altı su seviyelerinin korunması ve iyileştirilmesi ve su sayaçlarının kurulumu gibi farklı ve uygulanabilir doğa dostu yeşil altyapı sistemleri incelenip önerilmiştir.

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LIST OF SYMBOLS/ABBREVIATIONS

Abbreviation	Explanation
ASEAB	Associated Students Environmental Affairs Board
CSC	Campus Sustainability Committee
EIA	Environmental Impact Assessment
EMAS	Environmental Monitoring and Assessment
EPA	Environmental Protecting Agency
HE	Higher Education
ISO	International Organization for Standardization
LID	Low Impact Development
STARS	Sustainability Tracking, Assessment and Rating System
TBL	Triple Bottom Line
TL	Turkish Lira
UN	United Nations
USD	United States Dollar

1. INTRODUCTION

Industrial development and human activities throughout the world resulted in serious global concerns and issues including reduction in non-renewable energy resources, increasing energy costs, ecological effects of global energy use, use of advanced technologies, public interest and consciousness level, environmental pollution, climate change, ozone layer depletion, insufficient natural resources, loss of biodiversity, deforestation, and radioactive wastes which affected the world balance adversely. In addition to developments in industry, rapid growth of the world population and its changing distribution, whole countries are putting ever-increasing pressure on restricted natural sources of the nature. As a result of recognition of the risks and outcomes of those problems, the concept of sustainability introduced by The United Nations World Commission has played a significant role in governmental and non-governmental organizations in order to resolve the environmental issues socially and economically (Clugston and Calder, 1999).

Sustainable Development (SD) is a comprehensive challenge, which possess multidimensional concepts based on environmental, social and economic issues. The essential point of sustainability is to meet the human needs and to conserve limited resources for future generations. In other words, what is required for sustainability is to meet the economic welfare, protection of the nature and its natural resources and supporting the social development (Lundin et al., 1999).

Global actions are very crucial to understand and encourage sustainable development. For instance, education plays critical role to raise the knowledge and awareness of individuals and governments in sustainability (OECD, 2008). Universities and colleges can be viewed as a small city. University campuses consume natural resources in their academic and non-academic buildings, green spaces, various roads and vehicles, and therefore are in charge of the environmental issues. That's why, adopting sustainability is required for higher education institutions to establish environmental-friendly campuses in society, find and suggest innovative and feasible solutions for both global issues and their challenges (Johnson and Castleden, 2011).

One of the most significant international issues is the water problem. In many developing and third world countries, clean and fresh water is hardly accessible, whereas developed powerful countries consume water resources unwisely and damage fresh water resources adversely. Considering all these reasons, water deficit has been a remarkable financial, governmental and social concern in many sectors including education.

Considering the fact that there is water shortage in whole world resource, a sustainable approach to water resources can be implemented by practices including water reuse, rainwater harvesting, and minimal water consumption. Sustainable water management is an unavoidable strategy in order to foster the limited fresh as well as other water resources. To implement and improve sustainable and integrated water resource management, both communities and governments have expectations from universities and colleges. Due to significant role and missions of colleges and universities in community, they have a potential to be pioneer in sustainable development towards their studies, researches, attitudes, and actions (Cortese, 2003). As a result, universities including Duke, California and Yale Universities have tended to study the sustainable water management in their campuses by researching, analyzing and supporting logical, environmentally-friendly and innovative solutions and increasing the awareness (Johnson and Castleden, 2011).

In Turkey, universities, particularly Boğazici University is the leading university in the sustainability and green campus with their activities, missions and applications. Kilyos-Saritepe campus of the Bogazici University, has generated its own electricity utilizing renewable wind turbines and honored as the first campus in Turkey considering this issue. Moreover, this campus uses the treated water by its own wastewater treatment plant for irrigation. Despite the supply of renewable energy on the campus, Kilyos campus confronts water shortage problem, since it is growing rapidly in terms of infrastructure and population. The sources of water on campus comes from groundwater, surface water, and also water purchase and delivery by tankers of ISKI.

Kilyos campus has some drawbacks in terms of water resources and usage. The main current water source is groundwater which is not a sustainable resource since it may be finished. Since Similarly, water tankers delivering water to the campus which are financially a big burden for the university and environmentally unsustainable. For these reasons, establishing a sustainable water management for the current and future circumstance of the campus by developing innovative and feasible plans is necessary.

The objective of this study is to comprehensively analyze the Kilyos campus of the Bogazici University in terms of water sustainability and suggest suitable water practices by identifying current and future structure of the campus. This contains water resources, discharge of used water, the water need of the university, determining the cost of recommended water practices and proposed water preservation methods by which the university can decrease its water consumption. Moreover, some approaches and methods applied by leading universities for water sustainability will be investigated and the ones which are more suitable and applicable for Kilyos campus will be determined.

2. LITERATURE REVIEW

2.1. The concept of Sustainability and Sustainable Development

Increase in population along with overconsumption of resources lead the world to face with various environmental, social and economic problems such as water scarcity, wars, climate change, and decline in natural resources. Regarding concerns about environmental crisis and social inequalities in the world, United Nations (UN) Conference on the Human Environment in Stockholm, the first UN summit on environment, introduced the concept of “*sustainable development*” in 1972. The increasing challenges of environment, resources and social integrity in 1980s brought about the necessity of the description of sustainability as ‘*the development that meets the needs of the present without comprising the ability of future generations to meet their own needs*’ via the Brundtland Report. Definition of The World Commission on Environment and Development (1987) is perceived as one of the most remarkable definitions of sustainable development in the literature (Brundtland Commission, 1987). Over time, sustainability, which is an environmental progress and important value for institutions to gradually achieve desired circumstances, has been adopted by many stakeholders including governments, businessmen, non-governmental organizations, academics, and citizens from all over the world (Hodgkin, 1994).

Various definitions of sustainability and sustainable development have been generated by many declarations, academics and global conferences. According to Forum for Future (2008), sustainability is “*a dynamic process which enables all people to realize their potential and improve their quality of life in ways which simultaneously protect and enhance the Earth’s life support systems.*” Stated by Solow (1993), another definition for sustainability is to preserve productive capacity for the indefinite future. In other words, sustainability can be perceived as an important responsibility while utilizing natural resources. Hodgkin et, (1994) defined sustainability that if resources can be acquired in order to perform, provide and recover the processes coming from any source, it is possible to see advantage in terms of sustainable development.

Sustainability is the sum of long-term progress of responsibility. It involves environmental, economic and social dimensions, and the management concepts. In the later 1990s, John Elkington et al., (2004) created the term ‘Triple Bottom Line’ (TBL) which consists of three basic categories: social, environmental and economic fields (Figure 2.1). As being similar to the concept of sustainability, the TBL framework is based on investment relying on positive stocks of economic,

environmental, and social values (Elkington et al., 2004). In other words, sustainability can be viewed as a main tool and also need for human society to enhance living standards and reduce risks caused by industrial, social and political systems (Rodriguez et al., 2002).

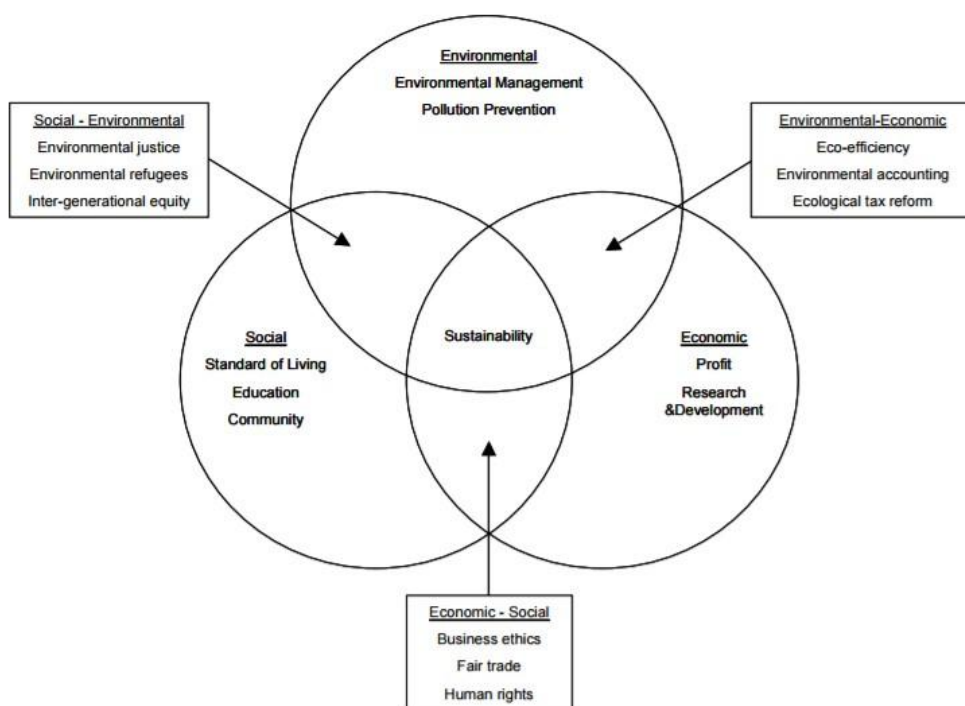


Figure 2.1. TBL framework of sustainability.

2.2. Water Management and Sustainability

When the well is dry, we learn the worth of water (Benjamin Franklin, Poor Richard's Almanac 1733).

Accessing to clean and safe water is a basic human right. It is a well-known fact that water is an integral part of life for all living creatures on the earth. Even though water covers roughly 71 % of the Earth's surface, only about 3 % of water sources is potable (USGS, 2016). However, due to the overpopulation, overconsumption, global warming and modernization, water resources are decreasing day by day, triggering water scarcity. It is supposed that nearly 2.4 billion people try to sustain their lives without improved sanitation facilities and it is estimated that this number will become double by 2030 (UNICEF, 2015). According to The United Nations World Water Development Report in 2015, it is expected that there will be 40 % scarcity of drinking water in the world by 2030, which is only 12 years from present day. In this regard, it is predictable that wars over

water will happen in the future if the required strategies are not taken into account for the sustainable use of water.

By the mid to late 20th century, water topics, especially sustainable development and integrated water resources management became a dominant trend in national and international medias because of increased worry and interest about water scarcity. In 1974, the Safe Drinking Water Act was established to manage domestic water systems (Cascadia Green Building Council, 2011). In 1992, concepts associated with water were seriously mentioned in International Conference on Water and Environment in Dublin and the Earth Summit in Rio de Janeiro.

In addition to governmental acts to water sustainability, universities are also the main centers that can find creative and innovative solutions for water topics. Most of these centers are susceptible to the environment which may enforce the sustainability as a principle in lectures and studies. It is inevitable for universities that water is a decreasing natural resource, and thus the universities should take necessary actions to create more water-friendly campuses. Encouraging water sustainability at the campuses protects the university's surrounding environment and basically supports establishment of a more sustainability-conscious population (Wright, 2004).

Currently, the 2030 Agenda for Sustainable Development consisting of 17 Sustainable Development Goals (SDGs) in 2015 has been approved by UN Member States to illustrate the role of communities, countries, institutions and in general all the human groups. As sustainable Development Goal 6, ensuring worldwide access to clean and safe potable water and improved sanitation facilities for each individual by 2030 is on this agenda.

2.3. Sustainability in Higher Education (HE) Institutions

Higher Education (HE) institutions have been viewed as a main structure to achieve sustainable development. The sustainability concept has gained much attention from the majority of communities compared to the past. Recently, various institutions, communities, nations and many universities throughout the world have found a common basis to overcome environmental problems such as reduction of non-renewable energy resources, increasing energy costs, ecological effects of global energy use, climate change, reduction of species diversity and water shortage, etc. (Alshuwaikhat and Abubakar, 2008). Particularly, universities are able to show their awareness and propose improvements through research, teaching, campus operations, conferences, workshops and student initiatives to focus more on sustainable development and integrate sustainability.

The curiosity about sustainability in academic institutions commenced in early 1970s with the Stockholm Conference generates a correlation between sustainability and higher education (Clugston and Calder, 1999). The Talloires Declaration in 1990 is approved as the initial declaration given by universities to show their commitment to sustainability in Higher Education. Jean Mayer, the President of Tufts University, came together with more than 20 university directors in Talloires, France, to express their worries associated with the situation of the Earth and provided a paper that specified the main processes that must be taken by universities to achieve more sustainable future. The meeting illustrated the role of the university in the way that “Universities educate most of the people who develop and manage society’s institutions, technologies, and tools to create an environmentally sustainable future. For this reason, universities bear profound responsibilities to increase the awareness and knowledge” (Talloires Declaration, 1990).

Until today, more than 500 university rectors and chancellors at institutions in more than forty countries have signed The Talloires Declaration (ULSF, 2018). This demonstrates that there is a growing awareness to develop sustainable campuses by reducing the adverse influences of the campus operations. There is no doubt that signing the Talloires Declaration was viewed as only a symbolic act by some institutions, while others perceived as a power and framework for planned development toward sustainability (Clugston and Calder, 1999). At the same time, other experts published documents in order to assess the development process of sustainability tools in higher education institutions (Shriberg, 2002; Cole, 2003; Alshuwaikhat and Abubakar, 2008; Kamal and Asmuss, 2013; Gómez et al., 2014). Furthermore, Ramos et al. (2004), Lozano (2006), Velazquez et al. (2005), Boer (2013), Roorda (2013), Wang and Ching, (2015) and Amaral et al. (2015) conducted studies in order to evaluate and indicate university achievements and systems in sustainability.

In addition to Talloires, over 1000 educational institutions have signed various international declarations such as: Halifax Declaration (1991), Kyoto Declaration (1993), Swansea Declaration (1993), COPERNICUS Charter (1994), Thessaloniki Declaration (1997), Campus Earth Summit (1994), Lüneburg Declaration (2000), Barcelona Declaration (2004), Graz Declaration (2005), Turin Declaration (2009) and Abuja Declaration (2009)) to demonstrate their loyalty (Figure 2.2) (Lozano et al., 2013). For instance, Halifax Declaration, Canada, contains environmental degradation and extensive effect of poverty (UNESCO, 1991). In Lüneburg Declaration, the importance of collaboration and cooperation is underlined to achieve the desired sustainability level in higher education (Newman and Robins, 2011). The Swansea Declaration from Association of Commonwealth Universities Fifteenth Quinquennial Conference in 2008 expresses the role of universities in communities. This declaration states that “Universities have a major responsibility to

help societies shape their present and future development policies and actions into the sustainable and equitable forms necessary for an environmentally secure and civilized world”. As it is noticed, it is possible for the rest of these initiatives to say that they are based on sustainable and environmental aims and points for the goals of the university (Alshuwaikhat and Abubakar, 2008).



Figure 2.2. The evolution of declarations related to environmental sustainability in universities.

Many of the universities which signed the declarations have not provided the required actions and standards of sustainable development into practice due to lack of area, experts, resources, and governmental interest (Valezquez et al., 2006). Furthermore, some universities establish their own institutional policies such as International Organization for Standardization (ISO) 14001, green building initiative, Environmental Monitoring and Assessment (EMAS), environmental stewardship, Environmental Impact Assessment (EIA) of projects and environmental protection, etc. in order to be sustainable campuses (Koç, 2014).

2.3.1. Defining a Sustainable Campus

The idea of sustainable campus has gained a lot of attention throughout the world for university representatives and administrators due to deficiency of governmental support, the recognition of the effects, the events and attitudes of universities on the nature. This concept has also been reinforced with the pressure of governments, environment protection association, sustainability activities, academic institutions, student actions and non-governmental agencies. In 1990, the Talloires Declaration at a universal conference in France became the first official statement provided by academic communities for environmental sustainability in higher education (Rodriguez, 2002).

Sustainable university is described by Velázquez et al. (2006) as “*a higher educational institution that addresses the minimization of negative environmental, economic, societal, and health effects generated through the use of the campus resources*”. Cole (2003) also explained the sustainable campus as ‘the one that acts upon its local and global responsibilities to protect and enhance the health and well-being of humans and ecosystems. It actively engages the knowledge of the university community to address the ecological and social challenges that we face now and, in the future’. A sustainable university campus can be also viewed as a fresh and open environment, which provides equal rights and peace having a successful economy through decline in energy and resource usage, the amount of waste reduction and convenient environmental management that enhances the current and future university community. Thus, it can be stated that there is a common correlation among the definitions of a sustainable university campus, which signifies a better harmony between economic, social and environmental targets in a successful organization and also lasting performance (Alshuwaikhat and Abubakar, 2008).

The need for a broader understanding of sustainable development in university campuses has been emphasized in many studies. In a study by Smith (1993), universities are viewed as “*a microcosm*” of environmental challenges that people encounter in various fields. In another research, it is accentuated that the concept of sustainability must play an active role not only in politics but also in other sectors like education (Leal Filho et al., 1996). According to Bernheim (2003), academic institutions are the essential part of the automobile-intensive, high consumption, waste-intensive global landscape. Due to increase in student and scholars’ population, the needs towards soil, water, and other natural resources are increasing accordingly, which brings on environmental disruption. Thus, it is fundamental for their environmental development to protect natural resources (Alshuwaikhat and Abubakar, 2008).

2.4. Water Sustainability in Universities

In recent decades, environmental sustainability has gained an intensive interest since the universities tend to conserve and minimize their renewable and non-renewable resources, specially water. In this regard, university leaders and experts in their fields have established some declarations for sustainability to see and report their advancements and achievements after planning and applying their strategies. These declarations have been announced in various publications (Lozano et al., 2015).

Since the late 1970s, various local and international declarations and agreements associated with sustainability in HE have been created and improved. Some of them are shown in Table 2.1 (McHugh,

2011). In those declarations and agreements, there are some definitions and principles about aims of sustainability for university efforts and activities. Among which, four declarations including the Talloires Declaration, Agenda 21 of the Earth Summit, ISCN Charter and the Bonn Declaration refer to water topics in university. The Bonn Declaration (2009) focuses on the significance of water sustainability in HE. For instance, in Talloires Declaration, certain environmental problems such as contamination and destruction of water source, and water scarcity is mentioned. Agenda 21 of the Earth Summit represents information and principles to manage water resources and systems gradually. Even though the other declarations do not directly refer to water topic, the majority of them dwell on general standards of sustainable development instead of specifically analyzing natural resources (Wright, 2004).

Table 2.1. An overview of whether and how water is addressed in declarations which are important to sustainability at higher education.

DECLARATION	YEAR	WATER
Tbilisi Declaration	1977	-
Talloires Declaration	1990	Water pollution; destruction and depletion of water
Halifax Declaration	1991	-
Earth Summit Agenda 21	1992	Water quality and quantity
Swansea Declaration	1993	-
Kyoto Declaration 1993	1993	-
CRE-COPERNICUS Charter	1993	-
Thessaloniki Declaration	1997	-
Lunenburg Declaration	2001	-
Ubuntu Declaration	2002	-
Graz Declaration	2005	-
ACUPCC (Climate Commitment)	2007	-
Draft International Sustainable Campus Network (ISCN) Charter	2009	Water use
Bonn Declaration	2009	Water as a priority issue and challenge

Universities are considered as ‘small cities’ possessing significant direct and indirect environmental influences stemming from their high population and different activities such as laboratory use, buildings and parks maintenance, consumption of water resources and chemical use on the environment. The aforementioned university-related activities causing environmental problems are needed to be monitored and controlled gradually (Alshuwaikhat and Abubakar, 2008).

By monitoring the environmental problems, it is easier to identify and suggest more sustainable options and strategies and further reduce their environmental footprints (Lukman et al., 2009).



3. WATER MANAGEMENT PRACTICES IN SMALL COMMUNITIES

With emergence of Millennium Development Goals, several developed and developing countries focus on activities of small communities for preservation and effective usage of ecosystems and natural resources, particularly water in a more healthy, sustainable and cost-effective way. Via planning, designing and altering their movements and habits, more attention to water management is necessary in small or remote communities for sustainable living, since basic needs and desired utilities like water are not accessed by them easily.

To guarantee a fast result and also permanent sustainability, compulsory needs for the growth and encouraging human and industrial resources should be included in actions attributed to water supplies of a small community. Small scale industries can be in cooperation with small communities to manage, design and improve their water systems. With regard to dependability of the system, wholesome and suitability of water, there are some critical factors including demand-driven method, constant community meeting, cost, time, simplicity, feasibility, comfort of long-term maintenance and repair efficiency, which should be combined into designs to enhance small water supplies (WHO, 2005).

According to WHO (2005), Water Safety Plans are obligatory for all water systems and should be adapted and designed for structures of different types of supply. In practice, there are specific applications and practices used by small communities like universities to support water conservation, water collection and create greener infrastructure. The most important ones will further be discussed and evaluated in the Chapter 6 of this study when the situation of Kilyos campus is taken into consideration.

Furthermore, different water management practices will be discussed and the appreciate ones will be selected and suggested to be applied to Kilyos campus.

3.1. Cisterns and Rain Barrels

Cisterns and rain barrels are low-cost systems consisting storage tanks which are used to catch and store rainwater from roofs and other impervious areas during storm events. Cisterns are generally preferred as commercial and industrial accumulation equipment for rainwater harvesting, collection and reuse because of their large size, whereas rain barrels are more suitable for residential regions.

Cisterns can store 200 to over 10,000 gallons of runoff water, therefore requires more space. Cisterns are placed underground, at ground level, or on an elevated stand, depending on the area conditions (Clark and Acomb, 2008). They are produced in various shapes, sizes and from different materials which help to save space.

Compared to cisterns, the capacity of rain barrels is generally in the range of 50 to 200 gallons, which needs small space on site. Although rain barrels require less space, they can be connected, or daisy-chained to increase the total storage capacity. In addition, rain barrels connected to the existing downspout of a roof, can be served to reuse the stormwater for watering plants and other agricultural and landscaping uses.

3.2. Green Roof

Green roofs typically designed to let vegetative growth can contain not only hard but also soft roof landscaping alternatives. In other words, these roofs are composed of a vegetative layer growing in a specially-designed soil, which sits on top of a drainage layer. Although green roofs are more expensive than conventional roofs, they are convenient for absorbing and holding large amounts of stormwater. In short, the main benefit of green roofs is to decrease storm water runoff when the green roofs are established in any building (Figure 3.2).

According to the EPA in 2004, over 75 percent of water runoff is decreased by green roofs during storm events. Moreover, green roofs provide sustainability benefits such as absorbing air and noise pollution, rooftop cooling by decreasing UV radiation absorption, providing living environments for birds, and encouraging biodiversity (NYC, 2017). The advantageous of green roofs are illustrated in Table 3.1 (Concordia University, 2015).

Furthermore, green roofs have a significant role to attain BRE Environmental Assessment Method (BREEAM) credits. This assessment method sets the standards for investigating the total environmental and sustainable performance of an individual building development. As a result of this, application of green roof has gained importance especially in universities. Using green roof at University of Wisconsin resulted in holding 6,192 gallons of water, which decreases the amount and velocity of runoff, and lets the rainwater to penetrate for better water quality, while also providing some insulation in the winter and evaporative cooling in the summer.

Green roofs with their beneficial properties can be applied in new buildings rather than current ones in campus. Since current roofs for green roofs are not suitable and economically feasible.

Table 3.1. The advantageous of green roofs in general terms taken from Concordia University.

Environmental Benefits	Economic Benefits	Legislative Benefits	Reputational Benefits
Reduction of storm water run-off	Energy savings for buildings due to lower climate control needs	Assist in climate change legislation by diminishing CO ₂ emissions	Contributes to LEED certification and AASHE STARS ratings
Reduction of the heat island effect	Potential for carbon offset/credits	-	Gamer positive media attention
Reduction of air pollution	Potential for urban agriculture projects	-	Potential for increased recreational places
Absorbs CO ₂ emissions	Extend waterproofing life expectancy	-	-
Potential to increase local biodiversity	-	-	-



Figure 3.2. Green roofs in Connecticut University.

3.3. Blue Roofs

Blue roofs consist of weirs at the roof drain inlets to control the rate of runoff from the roof. A waterproofing membrane within different elements should be established at the roofing system if the The blue roof method has been perceived as an alternative way over green roofs to separate storm-water reduction techniques (NYC, 2012). Blue roofs are non-vegetated methods which are based on collecting stormwater temporarily on the surface of the roof.

A blue roof is a system that catches rainwater directly on a rooftop, keeps it for a while and slowly releases it into the sewer system. During this period, some pit storage and vaporization losses can be observed. By this way, blue roofs severely decrease the amount of non-treated rainwater which would rather flow down into the channels, storm drains, and sea. Moreover, the rainwater accumulated in blue roofs can be used in outdoor irrigation, site infiltration system and rain gardens (Hammond, 2017).

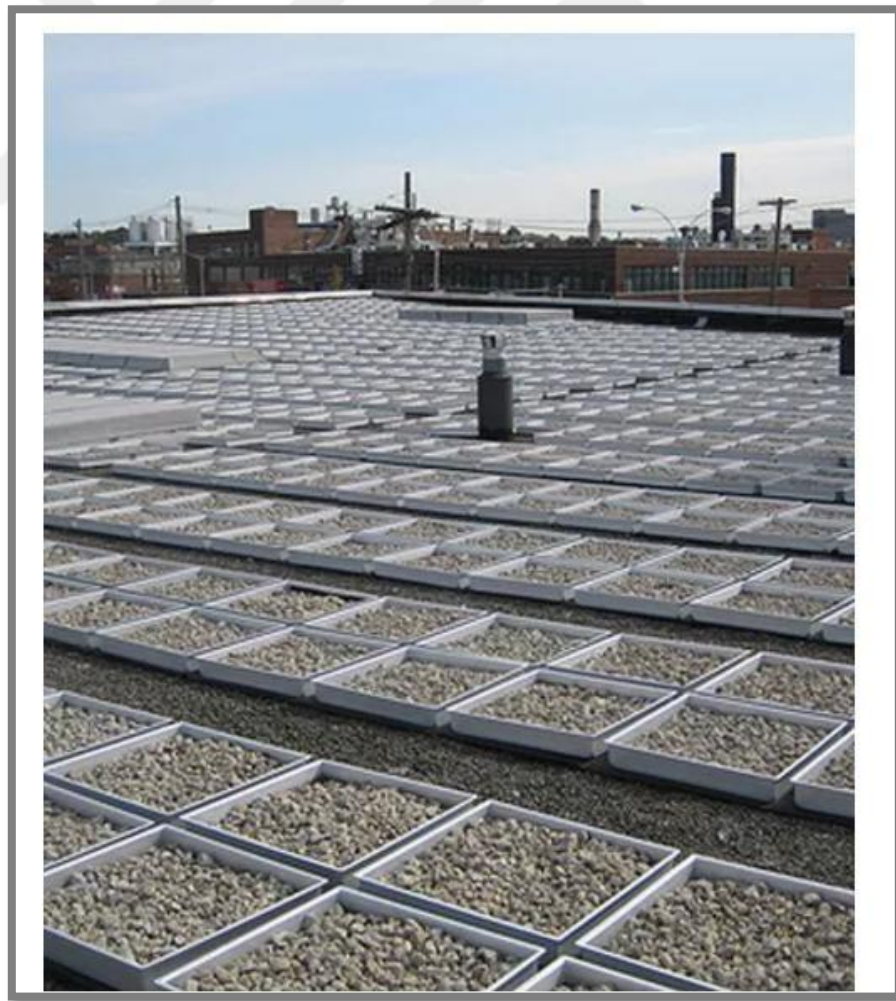


Figure 3.3. Blue Roof system (Gowanus Canal Conservancy).

Blue roofs are cheaper than green roofs since the former does not require much materials for production. Another advantage of blue roofs is being most effective and applicable when established on relatively building surfaces. Due to the light-colored roof material, they can also provide sustainable advantageous to make rooftop cold. Despite of the advantages, blue roofs have some negative sides such as less effective in energy reduction or habitat and aesthetic appeal (Connecticut Fund for the Environment, 2017).

Green and blue roofs may be used in combination as shown in Figure 3.4 (Shafique, M., and Kim, R., 2017). This combination via other approaches to ameliorate the performance of buildings for water storage and provide habitat for some animals such as bees (Pearson, 2013).

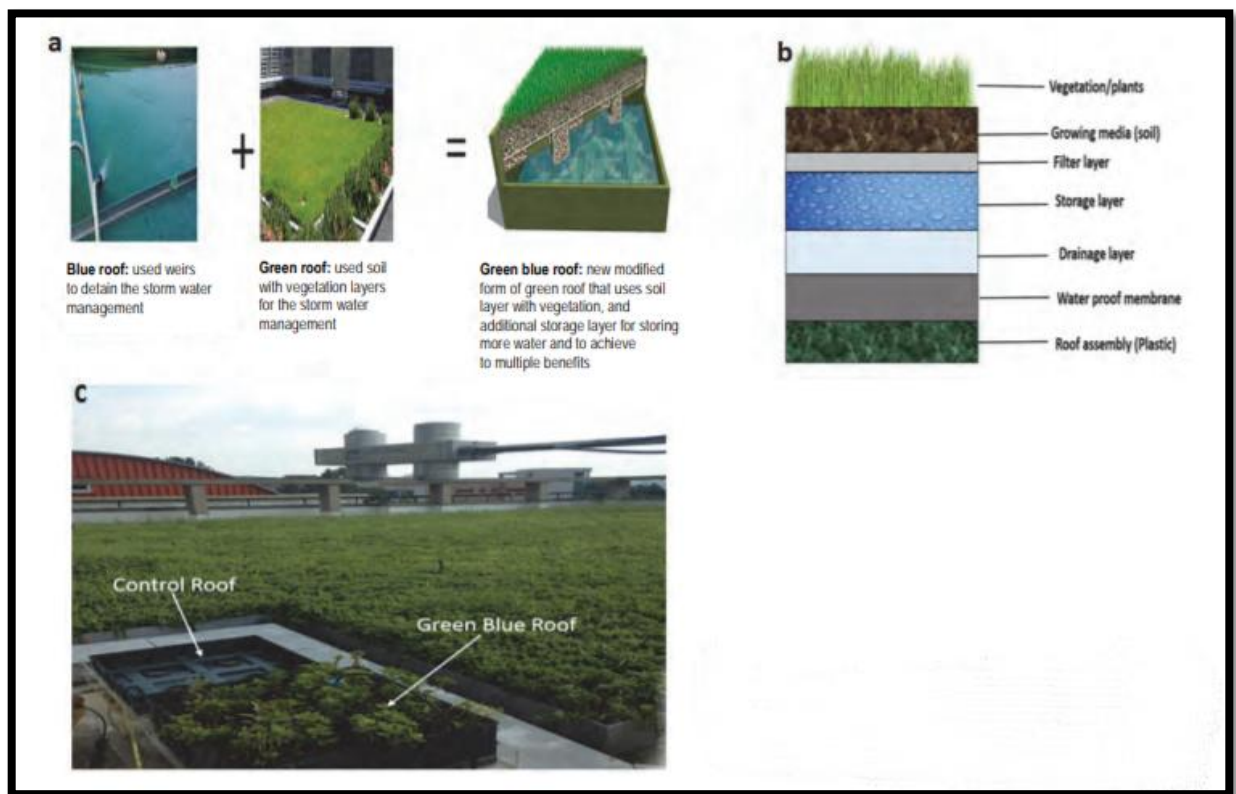


Figure 3.4. The combination of blue roof and green roof.

3.4. Rain Gardens

A rain garden is natural or man-made depression, which helps rainwater to directly flow into soil to be absorbed from impermeable surfaces including rooftops, streets, pavements, and other surfaces. Rain gardens are vegetated with bushes or enduring plants in order to maintain soil structure ranging from flooded to dry, and may be colorful (Severin, 2009). Rain gardens have some advantages as stated below;

- Absorption of nutrients and filtration of pollutants,
- Decrease the flow rate of water and help sustain enough stream flow for infiltration,
- Provide groundwater recharge,
- Improve the appearance of the environment,
- Prevent flooding and drainage troubles,
- Less equipment for municipal storm water treatment structures.
- Enhance stormwater (Dietz and Filchak, 2006).



Figure 3.5. An example of rain garden in University of New England.

3.5. Vegetation Swales and Bioswales

Similar to rain gardens, bioswales are vegetated drainage with drought-tolerant plants in order to retain and filter stormwater. Bioswales are applied for treatment of contaminants and reduction of nutrients and metals in runoff. Besides, considering side slope and soil structures, they can reduce volume and velocity of runoff to improve water quality (Clark and Acomb, 2008). In addition, bioswales are designed to decrease the amount of suspended sediments, metals, and hydrocarbons from surface runoff water (Anderson et al., 2016). Bioswales can be utilized to control stormwater, and also, they play an important role in best management practices, or treatment train.

Despite the similarities, there are some differences between rain gardens and bioswales. Firstly, bioswales are deeper than gardens. Secondly, bioswales are used to carry a certain amount of water from a large imperviable area to another area. In addition, they often need to use engineered lands in order to provide space for large amounts of stormwater (Yuan, 2016).

Bioswales are typically cheaper to design than curb and gutter or underground storm sewer systems for residential and commercial applications. Moreover, the most common sites for bioswales are generally linear systems, such as parking lot islands and medians, residential road swales or highway medians in length than width. The pollution coming from cars in parking area goes to bioswales during storm events. By following this, bioswales act as a primary treatment by filtering the water captured and discharge then filters the water and releases cleaner water into the storm drain system or a local waterway (Anderson et al., 2016).

Bioswales are considered as cost-effective tools for removing sediment and other pollutants from stormwater runoff. The pollutant removal rates of vegetated swales vary depending on soil type and type of vegetation used. Some universities such as Cornell University implemented this Low Impact Development (LID) with the collaboration of their students.



Figure 3.6. The planting of bioswale on Cornell University, 2014.

3.6. Desalination

Since 1960s, water technology spread constantly and provides a major element of fresh water supply in many arid countries (Lattemann and Höpner, 2008). Due to overconsumption of water resources and increasing population density, the tendency to purify water from the highly saline ocean waters consisting 97 % of the total water present in the Earth is noticeably increased in order to meet basic needs (Karagiannis and Soldatos, 2008). Specially, the presence of a long coastline provides a great opportunity to use the desalination system to overcome the probable water scarcity (Manju and Sagar, 2017).

Desalination is a process whereby salt and other minerals from seawater, brackish water, wastewater, or contaminated groundwater are removed to obtain pure water for drinking and other targets. Desalination allows to access water resources of the oceans and to give a reliable and independent source of fresh water at any coastal site. The concentration of salt in freshwater and seawater changes from 500 ppm to 35,000 ppm (Metke et al., 2016). The global capacity of installed

desalination plants accounts for 86.8 million m³/day. Currently, according to The International Desalination Association (IDA) (2015), there are more than 18,000 desalination plants reported in 150 countries.

Despite of achieving the pure water through desalination, separation of minerals from sea water has some disadvantages. According to the World Health Organization (WHO) report, the concentration of chloride levels of around 0.25 kg/m³ and sodium levels of 0.20 kg/m³ in potable water cause noticeable taste in water. In addition to noticeable taste, desalination generally consumes 75.2 Terra Watt-h per year, approximately 0.4 % of total energy which is the most energy-intensive water treatment process (Shahzad et al., 2017). It needs sufficient energy mostly supplied from conventional fuels. Installation of a desalination plant in developing countries is challenging due to high prices involved towards primary investments and its operation and maintenance. For instance, thanks to sufficient amount of conventional fuel resources, the governments of Middle East countries encourage desalination technology. It is reported that 70 % of world's desalination plants are located in the Middle East region (Manju and Sagar, 2017).

3.7. Graywater

Graywater (GW) is one of the most widespread water supply systems around the world which can be provided through domestic water reclamation and reuse (Benami et al., 2015). Graywater is defined as the wastewater generated from household appliances bathing, laundry and in some cases, kitchen use excluding wastewater from kitchen sinks, dishwashers, or toilets (Al-Jayyousi, 2003).

In municipal areas, graywater is generally used for toilet flushing, which can diminish individual in-house water demand by 40–60 % (Kim et al., 2009). In addition to flushing, GW is utilized for groundwater recharge, irrigation and landscape (AlJayyousi, 2003). Besides, due to graywater filtration systems, annual water bills can be decreased by 35% to 40 % and water consumption can also be reduced, which decreases wastewater generation. To help save the environment for the next generation, using this system in irrigation increases the productivity of sustainable backyard ecosystems and agriculture (Ghrai, 2011).

Table 3.2. Characteristics of typical graywater from some sources.

Source	BOD ₅ (mg/l)	COD (mg/l)	Turbidity	NH ₃	P	Coliform
Hand basin	109	263	-	9.6	2.58	-
Combined	121	371	69	1	0.36	-
Synthetic graywater	181	-	25	0.9	-	1.5x10 ⁶
Single person	110	256	14	-	-	-
Single family	-	-	76.5	0.74	9.3	-
Block of flats	33	40	20	10	0.4	10 ⁶
College	80	146	59	10	-	-
Large college	96	168	57	08	24	5.2x10 ⁶

The quality and amount of raw GW depends principally on sanitary standards, geographical location, demographics and the lifestyle within a household such as building age, the number of residents, eating habits, and detergents, soaps and shampoos used (WHO, 2006). As a result, the composition of graywater is not uniform. In Table 3.2, some parameters of contents of graywater from different areas are demonstrated. (Al-Jayyousi, 2003). Based on Table 3.2, GW has generally suspended high solids and turbidity (Benami et al., 2015).

While using water coming from recycling systems, four main factors including hygienic safety, aesthetics, environmental tolerance, technical and economic feasibility should be considered (Nolde, 2000). Therefore, using raw GW containing possible pathogenic microorganisms can pose health threat and lead to undesirable aesthetic results like odor generation and color change (Kim et al., 2009).

In most countries, there are not guidelines and standards for water reuse in buildings (Al-Jayyousi, 2003). On the other hand, especially Australia and USA use raw GW as agricultural irrigation whereas others permit the use of gray water without required treatment process. Due to the possible directly or indirectly health risk on human, some countries prohibit the use of this water (Benami et al., 2015).

According to the EPA, filtration and disinfection are necessary to utilize reclaimed water for toilet flushing. The effluent should not contain any noticeable fecal coliform in 100 ml of the treated water. (Al-Jayyousi, 2003). Moreover, Table 3.3. gives information about some water quality values and principles used in certain areas.

Table 3.3. Quality of different waters suitable for water recycling.

	Total Coliform/100ml	Fecal Coliforms	BOD₅ (mg/l)	Turbidity (NTU)	Cl₂, residual (mg/l)	pH
Bathing water standards*	10,000 ^(m) 500 ^(g)	2000 ^(m) 100 ^(g)	-	-	-	6-9
USA, NSF	-	<240	45	90	-	-
USA, EPA	Non-detectable	-	10	2	1	6-9
Australia	<1	<4	20	2	-	-
UK(BSIRA)	Non-detectable	-	-	-	-	-
Japan	<10	<10	10	5	-	6-9
WHO	100 200	-	-	-	-	-
Germany	100	500	20	1-2	-	6-9

*Bathing water standards suggested as suitable for domestic water recycling.

(g) guideline

(m)mandatory

The main point for using domestic reclaimed water is to remove pathogenic microorganisms. Likewise, there is a growing evidence that the elimination of pathogenic bacteria is essential for domestic GW reuse (Maimon et al., 2010). Considering the quantities and sources of GW, various technologies and methods ranging from simple systems in single houses to very advanced treatment schemes for large-scale reuse have been established to eliminate pathogens. Among them, chlorination and UV radiation are the most widespread treatment systems (Benami et al., 2015).

Additionally, rainwater may be combined with greywater and can lead to hybrid system. In this system, stormwater can be controlled at its source in order to prevent surface runoff and flooding unfavorable outcomes (Leong et al., 2016).

3.8. Rainwater Harvesting

Another related approach for sustainable water management is rainwater harvesting. Rainwater harvesting is used to save potable water, preserve the features of its water and diminish the risk of flooding. Rainwater harvesting generally needs quite simple system consisting of only a catchment basin like roof surface, parking area, a transportation system such as pipeline, gutters and downspouts

and a storage container like rain barrel or cistern (Hicks, 2008). The location and size of holding tanks, the material of conveyance systems is determined optionally (Sabota, 2009).

The use of collected rainwater depends on its quality. Rainwater can be used for domestic and non-potable purposes especially toilet flushing and irrigation. Although rainwater does not have high pollution, it may need sufficient treatment before using for potable purposes. Therefore, only filtration might be necessary to eliminate debris for protection of pipes and pumps (Leong et al., 2017).

3.9. Landscape Management

The purpose of landscape management is to avoid or minimize the discharge of pollutants including sediment, debris, pathogens, fertilizers, total residual chlorine and pesticides coming from landscaped areas from moving to storm drains. To provide a sustainable campus landscape the following steps must be taken:

- Irrigation system is established and controlled at least once during the dry season to prevent non-storm water discharges. Extra water for irrigation is also reduced by monitoring irrigation system.
- Any crack or leakage in the irrigation system should be determined and fixed regularly.
- The characteristic of defined soil should be determined and taken required precautions in case of any dangerous erosion possibility.
- Both equipment and area used should be surrounded with berm and cover to prevent pollutants going into storm water conveyance system.
- Collected plants should not directly discharge to the storm water drainage system.
- Fertilizers or pesticides should not be used if there is any possible natural event like rain or storm forecasted.
- It is important to use environmentally-friendly pesticides rather than copper-based pesticides.

3.9.1. Cleaning Activities

Another approach for reducing use of water is to block the discharge of wash water or pollutants generated from washing activities from going into storm drains. In addition to the pollutants contained

in the wash water, pollutants on the ground (oil and grease, food waste, sediment, litter debris, and dust) can also be picked up by the wash water as it drains towards the storm water system.

This practice is implemented to any outside building surface cleaning which provides wash water for some areas like stairs, roads, streets, courtyard, sidewalks, entryways, parking lots, waste storage areas, roofs, loading docks, and bleachers.

- i) Generally dry-cleaning methods like sweeping or vacuuming and sustainable and environmental-friendly products would be preferred for cleaning in academic buildings and dormitories, which reduces the use of domestic water.
- ii) Any wash water or cleaning products should not be allowed to go to the stormwater conveyance system.
- iii) Waste water generated from washing activities should be prevented to flow into close storm drains by implementing; sand bags or a easily carried berm to protect storm drain special designed mats or a weighed down plastic liner as a temporary solution.
- iv) Wastewater used for indoor or outdoor cleaning activities can be picked for using wet and dry vacuum mopping
- v) Discharge wash water;
- vi) Landscaped area if there are no chemicals in it.
- vii) Sanitary sewer if it contains toxic chemicals.
- viii) Not only the pollutants in the wash water but also pollutants on the ground including oil and grease, food waste, nutrients, tiny particles and dust would be taken under control by collecting accordingly and not letting drain towards the storm water system.
- ix) Workers should be properly educated for surface cleaning activities and removal of wash water.

3.9.2. Fire Sprinkler and Hydrant Testing/Flushing

The main issue is that any determined discharges of water from fire sprinklers or hydrants flushing and testing should not be allowed to flow through storm drain inlets. Good practices include:

- (I) The area close to storm drain can be covered to prevent water generated from outdoor work activities
- (II) This water can be put into a suitable tank or a tanker truck and removed as follows:
 - Fire sprinkler water must be discharged to the sanitary sewer system.

- Fire hydrant water collected can be used for cooling in buildings or discharged to and taken to the sanitary sewer system.
- If the amount of clean water is less than 25 gallons, it can be used for an impervious vegetated place.



4. THE AIM OF THE STUDY

Since the emergence of Brundtland Report, sustainability development has become a key point for many institutional fields particularly universities (UNESCO, 2016). Campus sustainability concept has many aspects, among which water is the main topic that is going to be covered in this study. This thesis mainly focuses on water management and sustainability in Kilyos Campus. This study aims to develop a sustainable approach to water management and to determine ideal strategies and practices by using water efficiently considering decreasing water resources used in Kilyos Campus, by looking for alternative water resources protecting current water sources, by taking certain comprehensive measures. The essential targets of this study are given as following:

- Give background information on the current state of water resources in Kilyos campus
- Decrease the water demand
- Find alternative water sources
- Suggest suitable and logical water practices with their costs
- Safeguarding current water resources
- Treat wastewater on-site and use that water for different aims like toilet flushing, irrigation, car washing and indoor cleaning
- Evaluate methods applied by other universities to save water and establish a more sustainable campus
- Plan and establish green infrastructure features to manage water usage and application

5. WATER MANAGEMENT EXAMPLES IN SUSTAINABLE CAMPUSES

5.1. The Practices for Water Sustainability in Universities

Due to increase in global issues such as climate change, water scarcity, depletion of natural resources, deforestation, air, land and soil pollution, many universities in developed and developing countries have taken remarkable steps to decrease their natural resources like water consumptions and to create a greener and more sustainable campus (Johnson and Castleden, 2011). When water sustainability is considered in HE institutions, National University of Singapore, for example, aims to diminish %20 of their domestic water consumption between 2012 to 2020 by applying certain strategies like replacement of old their fixtures with more efficient model ones, harvesting rainwater (NUS, 2017). Furthermore, another university having BREEAM certificate is Central European University, which utilizes drip irrigation for reducing fresh water resources (CEU,2018). Other green institution is King Abdullah University of Science and Technology (KAUST). They are planning to construct desalination plant in order to supply their water demand (KAUST, 2018).

Institutions in our country have significant roles with their practical operations towards sustainable future. For instance, Istanbul Technical University supplies water from lake at Ayazaga Campus in order to irrigate vegetation and uses drought tolerant plants like linden and redbud (ITU, 2018) In. Sabancı University is also using an artificial lake whose water is provided from the rainwater and treated sewage. The accumulated water is exploited to irrigate plants on the campus (Sabancı University, 2018).

In this study, certain universities including Duke University, Yale University and University of California, Santa Barbara, which are leading the way in sustainability, will be examined.

5.1.1. Duke University

Duke University is one of the leader universities in sustainable development, which has made remarkable actions on sustainability and conservation of natural resources since 2009. There is a Campus Sustainability Committee (CSC) with representative faculty, students, and working staff which was established to provide and also promote the conditions of the university for educating the students and achieving a more sustainable campus. Duke received various sustainability awards such as Sustainability Tracking, Assessment and Rating System (STARS) Gold Rating, Princeton Review

Green Rating of 98/100, Carolina Recycling Association's 2013 Outstanding College or University Program Award, Sustainability Tracking, Assessment and Rating System (STARS) Gold Rating and 41 LEEDTM certified buildings.

The university has performed significant actions to integrate sustainability into the campus. Duke has been working on reduction of water consumption considering the water regulations of the city. The university utilizes some non-potable water coming from the underground wells, rainwater cisterns, and retention ponds on the university grounds for irrigation and other applications. According to the data, approximately 10-15% of the water used for irrigation is non-potable. Since 2006, Duke has been successful to reach 40% reduction in potable water per gross square foot (Duke University, 2017).

In order to improve and develop water efficiency on the campus, the following steps have been taken:

- Water bottle refilling stations were established in non-residential campus buildings. 400,000 plastic bottles are saved via refilling stations.
- In 2012, Duke University applied a water audit to determine potential watersaving opportunities including faucets, toilets and showers in 6 buildings. By this audit, Duke is anticipated to conserve annually 8 million gallons of potable water, as well as cutting some of the energy to heat hot water.
- Rainwater and runoff from 22 percent of the main campus area collected in reclamation pond is used in cooling buildings of campus, which is expected to save approximately 100 million gallons of potable water per year.
- Hand sanitizers were substituted with the previous sterilizers in required places such as residential hall bathrooms, kitchens, laundry room and common areas.
- Thousands of low-flow aerators on lavatories, low-flow shower, and low-flow flush valves on urinals and toilets have been installed throughout the campus.
- Reverse Osmosis (RO) system was applied on the cooling tower blowdown to clean water and reuse in the cooling towers.

In addition, measurements and applications were performed for irrigation:

- Vegetation such as growing drought tolerant landscaping plants has been applied on the campus.
- Temporary system has been designed to irrigate essential athletic fields which involves the use of reclaimed water.

- Cisterns were installed to collect water.
- The size of irrigation ponds on golf course have been enlarged to allow more natural water storage.

In addition to the above methods, students with education about sustainability are also dedicated to sustainable development plan of Duke university;

- More than 10,000 low flow shower heads were freely given to homes of the university and Medical Center staff, employees and students which preserved about 73 million gallons of water.
- Duke University uses durable water bottle or mugs instead of single use bottles of water, which enhances water consumption in a more environmentally responsible manner at their brown bag luncheons.
- In order to increase water preservation awareness, simple and environmentally friendly behaviors at Duke University have been prompted by conserving and minimizing usage of energy, water, and paper, as well as money. In this respect, Duke's sustainability signs are designed and applied at decision-making points like light switches, faucets and paper towel dispensers.



Figure 5.1. Reclamation pond in Duke University.

The changes and measures applied by the university will save over \$120,000 per year for them in water and energy costs, however, the university spent \$ 150,000 to implement these developments (Roth, 2013). Moreover, Duke University began to fully utilize a new reclamation pond shown in Figure 5.1., saving 90 million gallons of city water in the first year of operation. Facilities Management has also completed the third phase of a multiyear water audit and retrofit project resulting in the installation of low-flow plumbing hardware in the top 30 water consuming university buildings (Duke University, 2016).

5.1.2. Yale University

Established in 1701, Yale university with 343-acre main campus is centered in New Haven, Connecticut; with total acreage of 1,153. It has more than 25,000 people on campus. The first Sustainability Strategic Plan of Yale was published in 2010 with the aim of reducing greenhouse gas emissions. Yale wants to be a leader of sustainability issue by using resources wisely and enhancing the ecological and environmental future of the campus. Yale was successful to alleviate greenhouse gas emissions by 16 % since 2005 and aims to achieve 43 % reduction by 2020 (Yale University, 2013). The other substantial consequences of the first plan are as following;

- The amount of solid waste has been decreased by 24 %
- The recycling rate increased by 28 %
- 95 % of food waste has been composted
- With the new construction (LEED) Gold certification was awarded

Moreover, the university have created and started to implement other sustainability management plans including Green Purchasing Guidelines, Sustainable Stormwater Management Plan (2013–2016), Water Management Plan 2013–2016, Sustainability Supplement to the Framework for Campus Planning and A Plan for Sustainable Transportation at Yale University.

Water is an important resource among other natural resources used in Yale University (Yale University, 2013). Water consumption for domestic use, practices, and irrigation in the campus is about 450 million gallons per year. The aim of the university is to decrease their potable water consumption by 5% until 2020 (Yale University, 2017).

To conserve, diminish and promote efficient use of water, the university has applied following methods;

- Treatment and recycle of gray water for some aims like flushing and irrigation.
- To decrease water consumption in buildings, replacement of old shower heads with a high-performance model one
- To check and observe irrigation leakages, install high-performance irrigation systems and control moisture of selected irrigation locations
- To determine and control the academic schedule in order to decrease frozen water demand over the summer and to prevent use of potable water

- Using collected stormwater in toilet flushing
- Establish green infrastructure for stormwater management

Furthermore, to move toward a more sustainable campus, the university has prepared sustainable stormwater management report. The report contains the following systems to be applied to the campuses;

- Bioswales in parking lots, road medians, and along roads
- Green roof
- Monitor and determine leakages stormwater systems
- Blue roof
- Use water meter
- Rain Gardens
- Enhanced Tree Pits
- Constructed Wetlands
- Subsurface Infiltration
- Permeable Pavement
- Collect rainwater and/or gray water for irrigation (Yale University, 2017).

It can be stated that Yale is aware of the value of water beyond its utility budget and the need for a long term effective and flexible water management plan.

5.1.3. University of California, Santa Barbara

The University of California, Santa Barbara (UCSB) Campuses are placed in the Santa Barbara County, on the Pacific coast of the United States. UCSB consists of four main campuses: the 422-acre Main Campus, the 184-acre Storke Campus, the 273-acre West Campus, the 174-acre North Campus.

The University of California, Santa Barbara has rigid interest toward environmental activities and sustainability since the 1969 oil spill event in the Santa Barbara Channel. In 1970, a group of faculties namely “The Friends of the Human Habitat” developed an environmental education program, which became one of the first undergraduate Environmental Studies Programs in the United

States. After two decades, UCSB signed the Talloires Declaration in order to make a public commitment, which was an important step to encourage sustainability.

The UCSB Office of Sustainability was established in order to plan, provide and control the sustainable improvements, efforts and perceptions during academic semester. After establishing of Sustainable Office, the primary sustainability plan of the campus was proposed in 2004 and approved by 2005. The main elements of the 2015-2016 Campus Sustainability Plan (CSP) of UCSB are based on the three main topics of sustainability: social justice, economics, and the environment. In the topic of the environment the president of the university, Robert Dynes in 2007, approved the Policy on Sustainable Practices in order to diminish influence of university on the environment and remove dependency on non-renewable energy.

In addition, the academic staffs and students in UCSB have also been active in increasing the environmental challenges. The University views its campus as a living area in which every individual possesses active roles in order to create more sustainable campus. In 1992, The Associated Students Environmental Affairs Board (ASEAB) was established. Recently, there are more than forty student organizations working on sustainability in the Office of Student Life and Associated Students.

According to UCSB's data on water consumption, potable water usage on campus was diminished by 12% from 2013 to 2016 despite of the increase in the population of the campus. This progress indicates the efforts of the USCBA toward water conservation and sustainability.

The following precautions have been taken in Campus sustainability plan UCSB 2015 in order to enhance water efficiency:

- The university is aimed to use recycled water for toilets and cooling tower
- 40 places specified for the use of recycled water in irrigation.
- New activities like water movie trailers, posters and advertisements on buses have been applied to inform the public
- About 1 million gallons of water per year is saved via water cooling system process.
- Marked high priority storm drain inlets across campus by putting "only rain in the drain" signboard in order to prevent contamination.
- Whole storm drain outfall was determined and analyzed.

To reduce water demand in landscape and irrigation, the below stated actions has been taken;

- Potable water used for irrigation decreased by 50 % in the whole campus.
- Reclaimed water has been started to utilize in some academic buildings and also about 90% of campus was irrigated with recycled water.

To decrease the amount of water for used plants, mulch has been preferred rather than turf in relatively appropriate locations.

In terms of industrial applications, the following measurements are taken by the university;

- Water-cooled vacuum pumps were replaced by the oil-cooled ones estimated to save over 5,500,000 liters of water per year.
- Recycled water is used for cooling towers.
- More than 50 single-pass cooling condensers in laboratories were substituted with the assistance of Goleta Water District's rebate program.

In addition, the following steps has been performed for residential and dining;

- The college retrofitted old dish machines with 200 new high efficiency front load washing machines expected to reduce water usage by 79 %.
- Installation of more than 3,000 low-flow aerators on lavatories which can decrease the faucet water use by over 70 %.

According to UCSB's Water Consumption Report Fiscal Year 2015 – 2016, as a result of given education by university, students and staff also have responsibilities to manage their water consumptions by taking shorter showers, turning off water during brushing teeth and reporting any leaks for signs of wasted water.

As a new innovative method, dual-plumbed system, which uses separate piping systems for reclaimed water and potable water within a plant, has been installed which can save approximately 600,000 gallons of water in every year.

5.2. General Information About Bogazici University

Founded as Robert College in 1863, Bogazici University was the first American university established outside the borders of United States. Approximately 100 years later, in 1971, today's

South Campus, including academic buildings, the library, laboratories and all facilities and personnel, was given to the Turkish government, thus Bogazici University was officially established.

The university has developed in education and architecture. Currently, Bogazici University has more than 16500 enrolled students. Today, it has 6 main campuses including South, North, Hisar, Uçaksavar, Kilyos-Saritepe and Kandilli with a total surface area of 1.672.106 m², most of which are placed on the European side of the Istanbul. Kandilli Campus is located on the other side of Bosphorus, while Saritepe Campus, is situated near Kilyos on the coast of Black Sea. Kilyos campus which is 34 km far from the Istanbul and has 1.272.600 m² surface area, has been given to Bogazici University by the Ministry of National Education in 1985. The Kandilli Campus with its observatory house and Hisar Campus were incorporated to the University in 1982 and 1989, respectively.

Bogazici University is the leading institution in Turkey toward environmental awareness in both education and research. The ultimate aim is being a successful, sustainable and green university in academic sector. Becoming a green campus started with establishing a green campus commission in 2010. A committee consisting of Bogazici University School of Foreign Languages, general directorate of construction, rectorate, student representative board, coordinator-ship of university have played a significant role in implementation and creation of the university's master plan.

With the help of awareness of personnel and students, university takes active roles in the prevention of environmental pollution, management and control of energy and natural resources to create more sustainable campus. Likewise, the reduction in emission and waste by improving recycling and reuse concepts are adopted in order to achieve a sustainable campus. In this regard, historical, cultural and environmental preservation of Bogazici university is one the most important initial objectives. Strategic plans of the university include developments in environmental consciousness, protecting the historical and green texture on campuses, achieving zero carbon approach by conducting researches, and designing a sustainable and green campus. As a consequence of these kinds of studies, the university aims to create a positive impression on international sustainable education platforms in terms of environmentally and socially. As a result, Sustainable Green Campus Application Committee was created in 2014 to implement desired goals. Although there are some annual plans of Sustainable Development and Cleaner Production center in Hisar Campus, there is no documented evidence available regarding attempts at assessing the environmental performance of the campus.

When it comes to green infrastructures in university, gray water systems in the Hamlin Hall are one of the most notable applications. As the first historical building with this utilization, it was awarded the LEED-Gold certification in Turkey (Erten, 2015). After 4 years, the same practice was applied to the 4th north dormitory of the university at the north campus. In both buildings, systems are designed to recycle 16 m³ per day of water. In order to deal with the high-water demand of the dormitories, water efficient armatures and fittings were integrated with a gray water system, which collect wastewater from showers and sinks to be reused in various areas such as reservoirs, toilets and irrigation.

Another application is implementation of a new lighting system with highly efficient LED bulbs between South campus walkway and Natuk Birkan Building in 2012 to decrease energy consumption. LED bulbs, which are 10 times durable than conventional incandescent bulbs, and 30% more efficient. Feasible and applicable methods of substitutability for other academic buildings and dormitories are being continued.

In addition to energy efficiency, Saritepe-Kilyos Campus with its wind turbine also has a tendency to be a green campus. This is the first University Campus in the world which generates its electricity utilizing its own wind power plant. In late 2014, in order to provide its energy, the renewable wind turbine was established. The energy capacity of the wind turbine is 1 MW. As associate Professor Emre Otay, coordinator of the project stated, the wind energy also helps to decrease use of excess electricity and carbon emission.

The other sustainable approach of the university is related to water conservation. To save water, the university has given sufficient importance to green campus studies. In this context, water saving cartridges attached to all the taps of dormitories in 2010 which led to 35% water saving. Another application for water efficiency is rainwater collection from rooftops of north and Kandilli campuses for irrigation and cleaning. The same strategy is being planned for the Hisar Campus.

6. KILYOS CAMPUS

Kilyos campus is located on the Black Sea coast. The area of this campus is 1.272.600- square meter, which has been given to Bogazici University by the Ministry of National Education in 1985. This campus includes dormitories for students, housing for academic staff members, classrooms for the English Preparatory High School students, offices and a library. Moreover, a small hotel and two cafeterias are located on this campus. In Figure 5.1, the layout plan of the campus is presented (Çamlıbel, 2011).

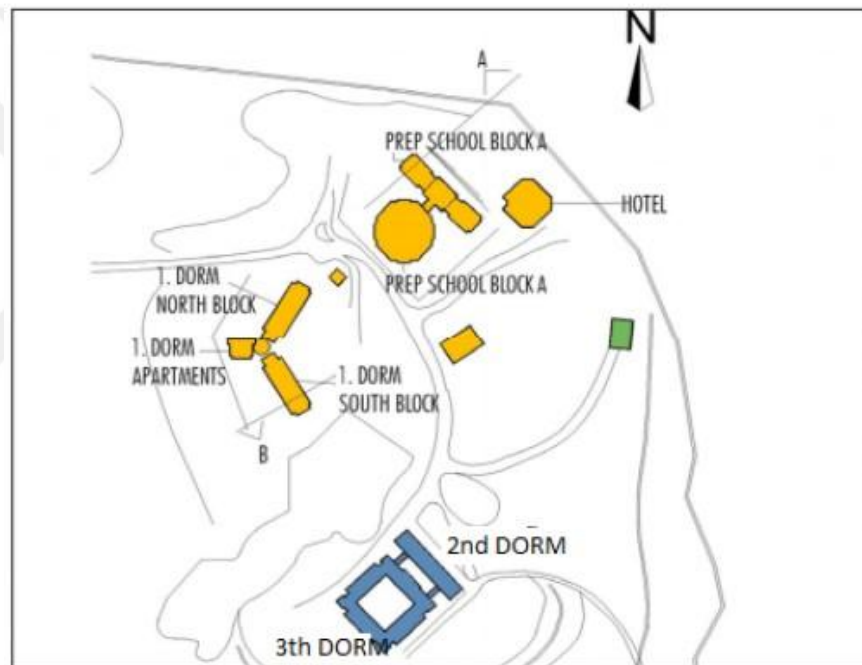


Figure 6.1. Settlement plan of Kilyos Campus.

The current total campus population is roughly 1500 people. The Figure 6.3 illustrates the trend in English preparatory student population on Kilyos campus from 2011 to 2017.

According to data from Bogazici University School of Foreign Languages, the student population has experienced continuous growth since 2011 (Figure 6.4).



Figure 6.2. A view from Kilyos Campus.

Furthermore, Figure 6.4 demonstrates the changes on the population of all English Preparatory students from 2009 to 2016. According to the data on student population, the total number of English preparatory students can be expected to reach approximately 3500 people in the year of 2030. For this year, considering new buildings, laboratories and graduate programs on Kilyos, in addition to English preparatory students, the number of other individuals including personnel, staff, lecturers and other students will increase as well. In total, roughly 5000 people can be estimated by 2030. It is necessary to think of the water demand when that population will start to study at Kilyos.

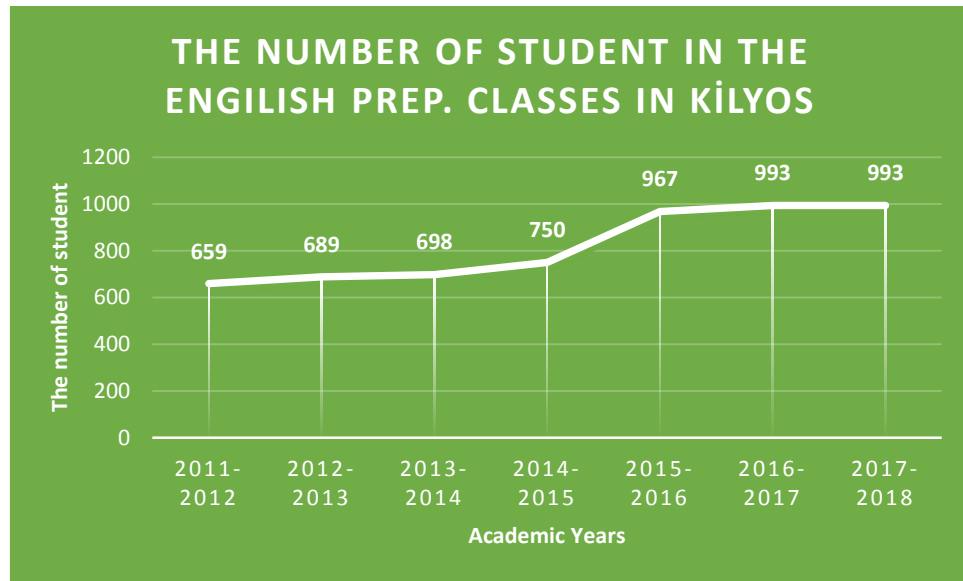


Figure 6.3. Increase in the number of English prep students on Kilyos Campus.

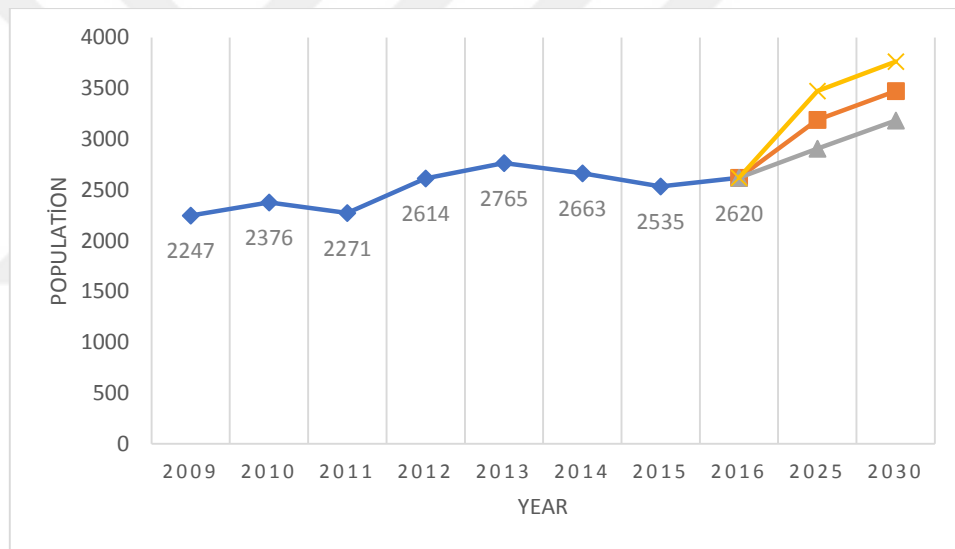


Figure 6.4. Growth in the number of all English preparatory students.

6.1. Current State of Water Kilyos on Kilyos Campus

Although the number of residents is not high, the amount of water supply on campus is not adequate to satisfy the demand of the campus population neither today nor in the future. This shows that the campus is faced with water shortage problem. Water comes from three main sources: pumped water from groundwater (127 tonnes/day), surface water (60 tonnes/day) and water tankers of the municipality (60 tonnes/day). However currently, surface water is not used due to sand contamination. In line with the information obtained from interviews with the authorities in the university, the campus purchases an average of 150 tankers of water per month, each tanker having a capacity of 23 cubic meters of water. Based on these figures, groundwater is the main source of

potable water and irrigation on campus over the whole year around. During winter, the daily water consumption is 240 tonnes of potable water whereas in summer time, this amount decreases since the dormitories are empty. Hence, the campus using only groundwater does not need to purchase water by water tankers in summer. Nevertheless, the Bümed Burc beach, the restaurant and the hotel used as a temporary dormitory in campus are active in summer.

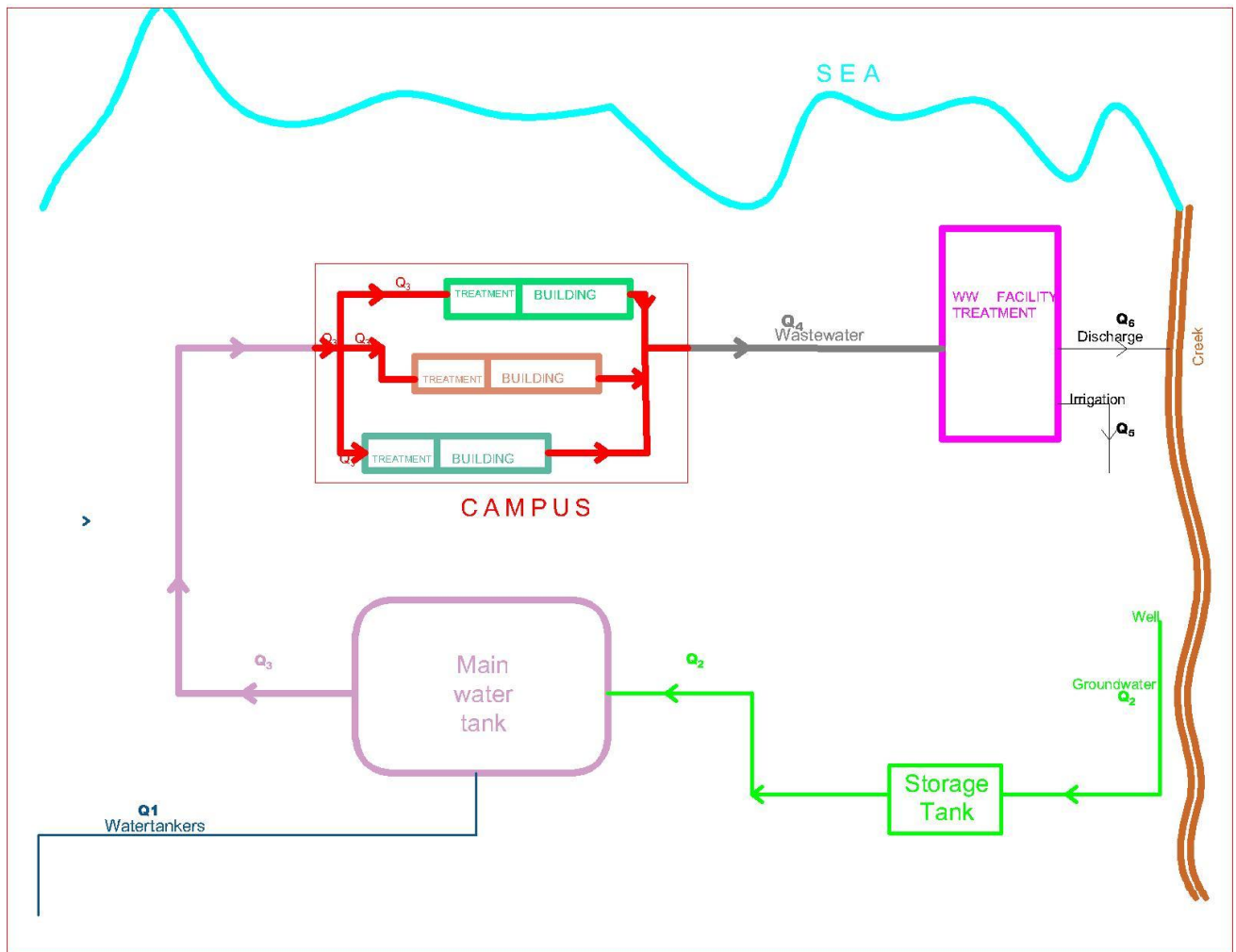


Figure 6.5. Water cycle of Saritepe- Kilyos campus.

Figure 6.5 demonstrates the way in which water coming from main tank goes to campus' buildings. After using, some of it is treated at wastewater treatment facility to irrigate plants, while rest is discharging to creek.

This year the hotel is used as a dormitory since one of the dormitories is being restored. The authorities state that there is no water meter to determine the amount of water consumed at the hotel. Furthermore, based on the information attained from the authorities, there is no general water meter

on the campus. Instead, only sub-meters are installed to measure water the consumption in lazy hall, canteen and beach.

Today, depending on the quality of the water in storage tank, certain treatment methods are applied on Kilyos campus. In the 1st dormitory, a water filtration facility with a capacity of 5 m³/h has been installed which consists of a sand-based activated carbon water filtration and a UV unit. Whereas in the second and third dormitories, a water softening facility with a capacity of 5 m³/h is utilized for the treatment of collected water in the tank. Moreover, it is also equipped with a chlorination section, a sand filter unit, an active carbon unit and a softening system. It should be noted that, compared to third dormitory, a cartridge filtration unit is utilized in the second dormitory. In heating center, a water filtration with a capacity of 16 m³/h consisting of a chlorination unit followed by a sand-based activated carbon filtration section is operated.

6.1.1. Wastewater Discharge

Kilyos campus has its own waste water treatment plant shown in Figure 6.6. Previously, a batch treatment configuration consisting of screening unit, a pump station, aeration tank, settling tank, sludge thickening tank and a dewatering chamber was utilized. The current wastewater treatment facility is operated with a Rotating Biological Contactor (RBC) which is 60-70 % more effective than the previous treatment facility, regarding energy saving. This plant is constructed to treat water for population of 3500 people, but currently there are only 1500 individuals. In addition, the facility has the capacity of treatment at the rate of 700 m³/day. To satisfy the “Water Pollution and Control Regulations on Waste Water Treatment Plant Technical Procedures”, 100-150 m³ per day of the sand-based activated carbon filtrated water is used for irrigation. The remaining part is discharged to adjacent river. These qualities may change in the future and treated water may be used not only for irrigation but also other targets like toilet flushing, washing machines, cleaning, car washing etc. In this sense, it is proposed that comprehensive and integrated evaluation of water resources is needed for sustainable water resource management of Kilyos campus.



Figure 6.6. Wastewater treatment facility on Kilyos Campus.

6.1.2. Water Bills

In accordance with meeting with the authorities; the campus does not supply its water demand by Istanbul Water and Sewage Administration (ISKI), therefore there is no need to pay bill for water since the campus is using groundwater as its water resource and the ground water is supplied without any permission of ISKI. Not paying for groundwater affects the economy of the university positively. However, the water transferred to the campus by ISKI's water tankers is not free, which costs the university greatly. Furthermore, the number of water tankers is increasing each term due to increase in campus population. The price of 100 water tanks having capacity of 23 m³ is 30,000,00 Turkish liras (\$7.359,62), (1 USD = 4,08 TRY April 2018) excluding tax.

6.1.3. Current Situation of The Water Problem on Campus

As mentioned previously, Kilyos Campus utilizes groundwater, which cannot be perceived as a permanent solution for sustainable water management. There is no doubt that the use of excessive groundwater leads to groundwater depletion and further reducing the level of groundwater aquifers.

Increase in the number of residents rises water consumption, which results in reduction of limited water resources. The following factors negatively affect water management:

- The campus is continuously using groundwater resources without any official control. The government can restrict or ban groundwater abstraction of the campus.
- Cost related to delivery of water by tankers, which is a serious financial burden for the university.
- New buildings such as dormitories, research centers, institutes, laboratories and restaurants are going to be constructed for graduate students, personnel and preparatory students, which leads to increase not only in population but also in water consumption.
- If the number of dormitories increases, it may create an opportunity for the English preparatory students to move to Kilyos Campus instead of Bebek North Campus during the summer semester.
- Currently, some preparatory students are in Bebek North Campus and the rest are in Kilyos campus. All will be studying on the Kilyos campus in the case that enough dormitories are constructed by 2030.
- The water treated at the wastewater treatment plant is only used for irrigation in the summer. The rest of the year, this purified water is not used and is discharged directly to the sea.
- In some parts, sprinkler systems aren't used for irrigation. In those areas, manual irrigation with pipe is preferred because of technical construction, which causes
- more water consumption. Besides, domestic water can be used for irrigation if there is not enough water coming from the treatment facility.
- The current wastewater treatment facility is designed for 3500 people which can encounter difficulties, when the campus population reaches over 5000 residents over 13 years from 2017 to 2030. As a result, the new treatment facility or a revision of the current one is mandatory.

According to acquired information from the authorities, there is no water meter (except the 3rd dormitory) in order to determine definite quantity of the water usage on the campus. Although there is water meter in the 3rd dormitory, it is not controlled and monitored. Yet, there are only sub-meters installed to get the price from the businesses like lazy hall, canteen and beach. Therefore, it is not possible to determine water leakages and the amount of water consumed in each building. Moreover, it has to be mentioned that there was no water meter to measure water consumption of the beach until 2016. Therefore, the beach was paying an average fee to the university. The water consumption of

the beach was measured as 1200 m³ and 957 m³ for the year 2016 and 2017, respectively. The beach was charged 4,74 TL (\$1.16) for 1 m³ of water.

On the other hand, there is a single pipe system in which both blackwater which is any waste coming from toilets and gray water are collected together. The collected blackwater and gray water is transferred to a wastewater treatment facility within campus. After the treatment, the wastewater is discharged into receiving water body which is a creek highly polluted by the waste of factories and farms located around the campus. This creek flows into sea, which causes pollution of the sea and poses risk for both aquatic life and human health.

According to the results of analyzing the groundwater sample taken in 2015, groundwater contamination was observed on Kilyos campus (Table 6.1). The presence of fecal coliform in the sample can exhibit potential contamination of the groundwater by animal or human waste from insufficient treated septic and sewage discharges, leaching through animal manure, stormwater runoff and excreta of domestic animals or wildlife.

Table 6.1. Different water quality in Kilyos in 2015.

Sample Date 10/Dec/2015				Report
PARAMETER	RESULTS			Regulation on water for human
	Stream (1)	Beach creek (2)	Creek (3)	
Ammonium, mg/L	0,01	9,25	11	0.50
Color Pt-Co	6	40	90	Acceptable
Turbidity, NTU	0,43	25,2	37,6	Acceptable
Conductivity, μ S/cm	403	1090	965	2500
pH	7,87	7,61	7,63	≥ 6.5 and ≤ 9.5
TDS, (mg/L)	161	436	396	-
Total Hardness, mg/L	196,9	384,7	355,3	-
Total coliform, number/100 mL	50	indefinite	indefinite	0
Fecal coliform, number/100mL	0	indefinite	indefinite	0

In addition to analyzing the groundwater, features of some water parameters for two different creeks which are given in Table 6.1. Figure 6.7 depicts the location of taken samples. Furthermore,

comparing the results to the regulated criteria represent that the both creeks are polluted, and coliform was observed in groundwater resource. The source of this contamination could be the spillage from the creek which is situated too close to the groundwater level or runoff while drilling the groundwater. Due to possible health risk on individuals, the campus did not use this groundwater resource for a while. However, they are currently using this groundwater well to supply water demand. Although the campus benefits from this groundwater resource today, the aforementioned pollution of groundwater may emerge again in the future.



Figure 6.7. Area of taken water samples.

6.2. Current Water Status on Kilyos Campus

Furthermore, it is a known fact that student population is a determinant factor for the water pollution load. In other words, more students lead to more pollution.

Considering the current situation, the campus does not have comprehensive water management, which can lead to severe drawbacks and adverse results as mentioned previously.

7. WATER MANAGEMENT SCHEME

In the case that all English preparatory students start to take lectures on Kilyos campus and construction of new structures such as laboratories, research centers and institutions for master and doctorate programs, the campus population will increase significantly compared to its current situation. Due to increase in campus population, potential water scarcity can be prevented by following two main scenarios;

(I) Desalination of sea water: potable water may be produced from sea water. This provides various advantages some of which are;

- Water delivered from ISKI's water tankers won't be needed anymore. Hence, financial burden of the university will be reduced.
- Sustainable groundwater will be possible
- Excessive water from desalination can be used for irrigation, which might decrease the energy consumption of wastewater treatment plant.

(II) Supplying urban water by ISKI, which provides many benefits such as;

- Water can be supplied continuously.
- Some parts of the water need of the campus can be supplied by groundwater results in sustainable usage of groundwater.
- Financial benefits, provided that groundwater is cheaper than ISKI's water.

7.1. Water Sampling and Analysis

Water sampling and analysis is used to determine characteristics of water used for potable purposes and offer feasible solutions for treatment. In this study, four different water samples including tap water, creek water, groundwater and wastewater were obtained and analyzed using standard methods. They were carefully analyzed in the environmental science laboratory as per standard practice and procedure. Moreover, the values were also compared with the ones reported by UTES company which is responsible for wastewater treatment facility at Kilyos campus (Table 7.1, 7.2).

According to Table 7.1, our results are in compliance with UTES analysis, even though there are some little differences between them. These differences may be attributed to the time that samples

were taken, arrival time of samples, used methods, human errors, etc... Tap water sample was taken in dining hall. Based on the results and the TSE-266 standards, the water samples are convenient for potable water consumption.

Table 7.1. Characteristics of tap water.

Parameter	Unit	TSE-266	Tap Water	UTES-Tap Water
Color	PtCo	Colorless and clear	1	Clear
Turbidity	NTU	5	0.33	-
pH		6.5-9.5	7.97	7.94
Conductivity	$\mu\text{S}/\text{cm}$	2500	935	971
TDS	mg/lt	1600	385	588
Chloride	mg/lt	250	90.8	52.5
Sulphate	mg/lt	250	71.45	58.45
Total hardness	ppm	500	80	45.1
Free chlorine	mg/lt	0.5	0.02	0.01
Nitrate	mg/lt	50	6	2
Nitrite	mg/lt	0.5	0	0.02
Ammonium	mg/lt	0.5	0	0
Iron	mg/lt	0.2	0	0.08
Potassium	mg/lt	12	1.54	1.67
Fecal coli	-	-	0/100ml	-
Total coliform	-	-	0/100ml	-

Table 7.2. Characteristics of creek and wastewater used for plants.

Parameter	Unit	Creek	Wastewater
Color	PtCo	150	54
Turbidity	NTU	29.1	3.56
pH	-	8.02	7.71
Conductivity	$\mu\text{S}/\text{cm}$	1310	1219
TDS	mg/lt	535	495
Sulphate	mg/lt	94.74	94.32
Nitrate	mg/lt	1.684	6
Nitrite	mg/lt	-	3.623
Potassium	mg/lt	9.77	12.52
Fecal coliform	indefinite	indefinite	0
total coliform	-	indefinite	-

Table 7.3. Characteristics of groundwater.

Parameter	Unit	TSE-266	Ground (June 2017)	UTES-Ground (2015)
Color	PtCo	Colorless and clear	61	Clear
Turbidity	NTU	5	8.42	1
pH		6.5-9.5	7.76	7.5
Conductivity	$\mu\text{S/cm}$	2500	486	444
TDS	mg/lt	1600	199	274
Chloride	mg/lt	250	34.75	22
Sulphate	mg/lt	250	0.4743	13
Total hardness	ppm	500	160	190
Free chlorine	mg/lt	0.5	0	0
Nitrate	mg/lt	50	0.47	1,6
Nitrite	mg/lt	0.5	0	0.02
Ammonium	mg/lt	0.5	0	0
Iron	mg/lt	0.2	0	0.3
Potassium	mg/lt	12	2.88	0.57
fecal coliform			30/100ml	0/100ml
Total coliform			1000/100ml	0/100ml

In Table 7.3, the features of groundwater sample, surface water sample and effluent generated from treatment are presented.

In addition to the quality of water in the campus, the rain data provided by Turkish Republic Ministry of Forestry and Water Affairs is shown in Table 7.4, which demonstrates monthly total precipitation for Kumköy-Kilyos/Sarıyer from 2007 to 2017.

Table 7.4. Monthly total precipitation in Kumköy-Kilyos/Sarıyer between 2007 and 2017(mm).

Year	1	2	3	4	5	6	7	8	9	10	11	12
2007	27.0	13.1	31.3	22.8	37.2	13.2	9.4	58.4	41.9	87.4	193.1	109.8
2008	36.1	49.1	67.9	11.9	1.9	10.2	20.3	29.8	156.6	54.2	134.0	91.9
2009	82.7	183.9	123.0	44.3	13.3	0.0	6.8	43.6	339.3	94.5	97.6	202.2
2010	170	109.0	59.8	40.4	23.0	147.3	66.2	5.7	78.2	256.2	22.6	128.8
2011	79.8	31.3	40.5	87.5	40.5	4.7	30.1	14.1	21.4	149.2	19.0	85.7
2012	92.7	103.5	46.5	104.3	44.8	7.1	0.3	26.0	26.0	245.4	59.0	197.4
2013	88.9	67.9	71.2	36.3	24.8	15.7	0.9	59.9	18.9	51.8	80.0	55.6
2014	33.0	43.3	93.8	35.1	68.2	47.1	29.9	57.4	311.1	69.5	68.0	90.9
2015	86.1	92.2	38.8	52.2	37.6	63.0	0.2	38.7	110.7	95.2	51.5	27.8
2016	143.5	94.0	86.3	21.4	63.6	11.6	32.0	25.0	38.8	34.0	108.6	94.4
2017	165.7	35.2	55.0	47.6	40.0	36.8	78.8	21.4	176.4	106.6	63.0	

Monthly average total rainfall for this area is shown in Table 7.5. The table gives information concerning the average rainfall in each month for 10 years (2007-2016) in Kilyos-Kumköy. The total precipitation for this period is 817 mm.

Table 7.5. Average monthly total rainfall for Kumköy-Kilyos/Sarıyer between 2007 and 2016 (mm).

Station	Total Year	1	2	3	4	5	6	7	8	9	10	11	12	Total
17059	10	84.0	78.7	65.9	45.6	35.5	32.0	19.6	35.9	114.3	113.7	83.3	108.5	817.0

According to Figure 7.1, September and October are the months with the highest rainfall, with an average of 114.3 mm and 113.7 mm, respectively, whereas this value is decreased to 19.6 mm in July as the minimum amount of precipitation during the year. It can be said that during September, October, November, December, January, rain can be collected from rooftops or rain barrels for harvesting.

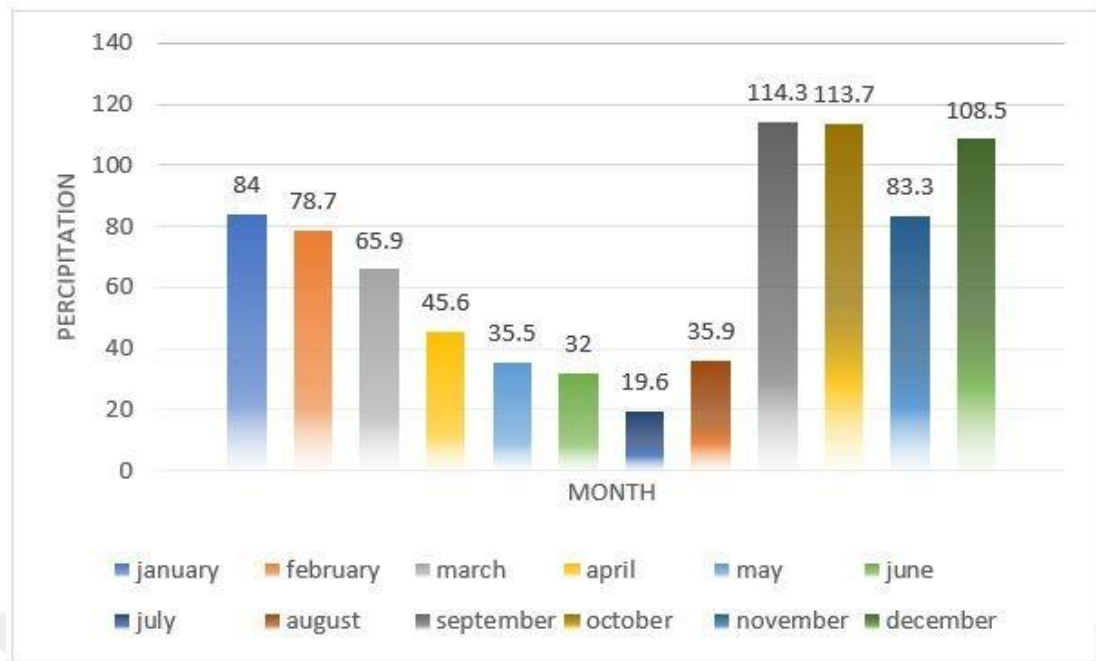


Figure 7.1. The average monthly precipitation (mm) for Kilyos-Kumköy based on 17059 station from 2007 to 2016.

7.2. Water Conservation

It seems that the current water volume is sufficient for now. With the increase in student population on the campus by 2030, water demand will be increasing accordingly. For instance, when the population reaches more than 35000 based on the Figure 6.4, the campus will encounter severe water deficiency. This population is valid for only English preparatory students. Considering graduate students, personnel, professors, the population may reach to 5000. In addition to population, the amount of groundwater, which is the main water source, is also decreasing as a result, using groundwater cannot not be regarded as a permanent and sustainable water resource for the campus.

In order to preserve water on the campus, the amount of water usage for irrigation is the key point of sustainable water management. Instead of using potable water, properly treated wastewater can be used for a fresh, physically attractive and lively landscape.

There are various applicable and sustainable approaches for irrigation and water use to conserve and decrease water usage;

- Preferring native and drought tolerant plants. Instead of daily irrigation, one or two times in a week will be sufficient for those plants.

- Planning comprehensive sustainable maintenance systems such as pest management, natural and non- toxic landscape care makes a safe area for the plants.
- Applying natural lawn care practices including healthy soil, drip irrigation or hand watering for grass areas to reduce water consumption.
- Declining the water flow rate in dormitories after a certain time especially night.
- Protecting and regulating the balance between the water need and the natural water resources.
- Determining and controlling water delivery efficiency, distribution efficiency, irrigation practices and also characteristics of water used in the university to preserve water.

7.3. Water Storage, Reuse and Recycling

It can be predicted that the number of population on the campus may stand at 5000 in 2030, which will lead to increase in water demand. Since the campus cannot meet this demand for the future with existing situation, the campus has resort to new logical and feasible strategies to manage its water usage.

Collection of water is one of the most widespread ways for sustainable water management. For example, excessive water coming from the main tank where all water taken is collected, can be stored in a tank or a container to be used in the future.

Generally, rainwater or stormwater is preferred as a water opportunity for harvesting and storage. This can be carried out in various manners;

- Water collection at surface
- Storage of rainwater or stormwater in cisterns or rain vessels.
- Collection of dew
- Collection of house cleaning water
- Collection of treated wastewater of the campus
- Any of the water harvesting and collection methods do not have any adverse and destructive impacts on the environment, since the water collected from nature is going back to the nature again. In other words, the balance of water in nature is preserved (Amr et al., 2016).

Another way for sustainable water management is water reuse. Water reuse is defined as more than one time use before it passes back into environmental discharge. Treatment is a key factor for water reuse. Compared to recycled water, reused water requires less treatment and that is why it is the main source in non-potable applications. The level and quality of wastewater treatment used depends on various parameters such as characteristics and amount of water. As long as sufficient treatment is provided for safe and clean water quality, the reuse of water perceived just as water reclamation or recycled water could be used for various targets like cleaning process, recreation, car washing, toilet flushing, football field, fire suppression systems, agricultural and landscape irrigation and artificial lakes. According to EPA, there is no reported direct adverse effect of reused water on human health until now. Furthermore, reused water should be preferred to protect groundwater resources.

7.4. Water Saving Recommendations

7.4.1. Desalination

As it was mentioned, Kilyos campus is located near the Black sea. Thus, seawater can be used as a fresh water resource. The campus can supply its whole freshwater need by implementation of seawater desalination. Desalination of saline water can be applied using various methods like: multi-stage flash distillation (MSF), thermal vapor compression (TVC), mechanical vapor compression (MVC), electro-dialysis (ED) and reverse osmosis (RO) technologies, among which RO has been dominant over the past decades due to growing demand, low energy consumption and decreasing price (Zhou and Tol., 2005).

With the development of technology and increase in desalination of saline waters, the cost of desalination has decreased over the years. Cost varies depending on some parameters including property of water, salinity of water, technology to be used, size and type of the facility, qualified labor, location of the plant, the required amount of energy, type of the contract and governmental regulations. The main factors of desalination costs are initial investment cost including the purchase of major equipment, auxiliary equipment, area, construction, continuing costs of operation, contingent costs etc and annual operating cost for electricity, labor and chemicals.

On the campus, recommended desalination plant can be the low capacity (23 m³/h) to meet the daily basic needs of the residents. Main units of desalination systems consist of;

- Pumps
- Source water intake
- High pressure pump
- High-pressure booster
- Transfer pump
- Filter feed
- Chemical dosing
- Brine transfer
- Seawater feed tank
- Cartridge filtration
- RO system
- Mechanical pump
- Ultrafiltration system
- Re-mineralization
- Fresh Water Holding System

The cost of desalination plant including operation cost, which has capacity of 500 m³ per day, including grids, treatment facility, desalination system, water taken from sea and water discharge systems offered by Aritım Mühendislik is \$ 415,000 excluding tax.

7.4.2. Water Audit

As stated previously, Kilyos campus does not have water metering systems referred as water audit. That's why, installing water metering in all of the buildings including hotel, laboratories, dormitories, academic buildings and staff housing and sub-metering systems for irrigation water is required to audit water consumption and determination of the most wasteful places and acquire information attributed to water saving. Besides, data collected from water meters applied on each toilet, urinal and bathroom on the campus' buildings especially dormitories, can be helpful to determine volume of water consumed per flush and further for leakage detection and occupancy use (National Best Practices Manual, 2007). However, installation of water audit for each bathroom, toilets in old buildings may not be so effective in terms of cost. As a result, installation of water meter on each building sounds more logical.

In following places water leakages will be determined when the water meters are installed in each of them;

- Kitchens, canteens, offices
 - Tap
 - Drinking water
 - Dish washers
 - Cooking
- Toilets and Bathrooms
 - Tap
 - Toilets and urinals
 - Showers
- Laundry
 - Washing machines
- Laboratories and cleaning activities
 - Indoor cleaning
 - Environmental Cleaning
 - Sterilization-disinfection
 - Cleaning of laboratory tools and machines
 - Car washing
- Irrigation

The price of a water meter includes not only its equipment but also its application and it changes from the number of occupants, equipment for water usage in buildings like pumps, laboratory tools and daily water consumption for each building to the size of audit.

Since detailed and accurate water data for each building on the Kilyos campus is unknown, some assumptions will be made to determine the cost of the required water audit. However, the water meters applied in 1st South Men's dormitory having capacity of 212 residents and 4th North Dormitory having capacity of 252 residents can be based to determine the approximate water consumptions. Although there is not enough data about water consumption for each month, considering those months shown in Table 7.6, monthly water use in dormitory having capacity of 464 residents is approximately 3000 m³.

Table 7.6. Water meter readings of Bogazici University.

Date 11/1/2017			
Place	First Reading	End Reading	Difference (m ³)
South 1th Men's Dorm	68268	70134	1866
4th North Dorm (cold water)	33980	353249	1269
4th North Dorm (hot water)	9625	10148	523
Total			3658
Date 9/10/2017			
South 1th Men's Dorm	64515	65287	772
4th North Dorm (cold water)	30695	32321	1626
4th North Dorm (hot water)	8327	8550	223
Total			2621
Date 14/11/2017			
South 1th Men's Dorm	65287	66832	1545
4th North Dorm (cold water)	32321	32967	646
4th North Dorm (hot water)	8550	9248	698
Total			2889
Date 6/12/2017			
South 1th Men's Dorm	66832	68268	1436
4th North Dorm (cold water)	32967	33980	1013
4th North Dorm (hot water)	9248	9625	377
Total			2826

The cost of water meters is based on size, technology and, material. In general, 2-inch (50mm) water meters are used in residential sites and small-scale industries.

According to 2018 water meter price of Baylan, the cost for 2-inch meters range from \$ 83 to 96 (average \$90) (April 2018) excluding tax and labor cost. When 6 buildings are considered, total price of water meters will be \$540.

7.4.3. Toilets, Bathrooms and Kitchens

Water use at toilets and bathrooms on campus can be reduced by using water conserving fixtures and equipment like water saving low-flow toilets, faucets and shower heads, waterless urinals, automatic self-closing delayed action faucets or tap at wash basins and shower points, high-efficiency

dishwashers and laundry appliances. Mainly, the university should prefer water efficient flow rates and low-flow faucet restrictors throughout the campus.

According to the meeting by authorities, information about the number of toilets and showers, flow rate of shower head and flush rate of toilets in the buildings of the campus are not available and generally single flush toilets (10 liters) are present on the campus. Only there are 3/6 liters dual flush toilets in 3rd Kilyos dormitory.

At present, standard toilets using average 10 liters per flush are used for the campus. It can be estimated that a normal individual like a student uses the toilets 4 times in a day with the total of 40 liters water consumption. Replacement of traditional toilets with low-flow ones or dual flush high efficiency toilets having capacity 1.5-3 liters for liquid waste and 2.5-6 liters for solid waste per flush will save water consumption (Ece Banyo, 2017; Williams Collage, 2010). The cost of high efficiency toilets having capacity of 1.5 liters for liquid waste and 2.7 liters for solid waste (average 2.1 liters) of Ece Banyo and the cost of dual flush high efficiency toilets having capacity 2.5 liters for liquid waste and 4 liters for solid waste (average 3.25 liters) of Vitra were compared by taking the current exchange rates into consideration:

Assumption of a traditional toilet use for a student on the campus;

- 1 USD = 4.08 TRY (April 2018)
- 1 day $\times$ 4 times $\times$ 10 liters = 40 liters of water in a day
- 30 days $\times$ 40 liters = 1200 liters of water per month
- 300 days $\times$ 40 liters = 12000 liters of water per year = 12 m³ per year

Water consumption for each flush in a dormitory with a capacity of 500 residents;

- $500 \times 1.2 \text{ m}^3 = 600 \text{ m}^3$ of water per a month
- $500 \times 12 \text{ m}^3/\text{y} = 6000 \text{ m}^3$ water use per year

Unit price for ISKI water (2018): 4.37 TL excluding tax/m³;

- Monthly cost = $600 \times 4.37 = 2,622.0 \text{ TL} = \$640$ excluding tax
- Monthly Maintenance fee= 4.37 TL
- TAX (%8) = $2,622.0 \times 0.08 = 210 \text{ TL}$

Environmental cleaning tax for 2018= 0.34 TL for 1 m³ of water;

$$\text{➤ } 600 \text{ m}^3 \times 0.34 \text{ TL} \div \text{m}^3 = 204 \text{ TL}$$

Total monthly cost for water consumption of a dormitory having 500 residents;

$$\text{➤ } 2,622 \text{ TL} + 4.37 \text{ TL} + 210 \text{ TL} + 204 \text{ TL} \approx 3,040.37 \text{ TL} = \$742$$

Calculation of the cost and water consumption of dual flush high efficiency toilet having capacity of 3.25 liters of Vitra for a student on the campus;

$$\text{➤ } \text{Average price of one dual flush reservoir} + \text{equipment excluding tax} = \$81.50 - \$102.2 \approx \$91.85$$

In one building, total cost for approximately 100 toilets is \$9,185.0 excluding tax.

If the construction of two new buildings are considered, total cost of dual flush toilets will be equal to \$18,370 excluding tax.

- 1 day $\times$ 4 times $\times$ 3.25 liters = 13 liters in a day
- 30 days $\times$ 13 liters = 390 liters of monthly water use for flush
- 300 days $\times$ 13 liters = 3900 liters = 3.9 m³ per year

Water consumption for each flush in a dormitory with a capacity of 500 residents;

- $500 \times 0.39 \text{ m}^3 = 195 \text{ m}^3$ of water per a month
- $500 \times 3.9 \text{ m}^3/\text{y} = 1950 \text{ m}^3$ water use per year
- Monthly cost = $195 \times 4.37 = 852.0 \text{ TL} = \$208$ excluding tax
- Monthly Maintenance fee= 4.37 TL
- TAX (%8) = $852.0 \times 0.08 = 68.0 \text{ TL}$

Environmental cleaning tax for 2018= 0.34 TL for 1 m³;

$$\text{➤ } 195 \text{ m}^3 \times 0.34 \text{ TL} = 66.3 \text{ TL}$$

Total monthly cost for water consumption of a dormitory having 500 residents;

$$\text{➤ } 852 + 4.37 + 68.0 + 66.3 \approx 991 \text{ TL} = \$242$$

Calculation of the cost and water consumption of dual flush high efficiency toilet having capacity of 2.1 liter of Ece Banyo for a student on the campus;

- $1 \text{ day} \times 4 \text{ times} \times 2.1 \text{ liters} = 8.4 \text{ liters of water in a day}$
- $30 \text{ days} \times 8.4 \text{ liters} = 252 \text{ liters of water per month}$
- $300 \text{ days} \times 8.4 = 2520 \text{ liters} = 2.52 \text{ m}^3 \text{ per year}$

Average price of a dual flush reservoir + equipment excluding tax = \$31-\$33.8 $\approx$ \$32.4

In one building, total cost for approximately 100 toilets is \$3,240.0 excluding tax.

If the construction of two new buildings are considered, total cost of dual flush toilets will be equal to \$6,480 excluding tax.

Water consumption for each flush in a dormitory with a capacity of 500 residents;

- $500 \times 0.252 \text{ m}^3 = 126 \text{ m}^3 \text{ of water per a month}$
- $500 \times 2.52 \text{ m}^3/\text{y} = 1260 \text{ m}^3 \text{ water use per year}$
- $\text{Monthly cost} = 126 \times 4.37 \text{ TL} = 550.0 \text{ TL} = \$134.8 \text{ excluding tax}$
- $\text{Monthly Maintenance fee} = 4.37 \text{ TL}$
- $\text{TAX (\%8)} = 550.0 \times 0.08 = 44.0 \text{ TL}$

Environmental cleaning tax for 2018= 0.34 TL for 1 m³;

$$\text{➤ } 126 \text{ m}^3 \times 0.34 \text{ TL} = 42.84 \text{ TL}$$

Total monthly cost for water consumption of a dormitory having 500 residents;

$$\text{➤ } 550 \text{ TL} + 4.37 \text{ TL} + 44.0 \text{ TL} + 42.84 \text{ TL} \approx 641.2 \text{ TL} = \$156$$

Another solution for saving water is to find and fix points of water leakages in structures with regular maintenance and control of toilets, urinals, showers and kitchens (National Best Practices

Manual, 2007). In the light of data and information presented above the following precautions and actions are suggested to promote water efficiency on the campus;

- To reduce water usage, the university should replace older flush toilets with low flow or dual-flush toilets having low capacity flushing cisterns.
- If current single flush toilets on the campus cannot be replaced with dual-flush toilets due to insufficient budget, plastic water bottles filled with water or bricks can be placed into toilet tanks particularly into single flush ones on the campus to minimize water usage per flush. This also prevents the overflow from toilet tanks.
- The university should also install waterless urinals to reduce water consumption, if required cleaning is done constantly to remove any odor problem.
- Leakages are the main reason of water wastage in buildings. Therefore, any water leakages from toilets, bathrooms and sinks should be detected by water meters, which helps to save water.
- In addition to water meters, feedback of people living on the campus is also a key factor to determine and show the broken equipment and water leakage

Other strategy to reduce water consumption can be achieved by high performance fixtures like low-flow showerheads and faucets producing from 1.9 to 5.6 liters (approx.3.75 liters) of water per minute. In Newarc 2017 catalog, the price of lavatory faucet with photocell and self-closing armature changes between \$278 - \$ 300 (average \$289), \$32 - \$ 38 (average \$35) without tax, respectively.

Assuming 100 lavatory faucets with photocell and 100 lavatory faucets with time adjusted armature is built for each existing and future buildings except laboratories.

The total cost of 100 units of self-closing armature required for one dormitory in campus is 3500\$ excluding tax

$$\text{➤ } 1 \text{ building} \times (100 \times \$35) = \$3,500$$

The total cost of 100 units of self-closing armature required for current 4 buildings in campus is \$14,000.0 excluding tax.

The total cost of 100 units of lavatory faucet with photocell required for one dormitory in campus is \$28,900 excluding tax

$$\text{➤ } 1 \text{ building} \times (100 \times \$289) = \$28,900$$

The total cost of 100 units of lavatory faucet with photocell required for current 4 buildings in campus is \$115,600.0 excluding tax

$$\text{➤ } 4 \text{ buildings} \times ((100 \times \$289)) = \$115,600$$

In addition to installation of low-flow shower-heads, shower filter heads given in Figure 7.2 can also help eliminate dirt in coming water and remove chlorine and other chemicals. Their prices are generally between \$4.65 and \$23 (average \$14). This kind of shower filters can be installed for all buildings on the campus;

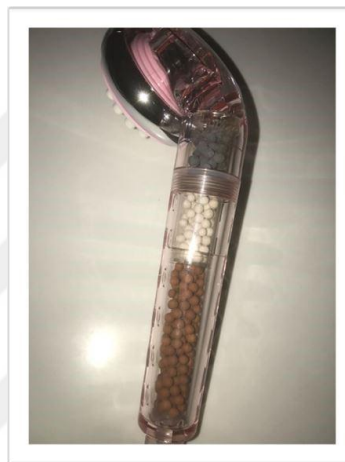


Figure 7.2. The picture of shower filter head

$$\text{➤ } \$14 \times 50 \text{ shower filters} \times 1 \text{ building} = \$700$$

$$\text{➤ } \$14 \times 50 \text{ shower filters} \times 4 \text{ buildings} = \$2800$$

7.4.4. Irrigation

As mentioned before, there are two different effluents from the wastewater treatment plant on the campus; one of which is directly discharged to the sea whereas the other is used for irrigation purposes which is generated through a different treatment facility. Irrigation is performed using water spraying system which is mainly active from May to October. Area to be irrigated consists of generally grass and short plants which require daily watering during summer.

Manual water irrigation with pipe is used for some areas, which rises water consumption. That's why, automatic water sprinkler systems should be applied to decrease the water consumption (National Best Practices Manual, 2007). The cost of these systems changes from \$320-690 (average

\$505) (offered by the authority responsible for the landscape at Bogazici University) depending on the technology used and the features of the land such as its size and slope.



Figure 7.3. Automatic water sprinkler systems on campus

The amount of water consumed for irrigation is also a remarkable factor in order to achieve a sustainable and integrated water management. Depending on time and structure of the irrigated land and weather, 1000 liters of water is necessary for daily irrigation of 100 m² area (offered by the authority responsible for the landscape at Bogazici University). In this regard, water saving irrigation systems such as micro sprinkler heads should be preferred. In terms of flora, the campus should be planted with native and drought tolerant plants to sorely diminish the water consumption. For instance, lithops, sage and sedum which have very low watering requirements can be planted instead of grass. In addition, this flora can give a more attractive configuration to the campus as well.

The price of lithops is between \$0.57-0.67 (average \$0.62), while the cost of sedum is between \$1.22-4.15 (average \$2.7).



Figure 7.4. Lithops taken from Balconygarden.



Figure 7.5. Sedum taken from bluestone.

Furthermore, artificial recharge of groundwater can be applied with reclaimed water used for irrigation by utilizing feasible civil construction techniques and landscape design. Due to no irrigation during winter, the associated treated water, considering its quality, can be used to recharge groundwater. Based on the collected data, the amount of water for irrigation is about 120 m³ per day. Wastewater treatment facility is designed for 700 m³ per day which can be achieved by 2030. Considering this, treated wastewater which is not used for irrigation can be utilized either to recharge the aquifer or by storing it in constructed ponds during the winter period for further usage rather than discharging into the sea. However, Kilyos campus is close to sea. There is no information and data about the aquifers on the campus. This may result that the water used for the recharge may go to the sea. Therefore, the aforementioned solutions can be used to prevent the occurrence of this drawback.

By applying artificial recharge to groundwater, campus can produce its water using its own water cycle.

7.4.5. Graywater

Economically, graywater reuse systems do not seem as feasible and effective for current old buildings on the Kilyos Campus due to their practical difficulties. Nowadays, such systems established in new structures are generally more cost-effective than those retrofitted into existing buildings. Thus, graywater utilization is a good water reuse option and can be installed for new buildings on the campus to conserve energy and water.

Graywater can be viewed as sustainable and safe water resource compared to rainwater harvesting; graywater recycling is not dependent on season or precipitation. There are various graywater systems depending on size, technology and price. The significant point in designing the graywater reuse is system depends on quantity and characteristics of wastewater generated from bathrooms, toilets, kitchens and laundry. After installation, water from graywater systems can be used directly in irrigation and toilet flushing and certain laundry practices. With a simple treatment process, graywater can be used for domestic purposes on new buildings and laboratories of the campus (National Best Practices Manual, 2007). In this study, mixed-sex dormitory was considered for graywater systems.

The main required components for graywater system;

- piping system for blackwater must be separated from piping system for graywater
- space to put tank holding graywater
- required wastewater treatment like filtration
- pump for distribution of recycled water

The cost of graywater system depends on its complexity to change the sanitary system, the area of the place to be supported, and the company responsible for instillation. For example, if it is assumed that 500 individuals are living in dormitories, the maximum water consumption will be roughly 75 tonnes per day.

As graywater systems installed in 1st South and 4th North dormitories, the same ones will be applied in the new buildings of Kilyos. Daily 16 m³ of graywater is produced in these dormitories.

These graywater systems, which contain pre-stabilization, pumping and immersed membrane bioreactor, pre-storage tank and water booster, is fully automatic running.

In addition to 1st South Dormitory and 4th North Dormitory, graywater system having capacity of 16 m³/day was applied in Kandilli Dormitory. The same system can be also installed in new buildings on Kilyos Campus because it is more cost efficient. This system consists of graywater storage tank (10 m³), ultra-filtration membrane bioreactor system tank (4 m³), tank for clean water, blowers, various pumps, chlorine preparation and dosing unit etc... Typical parameters of the main constituents of wastewater from bathrooms and lavatories and effluent quality requirements to use graywater for toilet flushing and irrigation are demonstrated in Table 7.7 and Table 7.8, respectively.

Furthermore, in wastewater samples taken from gray wastewater plants: some certain parameters like BOD₅, BOD, Oxygen saturation, Total coliform bacteria, Fecal Coliform bacteria, *Pseudomonas aeruginosa* and pH are determined by UTES every 3 months and an analysis report is prepared every 3 months on facility basis.

Table 7.7. Design influent parameters from wastewater.

Parameter	Unit	Concentration
BOD	mg/l	85-200
COD	mg/l	150-400
TKN	mg/l	4-16
pH	-	6.5-8.2
Total Phosphor	mg/l	0.5-4
Suspended Solid	mg/l	30-70
E. coli	1/100ml	105
Total Coliform	1/100ml	105

Table 7.8. Design effluent parameters from treated water to use graywater for toilet reservoir.

Parameter	Unit	Concentration
BOD	mg/l	<5
COD	mg/l	<50
TKN	mg/l	<5
pH	-	6.5-8
Oxygen Saturation	%	>50
Suspended Solid	mg/l	<1
E. coli	1/100ml	10 ⁵
Total Coliform	1/100ml	<100

The cost of this graywater system taken from UTES is around \$32,500.00 excluding tax. The system is illustrated in Figure 7.6.

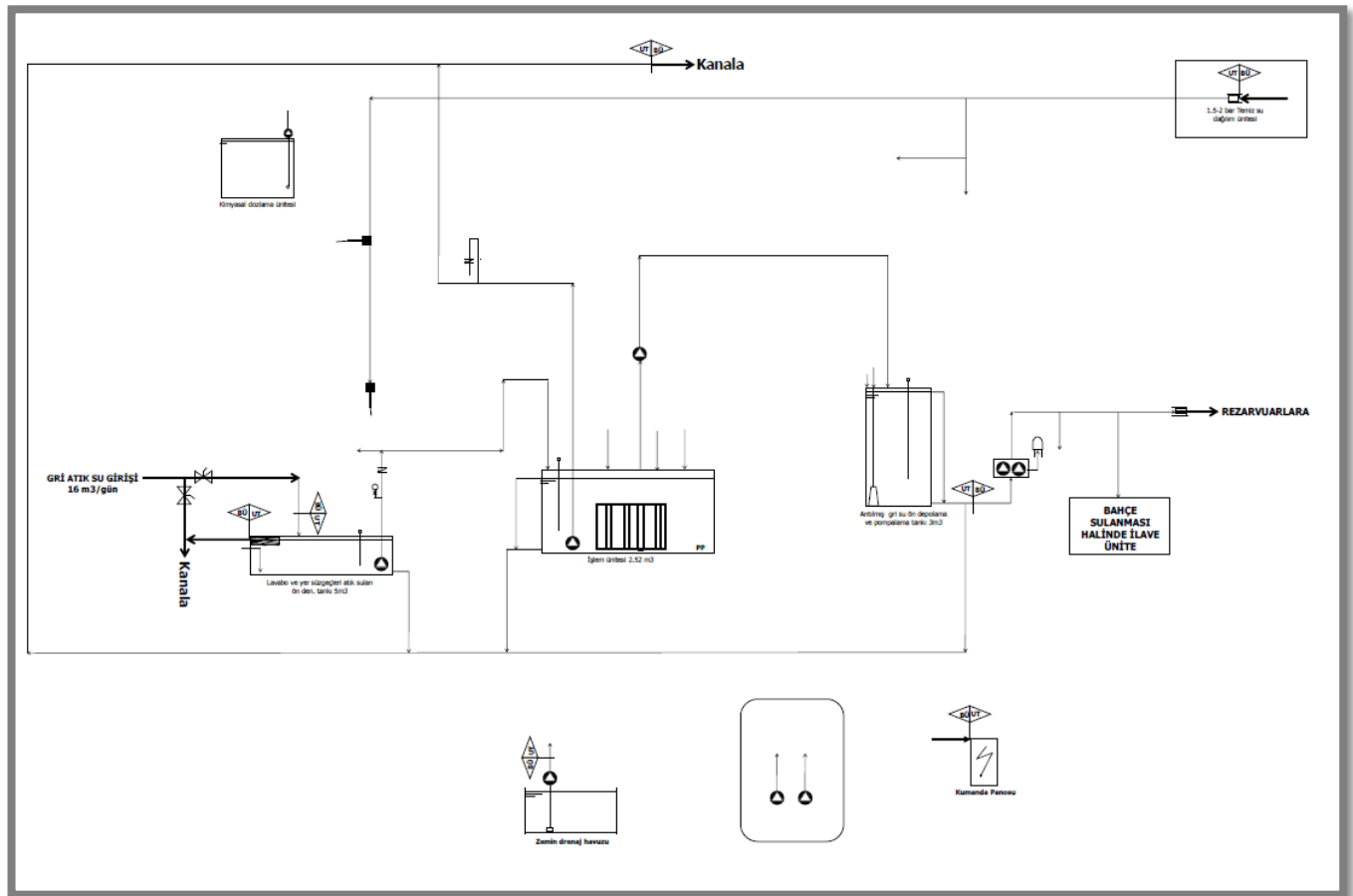


Figure 7.6. The design of graywater system in the Kandilli Dormitory taken from directorate of construction and technical works of Bogazici University

7.4.6. Rainwater Harvesting-Cisterns and Rain Barrels

Rain barrels are more suitable rather than cisterns for small-scale irrigation, harvesting and gardening purposes, due to relatively low cost. In addition to outdoor use, water coming from rain barrels can be used for laundry, hot water system and toilets. The important criteria for selecting rain barrels are weather, material, installation and operating cost, size and shape of buildings and gardens of the campus. There are various types of rainwater tanks; round, slim line, underground and under-deck water tanks. Also, the materials of these tanks are classified as metal, plastic, fiberglass and concrete. Plastic barrels can be preferred due to their high durability and low cost (Bailey et al., 2018).

Rainwater tanks can be placed under the ground, which saves more space compared to those which are on the ground. Therefore, the size of roof collection area is the determinant factor for

selecting the size of these barrels. Since rainwater barrels do not need extra modification and maintenance, they can be used for all the buildings of the campus.

Cost of rainwater tanks is between \$640 to \$1885, depending on its feature, size and technology used for manufacture. An average price of tanks is \$1262.

Example area of roof on the campus;

- The number of floors:5
- The number of students on each floor: 60 individuals
- Area of one room including bathroom and kitchen: 20 m²
- The total area of roof: 1200 m² $\approx$ 1500 m² can be accepted

Annual average precipitation in Kilyos is 817 mm, which equals to 817 liters of water per square meter.

The size of roof of the buildings on the campus to capture rain can be roughly 1500 m².

Total rainwater in a year = 1500 m² $\times$ 817 liters/m² = 1,225,500 liters $\approx$ 1,225 ton/year.

Coefficient for any leaks caused by irregularity of rainfall/tank overflow, different roof materials is 0.75. The result is multiplied by the safety coefficient (Tanık, 2017).

1225 ton/year $\times$ 0.75= 918 ton/year = 76 ton/month;

r=3m, h=3m tank can be selected for one building or the tank having r=2, l=10 can be used for 2 close buildings on the campus.

The next step is to determine the intended use of this rainwater tank. Based on the rain data, the rate of precipitation is generally high in spring and winter. However, during these periods, plants on the campus do not need much water because of the weather. Therefore, captured rainwater in these periods can be used for toilet flushing, washing machines, cleaning activities, recharge of groundwater or sending to main water tank to more efficient use.

As it is known, campus depends on groundwater source, which has put stress on the level of groundwater resource. As a result, rainwater harvesting can be used to recharge groundwater resources.

Furthermore, combined gray + rainwater system shown in Figure 7.7 can be also installed in the new buildings (Auqarista, 2010). Treated graywater and rain water can be used in groundwater recharge, toilet flushing, drip irrigation, sprayed irrigation, water features, car washing, external cleaning and firefighting (Water Supplies Department, 2015) (Figure 7.8). Collection tank of gray water and rainwater systems are generally located underground. After treatment of stored water, clean water can be pumped to building's toilet reservoirs.

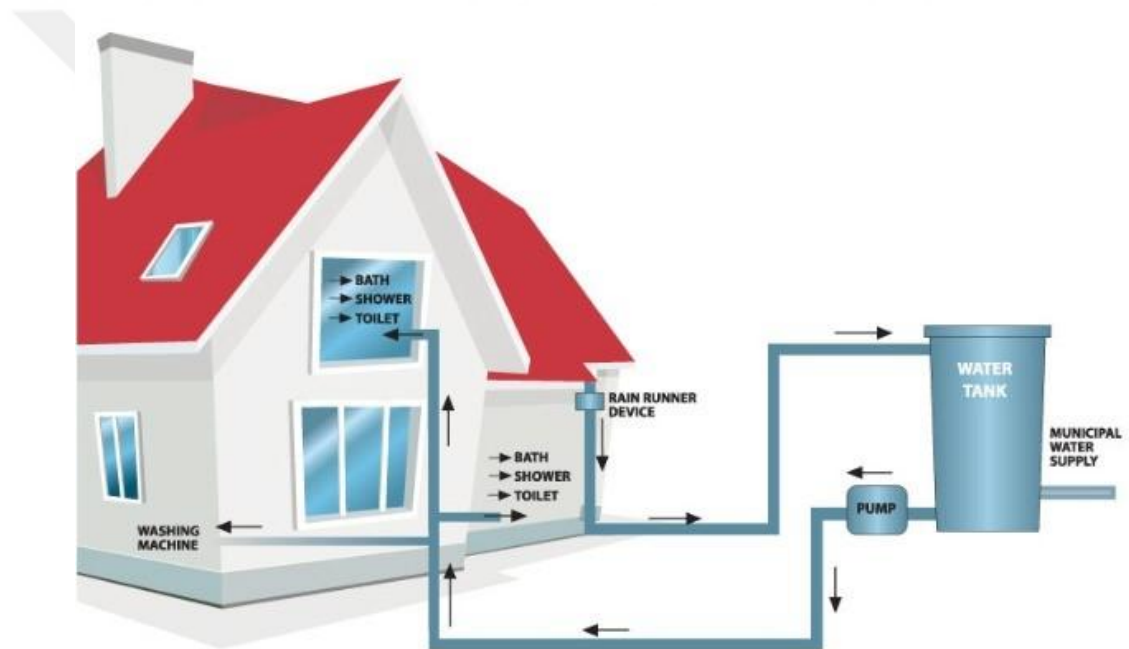


Figure 7.7. The design of gray water and rainwater system.

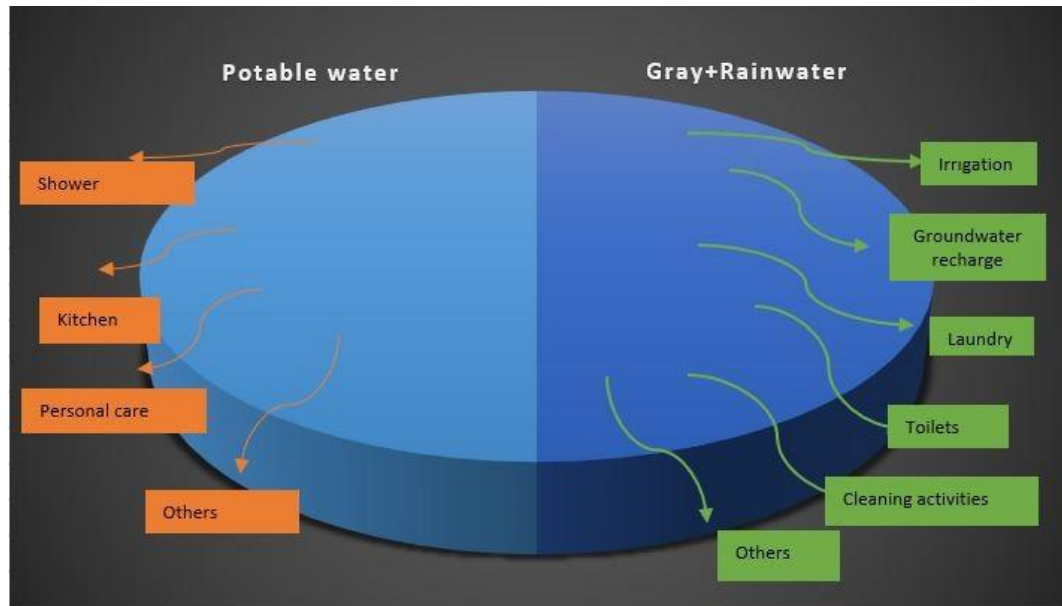


Figure 7.8. Feasible purposes for potable, gray water and rainwater.

7.4.7. Other Technologies

7.4.7.1. Hand sanitizers. Hand sanitizers dispensers are alcohol-based which are different from the conventional sanitizers. Applying this system on the campus can decrease the water consumption since no water is consumed while using hand sanitizers. Especially instillation of hand sanitizers dispensers in dining hall can be more practicable for students (Duke University, 2017). The cost of one hand sanitizer dispenser is around \$15. Number of hand sanitizer dispensers required can be about 40 for each dormitory on campus (\$600).

7.4.7.2. Under-sink water treatment systems. Another instillation can be under-sink water treatment systems which are used to kill undesired microorganism and remove other parameters like odor, chlorine and color. Applying these systems, the drinking water for the residents of the campus can be provided via tap water instead of purchasing water bottle. The unit price of these filters is between \$180 to \$275 (average \$227). The cost of instillation of 6 building on campus is \$1,362.

7.4.7.3. Shower water recycling system. In closed-loop shower systems, the wastewater generated from bathing can be recycled and used. A patented technology introduced a novel type of shower in which it can recycle the shower water. This way, 90% and 80% of water and energy can be saved, respectively using this technology. Their prices obtained from Orbital System Co. are about \$3,600 per unit. With the help of the nano-technology-based filter system in the shower, impurities and microorganisms in hot water can be eliminated effectively. Furthermore, via their application, amount of saved water and energy is determined (Figure 7.9).

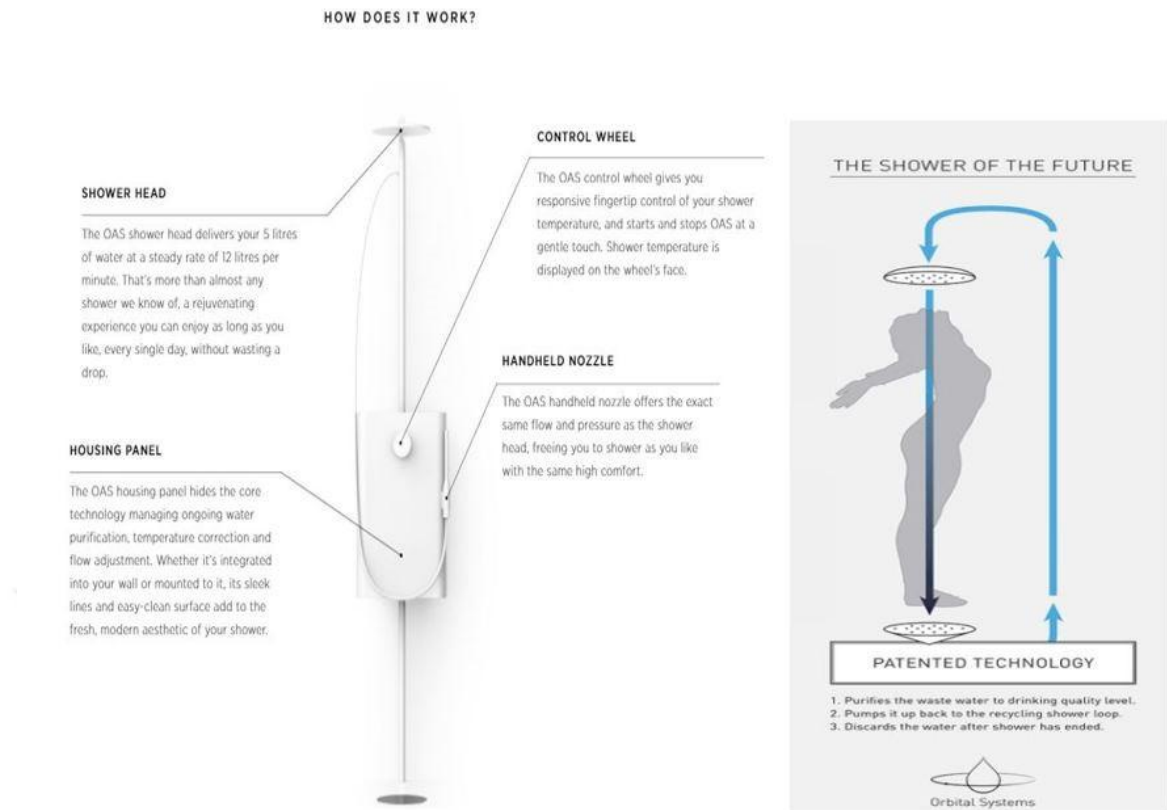


Figure 7.9. Design of orbital system showers.

5 closed-loop shower systems for each building can be installed as a pilot case, as the associated costs are high.

➤ $5 \text{ closed-loop systems} \times \$3,600 \times 6 \text{ buildings} = \$108,000$

8. CONCLUSION

As a result of global warming and increased pressure on environmental challenges, countries throughout the world face striking water shortage problems. Based on this, universities and higher education institutions have started to take essential steps to manage their water resources. In the course of this thesis, the water management of the Kilyos Campus of the Bogazici University, which is on its way to become a sustainable university, was investigated and suggestions have been introduced to enhance the water sustainability on this campus.

This study analyzed and gave information about the current water situation on Kilyos campus. In addition to the current state of water, sustainable and comprehensive water practices and strategies on Kilyos campus were proposed in order to develop a sustainable water cycle and to become an example for other universities, campuses on the campus and maintain water resources.

In order to provide the water demand on the campus, the following two main scenarios were studied to supply water resources;

- Desalination for water need
- Acquiring urban water from ISKI

Based on these scenarios, the campus can supply its water demand either using one of the aforementioned water resources or both of them simultaneously. Despite the supply of water resources, a more sustainable campus in water issue was the aim of this study.

Using population forecasting based on the Figure 6.4, the projected increase in population of campus will increase to 5000 by the year 2030. Based on this and the further water consumption resulted, the following conclusions have been reached in order to improve the water sustainability in Kilyos campus by 2030:

- High efficiency toilets consuming roughly 2.7 liters of water for one flush were recommended rather than current toilets having capacity of 10 liters for one flush.
- Water saving applications including low flow faucets and showerheads, automatic self-closing delayed action faucets and showerheads, waterless urinals and detection systems for were suggested especially for current and future new structures on the campus.

- There is not any water audit to determine water consumption and monitor leakages on the campus. That's why, water meters were proposed for existing and future buildings.
- Considering the data received from the meteorological office, annual average rainfall rate in Kilyos-Kumköy was calculated to determine the size of rain barrels for rainwater harvesting.
- Rather than grass, native and drought tolerant plants such as lithops and sedum were recommended to reduce the water consumption for irrigation.
- As a sustainable water resource, graywater reuse systems and associated costs were calculated to reduce stress on groundwater resources with the target to become more environmentally-friendly and sustainable campus.
- Some water technologies including hand sanitizers, sprinkler systems, under sink water treatment systems and showers treating water were recommended.
- Artificial groundwater recharge was proposed.

Considering the current structure of the existing buildings on the campus, the water consumption can be decreased by applying water saving appliances including lavatory faucet with time appliances, shower filters, water meters, hand sanitizer dispensers and automatic sprinkler systems. Installation of the aforementioned technologies requires an estimated budget of \$19,700 excluding tax (Figure 8.1).

Furthermore, for constructing the new buildings in future along with alleviating the water problem on the campus, dual flush high efficiency toilets, desalination facility, rainwater barrels and graywater systems are suggested. The total cost of installation of these systems is estimated about \$455,000 (Figure 8.1).

It should be noted that retrofitting the existing buildings is not logical and feasible in terms of cost and structure of the existing buildings. Therefore, investing in new water absorbing structures are more suitable for the above-mentioned water practices.

- Graywater, rainwater, desalination, dual-flush toilets, other technologies like closed loop shower systems can be constructed for future, whilst other applications including low flow faucets and showerheads, automatic self-closing delayed action faucets and showerheads, hand sanitizer dispensers, drought tolerant plants, waterless urinals and water meters for were suggested especially for current and future structures on the campus.

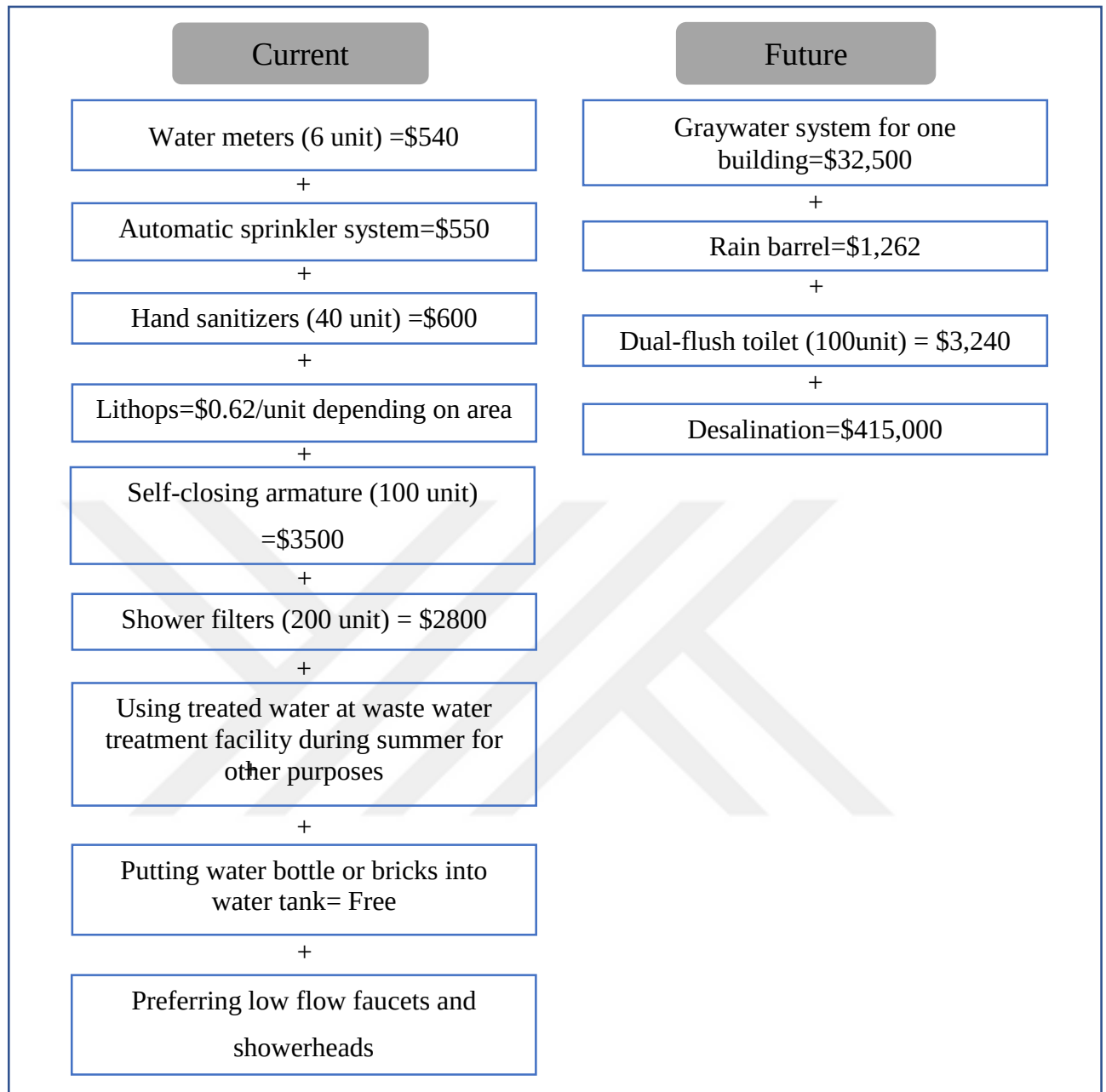


Figure 8.1. Cost summary of current and future infrastructures for improving water sustainability on campus.

Considering the substantial information presented in this thesis, using suggestions the provided can drastically decrease water consumption and further enhance a measurable decrease in wastewater generation.

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