Stormwater Management and Green Infrastructure Techniques for Sustainable Campus Design

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ABSTRACT

This study focuses on sustainable water resources management among extensive sustainable campus design principles. Water is a non-renewable asset for our increasingly arid geography due to reasons such as global warming. The sustainable approach to water resources consists of reclamation and capture of rainwater/stormwater, treatment and reuse of wastewater, protection and enhancement of groundwater quality and natural water bodies (creeks, streams, rivers, lakes and others) and creating water-efficient landscapes.

Green infrastructure systems provide natural drainage and infiltration, prevent floods, improve water quality, and enhance ground water. In this study rainwater/stormwater is treated as a non-renewable resource instead of wastewater. This water resource can be captured and reused for different purposes such as irrigation, groundwater recharge, green corridors and landscape amenity by integration of rainwater/stormwater features into the site design. This study develops strategies for use of green infrastructure systems and recommendations to guide the implementation of these strategies. As a case study, first the current state of stormwater sustainability at Izmir Institute of Technology (IYTE) Campus, located in Gulbahce-Urla (Izmir), is discussed. Then, to improve and sustain the hydrologic balance, green infrastructure best management practices (BMPs) for IYTE School of Architecture grounds are developed as a pilot study of an ongoing masters thesis.

Keywords: Green infrastructure, water management, high performance landscape, campus green spaces

Sürdürülebilir Kampüs Tasarımı için Yağmursuyu Yönetimi ve Yeşil Altyapı Teknikleri

ÖZET

İklim değişiklikleri ve çevresel etkilerin en aza indirgenmesi amaçlı olarak ortaya çıkan sürdürülebilirlik kavramı dünya genelinde üniversite kampüslerinin tasarımında etkin olarak rol oynamaktadır. Sürdürülebilir Kampüs kavramı ekolojik çevreye duyarlı ve çevreye olan etkilerini en aza indirgemeyi kendisine amaç edinmiş olan kampüsler için kullanılmaktadır. Bu çalışma geniş kapsamlı olan Sürdürülebilir Kampüs ilkeleri (etkin kaynak ve enerji kullanımı, atık yönetimi, geri dönüşümü olan malzeme kullanımı, su yönetimi, alternatif ulaşım yöntemleri gibi) içerisinden spesifik olarak su kaynakları yönetimi konusuna eğilmektedir. Küresel ısınma gibi nedenlerle gitgide kuraklaşan coğrafyamızda su kaynaklarının çok değerli olduğu bir gerçektir. Bu nedenle su yönetimi konusunun ön plana alınması kaçınılmazdır. Sürdürülebilir bir çevre için su yönetimi konusunun içerisinde yağmur sularının kazanılması, kullanılmış/atık suyun geri dönüştürülmesi, yeraltı sularının niteliklerinin korunması ve beslenmesi, doğal su koridorlarının (dere ve nehirler) korunması, sürdürülebilir peyzaj alanlarının oluşturulması, içilebilir suyun kullanımının minimize edilmesi gibi konular yer almaktadır. *Yeşil Altyapı*, yüzey suyu akışını geleneksel drenaj uygulamalarının oluşturduğu problemlerden (sel ve su baskınları, su kalitesinde bozulma, maliyet) sakınarak çevreyle uyumlu bir biçimde (doğal drenajı sağlar, su kalitesini artırır, sel ve su baskınlarını önler, yeraltı suyunu besler) ele alma yöntemidir. Bu çalışmada yağmur suyunun bir atık olarak sınıflandırılması yerine ekosisteme katkıda bulunacak ve yere düştüğü arazide farklı amaçlara (tuvalet rezervleri, sulama, rekreasyon koridorları, peyzaj elemanı vb) hizmet edecek biçimde geri kazandırılmasını sağlayacak az maliyetli ve yeşil altyapı elemanlarının kullanılması yönünde bir strateji geliştirilmiş ve bu stratejilerin uygulanmasında rehber oluşturacak öneriler üretilmiştir. Çalışma alanı olarak İzmir Yüksek Teknoloji Enstitüsü (İYTE) kampüsünün mevcut durumu yağmursuyu yönetimi açısından irdelenmiş ve henüz devam eden bir yüksek lisans tezinin pilot çalışması olarak İYTE Mimarlık Fakültesi için açık alan tasarımı ve altyapı uygulamaları konularında yeşil altyapı teknikleri önerileri geliştirilmiştir.

Anahtar Kelimeler: Yeşil altyapı, doğal drenaj, sürdürülebilir kampüs tasarımı, yağmur suyu yönetimi

1.INTRODUCTION (GİRİŞ)

1.1 Aim (Amaç)

This paper is concerned with a sustainable approach to stormwater management for sustainable campus design with an aim of treating rainwater/stormwater as an amenity and non-renewable resource which can be captured on site and used for irrigation, ornamental water features, drinking water, and groundwater recharge. This paper is a part of an ongoing study of a masters thesis titled “Development of an Integrated Water Management Strategy in Sustainable Campus Design: Recommendations for İYTE Campus” which is projected to be completed in one year. This paper consists of first a brief introduction of the concepts of sustainability and sustainable campus design principles with a focus on sustainable water management. Secondly, examples and best management

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practices (BMPs) from the university campuses across the world are introduced; and thirdly, water sustainability at IYTE campus is discussed and a pilot study of the thesis (green infrastructure BMPs for the Faculty of Architecture grounds) is developed.

1.2 Problem Definition (Sorun Tanımı)

Sustainability concept arise with the climate changes and increasing environmental problems. Around the world, most of the campus master plans and designs increasingly adopts sustainability approach. Water management is a significant issue because of global warming and increasing scarcity of water resources. Conventional 'hard engineering' stormwater infrastructure and drainage cause problems such as runoff, flood and water quality degradation. In green infrastructure "soft engineering" approach, rainwater/stormwater is treated as a non-renewable resource instead of wastewater and the ways in which it can be reclaimed and reused are developed.

1.3 Method (Yöntem)

Initially, a literature survey on the evolution of sustainable campus design principles with an emphasis on water management, examples of sustainable campuses and implementation of sustainability principles and green infrastructure techniques for water resource management across the world has been carried out.

A review of the campus master plan and identification of strategies for integrating sustainability into design standards and long-range development plans is performed as one of the first steps to greening a campus. Analysis of the campus master plan (existing situation and built up) includes existing land use, pervious/impervious areas, construction area, landscaped/natural green areas, as well as water and wastewater study to analyze the existing campus water distribution and wastewater collection systems. Pre-development and post-development site conditions such as topography, soil structure, geological and hydrological structure, vegetative cover, microclimatic conditions, existing stormwater infrastructure system are analyzed in detail.

Once the analysees are complete, the U.S. Green Building Council's (USGBC) LEED for Neighbourhood Development (LEED-ND) criteria is to be used as a guideline in order to accomplish sustainability on campus. LEED- ND, the newest rating system, offers a means to integrate principles of environmental sustainability into new, large- scale developments such as campus expansion projects through a holistic approach to neighborhood planning. The rating system is divided into three categories: Smart Location & Linkage, Neighborhood Pattern & Design, and Green Infrastructure & Buildings. Green Infrastructure & Buildings section has the potential to reduce energy use, water use and stormwater runoff, and produce other benefits, such as improving indoor air quality and supporting locally-sourced materials. The Green Infrastructure & Buildings section focuses on measures that can reduce the environmental impacts associated with the construction and operation of buildings and infrastructure. It promotes more efficient energy and water use (www.usgbc.org,2009).

2. SUSTAINABLE CAMPUS DESIGN PRINCIPLES AND ENVIRONMENTAL ASSESMENT METHODS (SÜRDÜRÜLEBİLİR KAMPÜS TASARIMI İLKELERİ VE ÇEVRESEL DEĞERLENDİRME YÖNTEMLERİ)

Sustainability is a general term derived from the word "sustainable" which means "capable of being maintained at a certain rate or level (Oxford Dictionary, 2009). Sustainability means "…a dynamic balance among three mutually interdependent elements: (1) protection and enhancement of natural ecosystems and resources; (2) economic productivity; and (3) provision of social infrastructure such as jobs, housing, education, medical care and cultural opportunities" (Bell and Morse,1990).The international usage of the term 'sustainability' was first seen in the World Charter for Nature, an organization of International Union for the Conservation of Nature and Natural Resources (Yazar,2006).

Campus sustainability has become an issue of global concern and the Stockhom Declaration of 1972 was the first to make reference to sustainability in higher education and has recognized the interdependency between humanity and the environment and suggest several ways of achieving environmental sustainability (Mat et al,2009). Among many some universities are leaders in sustainability such as Arizona State University (ASU) which has been transforming its campus into a model of sustainability with edible landscaping and campus grown food program, ASU Campus Solarization, as well as including a School of Sustainability, the first of its kind.

Sustainable Campus Design Principles consist of efficient energy use, transportation, water, recycling and materials. Energy consumption cause the most important environmental impact associated with campus operations. Energy sources used by campus operations and the equipment chosen for buildings are crucial for sustainability. To reduce the energy consumption, **renewable energy** (Solar panels, wind tribunes, geothermal, natural gas) should be used; **thermal Insulation**: Energy efficient heating/cooling system in conjuction with a thermally efficient building shell (light colors for roofing, high R-value and ceiling insulation, minimal glass on east and west exposures). **Transportation modes and kind of fuels** (For more environmentally-friendly transportation, car use should be reduced, public transportation should be encouraged, and alternative fuels (bio-diesel,naturalgas) should be used. Bike roads and biking parks should be designed. Quality and safe walking roads should be designed.) **Efficient water management (**Environmental problems such as climate change, pollution growth and uncontolled developments cause water scarcity and degrade water quality. Increasing water scarcity requires efficient water management to meet the future demands. To provide efficient water management with sustainable stormwater management, reuse of greywater systems and decrease in use of the potable water is essential). **Recycling** the solid waste is important to reduce the negative effects on environment. In the construction of buildings the kind of material and its effects to the environment is important for sustainability. Energy efficient and **recycled materials** should be used as well as local products (Lukman et al,2009).

Regional or national initiatives such as the North American Sustainability in Higher Education (AASHE) network, the US-based Ivy League for Climate Change Initiative, and the UK Higher Education Environmental Performance Improvement (HEEPI) initiative often refer to national policies, laws and certification schemes for environmental building (such as the US LEED scheme, the Swiss SIA recommendations and the 'Minergy' label, the UK BREEAM, or the French HEQ) and further develop and adapt them to make them more applicable to campus design.

There are different environmental assessment methods in Sustainable Campus Design for Neighbourhood Development (LEED-ND) by Unites States Green Building Council (USGBC) integrate principles of environmental sustainability into new, large-scale developments such as campus expansion projects through a holistic approach to neighborhood planning. In the United Kingdom, BREEAM (Building Research Establishment Environmental Assessment Method) is the leading and most widely used environmental assessment method for buildings. It sets the standard for best practice in sustainable design and has become the de facto measure used to describe a building's environmental performance. In Europe EMAS (European Eco-Management and Audit Scheme) that brings changes in environmental performance and in Canada, Campus Sustainability Assessment Framework (CSAF) is environmental measurement system used in Canadian Universities.

LEED for Neighborhood Development (LEED- ND) offers campuses that are undergoing major expansion or new large- scale development projects guidance and recognition for integration of environmental considerations into all aspects of design and development and projects' efforts to implement environmentally responsible planning, rather than applying green only at the building level. With respect to universities and colleges, the program lends itself to universities that are in the process of expansion or major development, redevelopment or design. Columbia University (plan for a 17- acre expansion project in the Manhattanville neighborhood), California State University Sacramento (Ramona Village project, a faculty and staff housing project) and Johns Hopkins are three institutions currently involved in processes to achieve LEED- ND certification for various projects (Ried,2008).

The University of California Merced is the first university in the US with campuswide LEED certification, at the silver level. Grand Valley State University (Grand Rapids, Michigan) used its campus master planning process to integrate LEED certification into campus buildings. It also was able to tie the process to the campus' standard landscape master plan, parking master plan and storm water master plan. By integrating the LEED certification planning into a larger comprehensive campus planning exercise, the University was able to consider campus- wide systems and solutions. With respect to storm water planning, the university initially thought they would have to add drainage and expand infrastructure to mitigate excessive storm water runoff caused by large amounts of surface parking on the campus. However, by simultaneously conducting the LEED green building process with campus master planning, the university was able to create an integrated parking master plan and storm water plan that called for porous parking and storm water drainage into a nearby wetland to be used for scientific research. This example highlights the synergies that can be generated from integrating the green building and planning process into larger campus- wide strategic planning (Ried,2008).

3. SUSTAINABLE STORMWATER MANAGEMENT THROUGH GREEN INFRASTRUCTURE TECHNIQUES (YEŞİL ALTYAPI TEKNİKLERİ İLE SÜRDÜRÜLEBİLİR YAĞMURSUYU YÖNETİMİ)

Storm or surface runoff moves on the ground by gravity and flows into streams, rivers, ponds, lakes and oceans. Urbanization effect the drainage systems, because urbanization increase the amount of the impervious surfaces (roofs,streets,parking lots and sidewalks) and decrease the amount of pervious areas. Therefore, cause an increase in the volume of stormwater runoff. Stormwater management strategies are for the prevention of stormwater runoff and hold and reuse it.

Green infrastructure design is engineering design that takes a "design with nature" approach or *engineered* green infrastructure is human-designed devices that mimic nature in function, or strive to reduce their impact on ecological systems and function. Same techniques are called Sustainable Urban Drainage Systems (SUD) in the United Kingdom. Some call high performance landscapes-infrastructure. Green Infrastructure is defined by the US Environmental Planning Agency (EPA) Office of Wastewater Management as "an adaptable term used to describe an array of products, technologies, and practices that use natural systems – or engineered systems that mimic natural processes – to enhance overall environmental quality and provide utility services. As a general principal, Green Infrastructure techniques use soils and vegetation to infiltrate, evapotranspirate, and/or recycle stormwater runoff."

Green infrastructure techniques for sustainable rainwater management include such designs as:

- GreenRoofs or eco-roofs,
- Downspout disconnection
- Rainwater harvesting and reuse systems (water retention tanks)
- Natural stormwater drainage systems (bio-swales, vegetative swales)
- Stormwater Planters, Curb Extensions and Infiltration Gardens
- Stormwater Basins (detention and retention basins, ponds)
- Efficient Landscaping and Irrigation (Xeriscaping, Native Planting, Mulching, Shading)
- Reduce the area of impervious surfaces and use of pervious paving (pervious asphalt, concrete and structural grass- paving systems),
- Stream rehabilitation and daylighting projects

There are numerous significant environmental, social and economic benefits that result from sustainable and efficient use of water resources. Some of which are as follows: Potential reduction in peak runoff rates and volumes and the consequent negative environmental impacts (including flooding, pollution and erosion); reduction in drinking water consumption and provision of a sustainable water resource; reducing the Heat Island Effect; an improvement in the aesthetics; opportunity to increase community awareness on the best practice in environmental protection and water conservation to the local, national and international community. It provides for long-term economic benefits and potential cost savings;

Green campuses across the world are adopting green infrastructure programs to manage wet weather. Many of these campuses have moved beyond demonstration projects to incorporating green infrastructure in campus master plans (See Table 1). For example, rather than spending millions on an underground stormwater system, the Stanford University constructed a wetland to act as a buffer from heavy rain runoff and as a buffer area which can recharge groundwater supplies (Tuna,2006).Among many some examples of implementation of the green infrastructure techniques are mentioned here. such as detention, filtration, and rainwater harvesting

A: Rainwater Storage and Reuse Systems; Greenroofs, retention tanks,cisterns,barrels

B: Reduce impervious surface area

C: Biologically based stormwater management features (swales, wetlands, infiltration basins, retention ponds)

D: Reduce the consumption of clean water and reuse stormwater,greywater

E: Efficient Landscape and Irrigation

F: Native Planting and adaptive species

G: Air conditioner condensate reuse

Table 1. Green Infrastructure BMPs at some North American Universities

Sustainable CampusWater Management Applications	**A**	**B**	**C**	**D**	**E**	**F**	**G**
Princeton U.	X	X			X		
Stanford U.		X	X	X			
Cornell U.			X				
Virginia U.		X	X			X	
North Carolina U.	X						X
Victoria U.		X	X				
Oregon U.		X	X		X		
Georgia Tech. U.	X		X		X		X
Portland State U.	X	X	X		X	X	
Arizona State U.	X				X		
Un. of Florida	X	X	X				
Un. of Arizona	X	X	X		X	X	X

The Stata Center rainwater system: At the Massachusetts Institute of Technology campus (Cambridge, MA) consists of a rock-filled swale, which is essentially dry, except in the event of very large storms. Roof drains convey water directly to the underground detention/ storage chamber, while a network of pipes and conduits convey water directly underground. Solar powered recirculation pumps recycle water back up to the surface for reuse in water cisterns and toilets within the buildings, and an impervious layer beneath the subterranean detention chamber aids in storage of water. The design addresses a variety of stormwater functions such as detention, filtration, and rainwater harvesting (Padmanabhan, 2009).

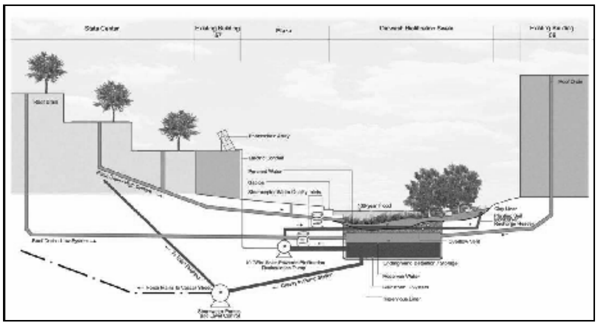

Figure 1: MIT's Stata Center rainwater system(Padmanabhan,2009)

The Stephen Epler Hall: At this dormitory on the Portland State University campus, water shoots down a five-story downspout into a rock-filled basin, gushes out a small scupper into a runnel that directs water across the space, then falls into a "biopaddy" { a sunken plant-filled basin) (2008).All of the basins are laid along a slope (to match the grade of the site), which helps water to drain into the next biopaddy via runnels during times of storm overflow. This way, the plaza stays dry (Padmanabhan,2009).

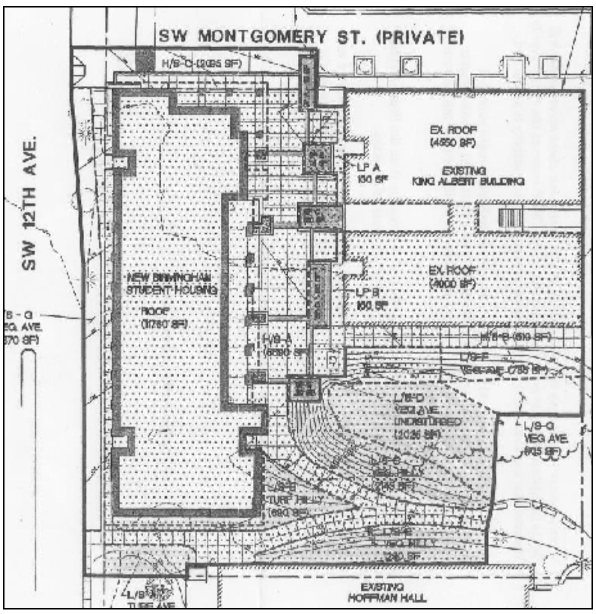

Figure 2: Site drainage to rainwater harvesting system (Turner,2005)."

Villanova University (Pennsylvania) Stormwater Research and Demonstration Park: In 2002, The Pennsylvania Department of Environmental Protection (PADEP) and Villanova University's Department of Civil and Environmental Engineering formed the Villanova Urban Stormwater Partnership (VUSP). Current Best Management Practice study sites include a pervious concrete/porous asphalt comparison, a bioinfiltration traffic island (constructed in 2001), an infiltration trench, a storm water wetland (constructed in 1999) and a green roof (constructed in 2006). The green roof design was a retrofit of a small portion of Villanova's Center for Engineering Education Research (CEER) roof on a second storey terrace. The BMP Park plays an important role in advancing stormwater management practices.

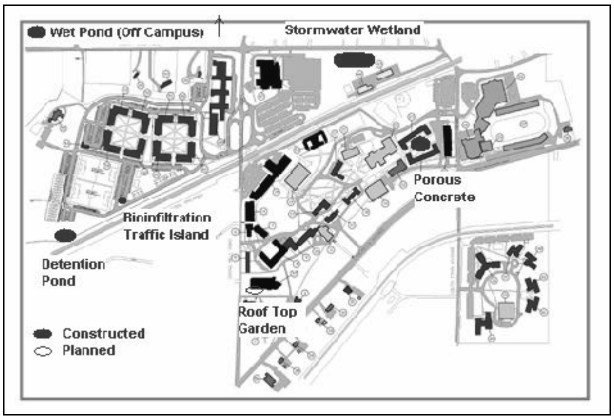

Figure 3: Villanova University Stormwater Research & Demonstration Park (http://www3.villanova.edu/vusp/bmp_research/bio_traffic)

The Eco-Commons Concept: The Eco-Commons at Georgia Tech University comprises of a series of open spaces replacing existing parking lots, linked both physically and hydrologically as a continuous park extending through the north side of the campus. Since a sustainability goal for the project was to reduce storm water runoff to 1928 conditions, the designers worked to maximize infiltration, with hydrology and storm water management in mind. A cistern system reuses rainwater and HVAC system condensation for site irrigation (Prakopcyk and Staudt,2010).

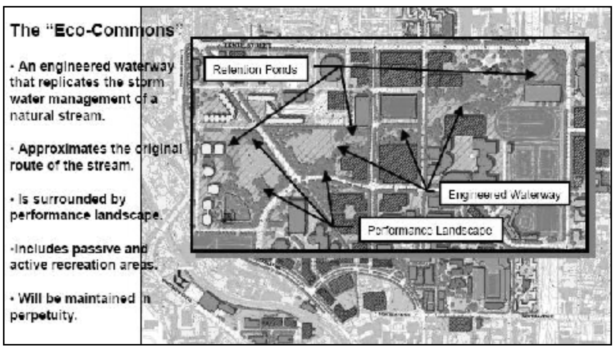

Figure 4: Georgia Tech Eco-Commons Project (http://www.stewardship.gatech.edu/stormwater)

There are other colleges that also adopt reuse of air conditioning condensate such as University of Arizona (Arizona), Duke University (North Carolina), Emory University (Georgia), and Griffith Universiy (Australia). For example, the Sonoran Research Laboratory (University of Arizona) in front of the

Landscape Architecture building, has been turned into a garden from a parking lot. In this garden plants get water through air conditioner condensate as well as rainwater harvested from the adjacent building. Only 30 % of irrigation water comes from the building's roof. The rest come from the air conditioning condensate as well as back flushing of drinking-water filters. The garden is generally comprised of trees (mesquite, willow, and palo verde) that are native to the area. Urbanite, a ground cover made of broken-up chunks of brick and concrete, is scattered across pockets of drainage. When blended into the surrounding environment it not only looks good, but it also serves to slow down water run off so the ground has more time to absorb it (Sorvig,2010).

Figure 5. The Sonoran Research Laboratory (University of Arizona) (Sorving,2010).

4. IZMIR INSTITUTE OF TECHNOLOGY CAMPUS (İZMİR YÜKSEK TEKNOLOJİ ENSTİTÜSÜ KAMPÜSÜ)

Izmir Institute of Technology (IYTE) campus is located nearby the small rural village of Gulbahce (Urla) and approximately 50 km from the city center of Izmir. The campus site is still under construction. Although the entire campus covers 3500 ha (8650 acres), the campus built up area is only 154 ha at the present. Current total building construction area is 13,6 ha and total woodland is 33,1 ha.The current density of the campus is 0.05 ha which is quite low because of the scattered development of the campus. These numbers will increase once all the buildings are constructed with added impervious pathways and parking lots to house the determined future population of 10000 people.

The campus is being developed on an undisturbed site since 1994 nearby a small village with major agricultural production. The site has a slopped topograpy and is covered dominantly with native plants. The campus landscape is typical of the Aegean region with a rising and falling topography, maquis (maki) and

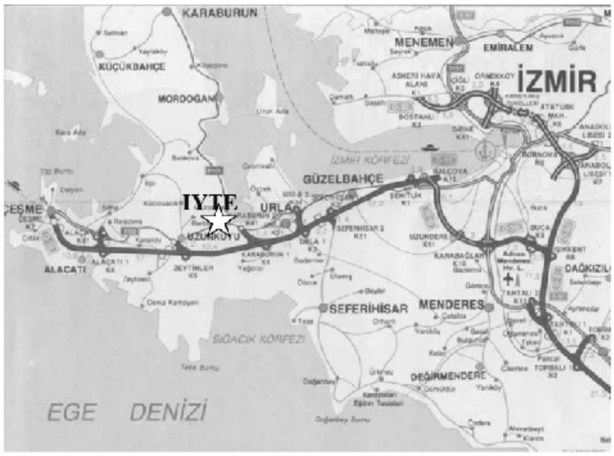

Figure 6: Location of the IYTE Campus

olive trees and a number of streams with a water fall running during rainy seasons and a natural pond. Pine trees have been added to the area later on. There are some turf areas as well but not expansive since maintenance and irrigation is not easy with a hot and humid climate and scarce water resources as there ıs no rainfall for several months. Type of soil is clay with low infiltration rate, so underground water resources are also limited. There are natural stream channels on campus but as the university has grown, some of the streams have been burried in concrete channels and one stream has been changed its course due to development of Faculty of Science building. There are geological faults in the area and thermal water springs as well.

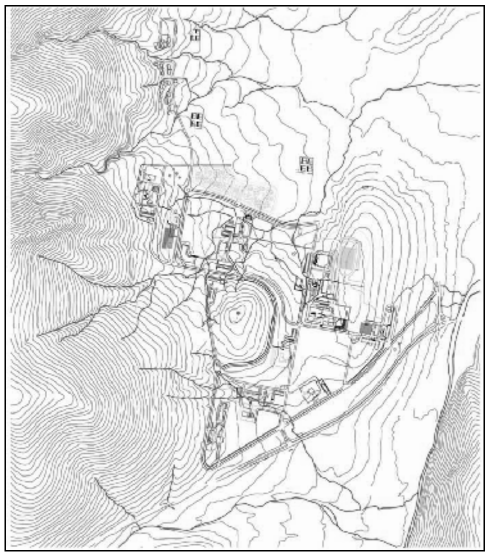

Figure 7: Current Site Plan of IYTE

The master plan of the campus has gone through several changes throughout time. The designers of the first master plan describe the campus site as "The site has a great scenic beauty and uncontaminated environmental condition with a view of the sea along the entire northern side" "as seen elsewhere (Pisciotti,1994)." Unfortunately this plan did not take into account several significant attributes such as topography, location of the high voltage transmission line and the geographical fault near student housing.

Therefore had to be changed during implementation. The Faculy of Architecture has prepared a Master Plan proposal and this has been followed so far.The student housing has been relocated to a location near the academic buildings from its first location by the geographical fault and the geothermal springs. The faculty housing also has been relocated near the current academic buildings from its remote location on the periphery of the campus area by the sea.

IYTE campus gets its water from nearby Urla Municipality and frequently runs into problems with water supply because of being dependent and increasing population in the area. An elevated water storage tank located on the hilltop behind the central cafeteria supply the campus with water by providing flow to the campus by gravity. Student housing water supply is also supported by a well recently drilled near the faculty housing on the North.

The campus has a conventional stormwater system which drains to the streams through the runnels infrastructure system, the potholes are filled with rainwater on rainy days.There is drainage problem at some areas because of the slope and the clay soil. In the past flood occurred in the Faculty of Science grounds due to its location on an sloped area and inefficient and undermaintained stormwater system.

The existing campus has a 12.1 % imperviousness ratio. The future developments will increase this ratio further away from the current level. What is facing the University is to mitigate the impact of its proposed future development Thus, a stormwater master plan should be developed to help the University explore how a “restorative approach” can be applied in concert with sound stormwater management practices that seek alternative practices and strategies to create a sustainable campus that conserves natural resources, restores environmental quality, and produces an aesthetically pleasing campus environment.

When IYTE Campus is analysed according to the sustainable water management approach and green

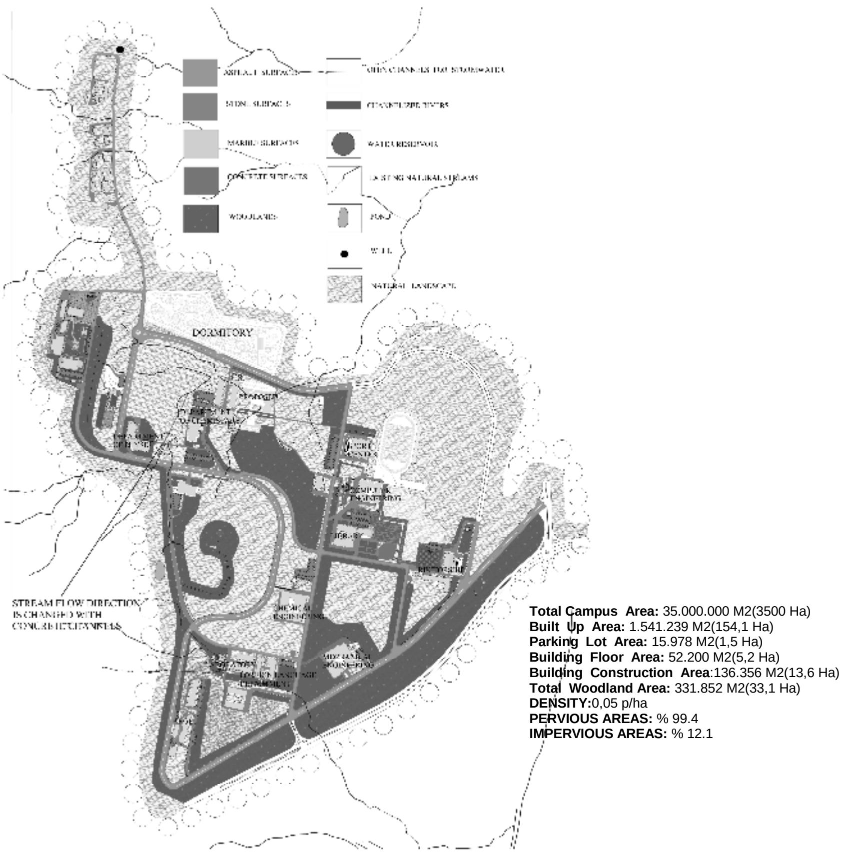

Figure 8: Current Pervious/Impervious Areas of IYTE Campus

or concrete channels. In general the campus drainage was subdivided into 2 subbasins (north and south) based on topography and drainage network. The stormwater runoff is largely untreated at the present. The roof of the buildings are impervious and don’t have water storage systems. The roads, pathways, parking areas, and plazas are impervious. Because of the impervious areas and inefficient and undermaintained stormwater infrastructure techniques, most of the problems are established. Firstly; IYTE has a scattered development, it should be compact because of the sustainability and infrastructure cost and the campus has a traditional stormwater system, the sytem drain the stormwater to the streams through the runnels or concrete channels.

Besides the problems, we express some better sides.The sewage system and stormwater system are separate.The campus site has water treatment plant.Sewage is directed to the treatment plant. In the future the recycled water will be used for irrigation on campus. At the present the rainwater from the downspouts from the roofs of most of the buildings are disconnected and therefore drained to the open either pervious or impervious rather than directly being connected to the stormwater system with an exception of the library building.

Table 2.Impervious/Pervious Areas of IYTE Campus

Total Campus Area	35.000.000 M2(3500 Ha)
Built Up Area	1.541.239 M2(154,1 Ha)
Parking Lot Area	15.978 M2(1,5 Ha)
Building Floor Area:	52.200 M2(5,2 Ha)
Building Construction Area:	136.356 M2(13,6 Ha)
Total Woodland Area	331.852 M2(33,1 Ha)
DENSITY	0,05 p/ha

Some of the existing practices of growing native olive trees and terebinth (sakız tree) seedlings on campus green house, and afforestation with these, production of olive oil, existence of wastewater treatment plant, and paper recycling are considered as promising initial steps toward campus wide sustainability of IYTE. There are also plans for wind tribunes as well as use of recycled waste water for irrigation.

5. SUSTAINABLE STORMWATER BMPs FOR IYTE FACULTY OF ARCHITECTURE (İYTE MİMARLIK FAKÜLTESİ İÇİN SÜRDÜRÜLEBİLİR YAĞMURSUYU YÖNETİM TEKNİKLERİ)

Here the Faculty of Architecture grounds is used as a pilot project area for the initial green infrastructure recommendations. Like the rest of te campus, there is a conventional stormwater system and stormwater flows first to the river and then to the sea. There are impervious surfaces; made of granite, stone, marble and concrete.There is drainage problem because of the sloped topography of the site; so erosion occurs at most times in slopped areas especially behind the A and B buildings where a retaining wall exists.

The stormwater BMPs that have been developed (Figure 10) focus on the ability to provide volume reduction and infiltration enhancement. Areas for natural drainage such as swales or planter boxes and ponds are necessary. A pond will collect and infiltrate water collected from the proposed swale system. The impervious surfaces such as parking areas and pedestrian and vehicle roads should be converted into pervious. An underground water retention tank is proposed where an impervious basketball court exists. The vegetated areas and woodland areas should be increased.

Opportunities for potential land cover conversions (from impervious surface to planted area, from grass lawn to planted areas) and curb cuts should be assessed. Areas behind the buildings A and B should be forested for erosion prevention. There should be water efficient landscaping and native planting as use of indigenous plants eliminates the need for irrigation. Buildings with flat roofs (A,B and E) are also suitable for possible green roof development for stormwater management and rainwater harvesting.

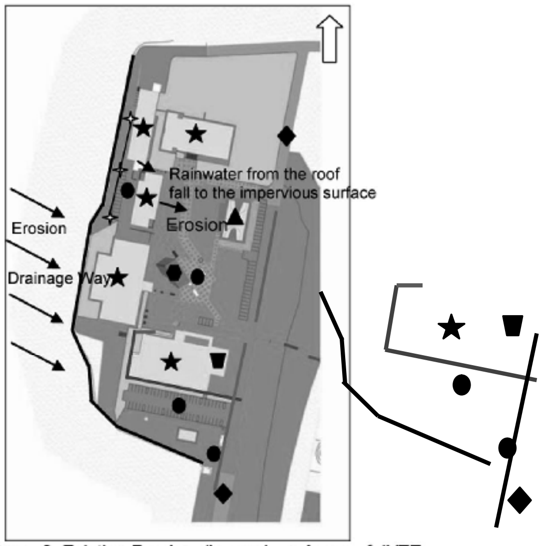

Figure 9: Existing Pervious/Impervious Areas of IYTE Faculty of Architecture

★ Impervious roof
● Impervious stone surfaces
● Impervious concrete surfaces
◆ Impervious asphalt surfaces
▲ Impervious sport field
▼ Impervious marble surface
→ Stormwater Semi-open Channels
Natural Landscape
Woodland Area
Retaining Wall
Stormwater Gutter
Stormwater Open Channels

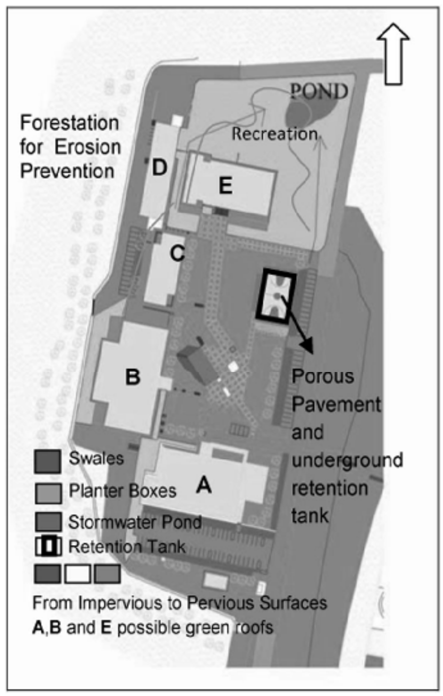

Figure 10: Proposed Green Infrastructure BMPs for IYTE Faculty of Architecture

6. CONCLUSION (SONUÇ)

This paper has discussed the current state of stormwater sustainability at IYTE campus and proposed initial green infrastructure BMPs for the Faculty of Architecture grounds as a pilot study of an ongoing masters thesis. The thesis will develop campus wide recommendations and strategies that seek to improve and sustain the hydrologic balance of the campus. These include but not limited to on campus stream rehabilitation**,** minimizing construction-related vegetation removal; minimizing impervious surfaces and building area, and reducing water consumption for outdoor landscape irrigation by native plants, use of captured rainwater or recycled wastewater, stormwater, and air-conditioning condensate. All these strategies will develop a comprehensive stormwater management plan for the campus that retains rainfall on-site, through infiltration, evapotranspiration, and/or reuse. For this USGBC's LEED- ND Stormwater Management and Water-Efficient Landscaping criterias are to be used as a guideline.

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