GUIDELINES FOR DESIGNING GREEN ROOFS THAT PROMOTE HUMAN HEALTH AND WELL-BEING

by

TIANCHI YOU

(Under the Direction of Robert Alfred Vick)

ABSTRACT

In dense, urban areas, where pollution is highly concentrated, green roof s show tremendous potential as a method of beautifying cityscapes, improving air quality, supplying extra farmland, saving energy, fulfilling many other multi-functional applications, and most importantly, promoting human health and well-being. This paper examines the guidelines from The Sustainable Sites Initiative™ (SITES) that have been applied generally for evaluating sustainable spaces, and the paper seeks to draw out the significance and applicability of some of these guidelines as guidelines for designing green roofs in particular. Using three case studies, these guidelines are applied as criteria for evaluating green roofs in terms of their effectiveness in promoting humans' physical, mental, and social well-being. Finally a projective design addressing human health and well-being illustrates and evaluates the application of the design strategies on the Boyd Building at the University of Georgia in Athens, GA.

INDEX WORDS: green roofs, human health and well-being, health-promoting, guidelines, SITES, design strategies, Boyd Building

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TIANCHI YOU

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TIANCHI YOU

Major Professor: Robert Alfred Vick
Committee: David Spooner
Jack Crowley
Maureen O’Brien

Electronic Version Approved:

Suzanne Barbour
Dean of the Graduate School
The University of Georgia
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DEDICATION

For those who create inspiring landscapes and architecture.

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CHAPTER 1

INTRODUCTION

Problem

People have altered the environment extensively causing significant environmental degradation, and in turn, we suffer greatly in terms of human health and well-being. Aside from obvious environmental effects such as the Urban Heat Island (UHI) effect, and air and water pollution, destructive human activities, such as urbanization and deforesting, have produced tremendous substantial environmental, mental and social stress. In this dire situation, people must recognize their responsibility for the current state of the planet and take steps to ameliorate the deleterious influences of our actions (MEA 2005).

In response to the stress mentioned above, beginning with Frederick Law Olmsted, the landscape architecture profession has carried on this responsibility to create green infrastructures that mitigate the negative effects of human behaviors. Olmsted tended to apply a distinctive style to his landscapes and designed unique spaces with beneficial psychological effects. He created comprehensive parks and parkway systems, such as New York's Central Park, to meet the needs of the industrializing society of North America in the nineteenth century (Beveridge and Rocheleau 1995).

Green infrastructure is a multifunctional network of natural or artificial green spaces connecting habitats that sustain water and air and conserve the health of humans and ecosystem biodiversity (Tzoulas et al. 2007). The green spaces ameliorate the air pollution and UHI effect (Whitford, Ennos, and Handley 2001), and they may encourage people to stay physically active.

Green space offers a psychologically relieving environment, as well as offering social benefits by providing spaces for gathering, especially in residential areas (Kim and Kaplan 2004). If we want to provide a comfortable environment for future generations, we need to pay attention to both the natural and human environment by designing sustainable sites that promote human health and well-being.

Green roofs are one of the most promising solutions among green infrastructures. Most cities used to be green natural spaces; before humans interfered with developments. Everything balanced well, such as precipitation and infiltration, without any needs for stormwater management. Green roofs play an important part in restoring ecosystem services and offer the most competitive spaces in the city for greening because they can change the wide-spread urban wastelands to green urban spaces without taking up the overpriced ground-level spaces. They also provide elevated garden spaces, offering spectacular views over the city and aesthetic views for other taller structures. Not only do different types of green roofs, being the "green space" in the air, work to mitigate the negative effects from urbanization, but they can also provide potential spaces for personal meditation and group gathering. A close analogy can be drawn between the many ecological, psychological, and social benefits of green roofs and the "physical, mental, and social aspects" identified in 1948 by the World Health Organization (WHO) as capturing the basic essence of human health and well-being.

This thesis will provide a comprehensive discussion of different guidelines that promote human health and well-being, followed by a set of design strategies. Three case studies and a projective design are followed to showcase that green roofs can play an important part in promoting human health and well-being.

Research Questions and Purpose

The intention of this thesis is to answer the question, how can green roof design promote human health and well-being for on-site users? The question arises from concerns about human health and is intended to mitigate the negative and promote the positive effects on human health and well-being from the environmental, mental and social stress. The intent is to suggest a set of guidelines for future green roof designs. The selection of the guidelines and recommended strategies are based on The Sustainable Sites Initiative™ (SITES) v2 Reference Guide for Sustainable Land Design and Development, with appropriate modifications. The designed site, located on the Boyd Building on the University of Georgia main campus, is intended to demonstrate how to maximize health and well-being through effective design.

To ensure clarity, two key terms will be defined. The Oxford English Dictionary defines health as "soundness or well-being of body; that condition in which its functions are duly and efficiently discharged." Another entry includes the concept of mental well-being as well. While well-being is defined as "the state of being healthy, happy, or prosperous;" it can also be "physical, psychological, or moral welfare." Health and well-being both describe physically and psychologically sound states, implying an absence of illness and infirmity. Health and well-being are used as interchangeable terms in this paper. As my thesis is focused on green roof site users, they are defined as individuals who are expected to occupy, work at, or pass through the site. Users may visit the site regularly or periodically. Site users will range in age, ethnicity, and socio-economic status, but all users' needs should be considered.

Sub-questions

This thesis addresses the following sub-questions:

1. What are green roofs and what are the benefits of green roofs?

2. How to define health and well-being?

3. Why The Sustainable Sites Initiative™ (SITES) is a better rating system than other alternatives to be based on for designing health-promoting green roofs?

4. What is the methodology of selecting guidelines from SITES?

5. What are the guidelines, design strategies and program elements for designing green roofs to promote site users' health and well-being?

6. How can the guidelines, design strategies and program elements be applied on green roof projects?

Methodology

Descriptive research strategies: information on definitions and discussions were gathered from the most appropriate and authoritative sources, including peer-reviewed journal articles, previous studies, government reports, and other resources. Case studies were evaluated according to the concluded guidelines on health-promoting features and performances (Deming and Swaffield 2011).

Classification strategies: first, health-promoting guidelines and design strategies were selected from SITES, and adapted to green roofing. Later, these design strategies are classified into different program elements for general design considerations on future green roof (Deming and Swaffield 2011).

Projective Design: to use knowledge gained from the previous discussion, a design application was followed by the summary of the design guidelines and strategies to understand the applicability of the guidelines (Deming and Swaffield 2011).

Structure

Chapter 2 introduces general information about green roofs, including their history, contemporary status, and future. Green roof development varies by country. Each green roof benefit is discussed in its public and private aspects, respectively.

Chapter 3 defines health according to physical, mental and social criteria. After a brief introduction of SITES, all qualified guidelines are selected if they can promote human health and well-being for green roof site users. Then each guideline is discussed and followed by recommended strategies that will help to achieve each guideline in future green roof designs. Finally, recommended strategies are summarized and listed.

Chapter 4 describes successful green roof cases, such as the American Society of Landscape Architecture (ASLA) headquarters green roof in Washington D.C., the Solaire rooftop at 20 River Terrace in Manhattan, and Chicago's Millennium Park. A brief introduction of each case is presented in addition to an analysis of how each case promotes health via applying the guidelines listed earlier.

Chapter 5 is the projective design, intended to maximize the health promoting effects of green roofs using the recommended strategies included in the list. This design shows the possibility for achieving the promotion of human health and well-being through green roofs. Later, the green roof design is evaluated by the guidelines.

Chapter 6 concludes the thesis, expressing final thoughts and summarizing the findings of the research and projected design.

Limitation

Health measurement is difficult because it is subjective in different aspects. To begin with, it can be difficult to define consistently, as it involves physical, mental and social aspects.

Furthermore, ideas about health vary across individuals and cultures, so it is hard to generalize about the quality of individuals' health. Additionally, health data is difficult to acquire due to concerns about privacy laws. Last but not least, only with special training can health measurement be quantified.

Delimitation

The thesis is focused on promoting health for green roof users in the design process. Selected guidelines and recommended strategies are adapted from SITES, and have been discussed and modified to address specific green roofs health promotion. Physical, mental and social well-being are subject to immediate or delayed effectiveness. They can affect the individual as well as large populations, directly or indirectly, at different points in time. Moreover, this thesis does not consider cost in relation to the health benefits of design features, although cost plays an important role in applications in terms of affordability and practicality. The focus of the present research is to evaluate available design options in terms of their ability to promote health and well-being, primarily from the perspective of site users, whose experience of the site is not directly affected by the underlying costs of the design. Furthermore, an in-depth discussion of weight and other structural design constraints would require an extensive discussion/ investigation of engineering properties, beyond what has been feasible given the limitations of the present study. The above considerations are not addressed in detail in relation to physical, mental and social well-being in green roof design.

CHAPTER 2

A BRIEF INTRODUCTION TO GREEN ROOFS

Green Roofs: History, Contemporary Status, and Future

The known history of the first green roof dates back to 100 BCE, beginning with the famous Hanging Gardens of Babylon, considered one of the Seven Wonders of the Ancient World. Europeans pioneered, tested, and established the standard for modern green roof elements, including plant materials, growing media, waterproofing, roofing materials and so on over 30 years ago. Such elements are detailed in 1998's in *Forschungsgesellschaft Landschaftsent-wicklung Landschaftsbau e.v,* or FLL (*Guidelines for the planning, Execution, and Upkeep of Green-Roof Sites*), and have since been widely implemented throughout Europe (Cantor 2008). However, it is the widespread construction of flat roofs, solid materials and improved techniques that allow the rapid development of green roofs (Dunnett and Kingsbury 2008). Green roofs became so popular that by 2001, 14 percent of all German flat roofs, totaling more than 145 million square feet (13.5 million square meters), had been greened (Herman 2003, Snodgrass and Snodgrass 2006).

Green roofs, also known as eco-roofs, basically entail replanting vegetation as a specialized roofing system on human-made structures, replacing greenery destroyed when the buildings were constructed. The green roof system is like a thick sandwich with many layers, from top to bottom: vegetation, growing medium, filter fabric, drainage and water retention layers, root protection layer, insulation, waterproofing, and roof deck. Some can be omitted or combined depending on different manufacturers and conditions (Hanson and Schmidt 2012).

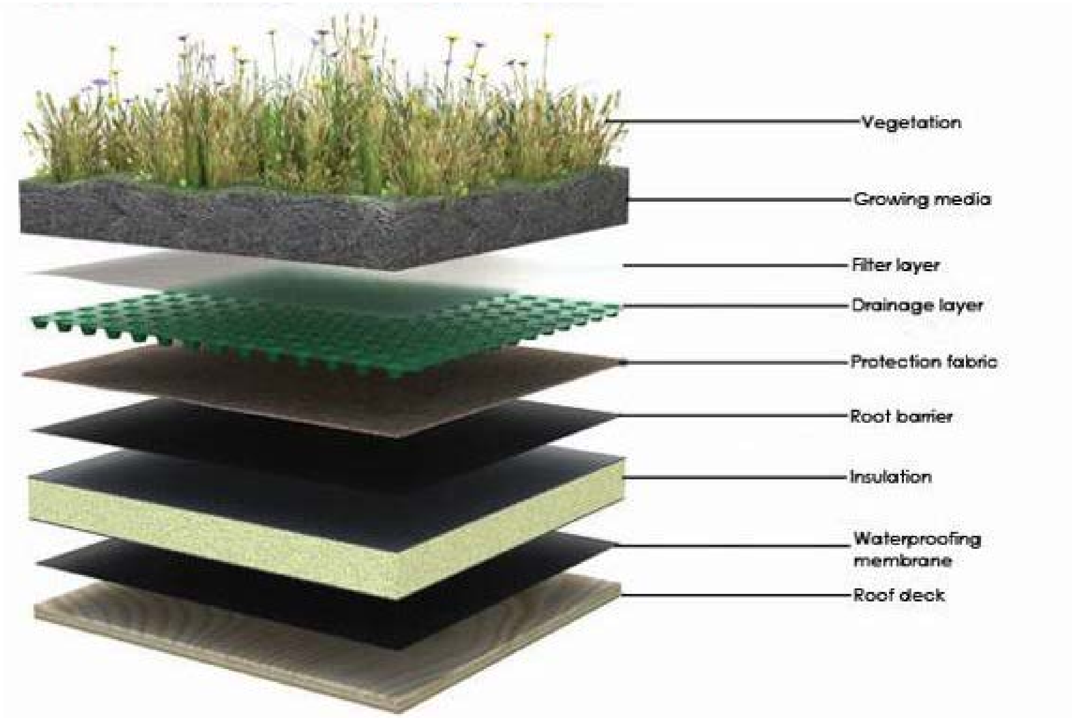


Figure 2.1 Green roof system
(Source: from http://www.cwemi.org/green-roof-technology/)

Green roofs often fall into three categories as shown in the diagram below: intensive, semi-intensive, or extensive green roof. They are usually classified according to the growing medium depth and the level of effort needed to maintain them (Weiler and Scholz-Barth 2009).

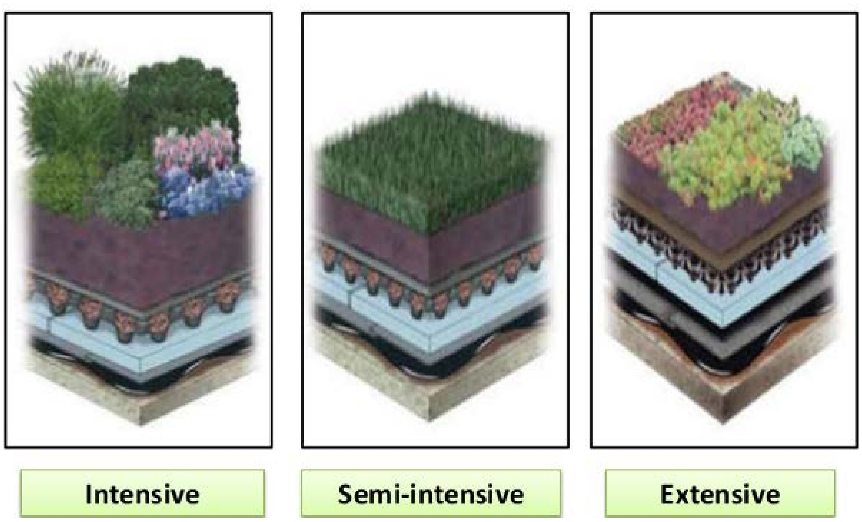


Figure 2.2 Green roof types (Source: from Andrew Myrthong)

Intensive green roofs have a thicker layer of growing medium, normally the green roof system build-up height is 5.9 -15.7 in (150 – 400 mm), it could possibly be over 39.4 in (1000 mm), with the weight as 35-100 lb/sqft (180 -500 kg/m2) (The International Green Roof Association 2016). They are able to bear heavy weights. The plants on-site can range from grass to trees as long as they are shallow-rooted to not destroy the roof. They are mostly pedestrian accessible and located on newly built structures given the heavy system weight (Carter and Fowler 2008). They often require regular maintenance, but they provide benefits such as shade, sitting areas, water storage, and high aesthetic value.

Extensive green roofs, by contrast, have a lighter and thinner mixture of vegetation and soil, the green roof system build-up height is often 2.4 -7.9 in (60 – 200 mm), with the weight as 13-30 lb/sqft (60 -150 kg/m2) (The International Green Roof Association 2016). They are mostly with plants such as sedums, that behave well in dry environments and can survive in adverse and exposed conditions (Cantor 2008). They are not necessarily intended for public use and may not be visible on a regular basis (Dunnett and Kingsbury 2008). It is easier for them to be established on existing structures, hence they are widespread. They are by far the most common in Germany due to ease of implementation, reduced maintenance requirements and relatively low cost (Harzmann 2002). Most research has been focused on extensive green roofs since mid-1970s when green roofs were first categorized as extensive and intensive (Dunnett and Kingsbury 2008).

The semi-intensive green roofs balance the differences between the two extremes (Dunnett and Kingsbury 2004). The semi-intensive green roof system build-up height is often 4.7 – 9.8 in (120 – 250 mm), with the weight as 25-40 lb/sqft (120 -200 kg/m2) (The International Green Roof Association 2016). Twenty-five percent of their growing medium is above or below

6 inches. More diversified plants can be seen on semi-intensive green roofs while pedestrians can have partial access. Compared to extensive green roofs, semi-intensive green roofs demands more maintenance, higher costs, and more weight, while offering more design possibilities with various types of vegetation just not the tall growing shrubs and trees (The International Green Roof Association 2016). Semi-intensive green roofs are considered to have plentiful potential since they combine and maximize the best elements of both traditions to create sustainable rooftop spaces in all circumstances (Dunnett and Kingsbury 2008).

Table 2.1 Green roof types and characters (Source: from The International Green Roof Association http://www.igra-world.com/types_of_green_roofs/index.php)

	Extensive Green Roof	**Semi-Intensive Green Roof**	**Intensive Green Roof**
Maintenance	Low	Periodically	High
Irrigation	No	Periodically	Regularly
Plant communities	Moss-Sedum-Herbs and Grasses	Grass-Herbs and Shrubs	Lawn or Perennials, Shrubs and Trees
System build-up height	60 - 200 mm 2.4 -7.9 in	120 - 250 mm 4.7 – 9.8 in	150 - 400 mm on underground garages > 1000 mm 5.9 – 15.7 in
Weight	60 - 150 kg/m^2	120 - 200 kg/m^2	180 - 500 kg/m^2
	13 -30 lb/sqft	25 - 40 lb/sqft	35 - 100 lb/sqft
Costs	Low	Middle	High
Use	Ecological protection layer	Designed Green Roof	Park like garden

Contemporary green roofs are developing at different speeds due to varying climatic, cultural and political conditions around the world. In Europe, Germany is no doubt leading the roof greening, motivated primarily by environmental concerns. Switzerland and Austria have similar incentive programs to encourage green roof implementation. Northwestern European countries such as Britain and the Netherlands are slow in comparison of green roof development, partly because of their conservative bias in favor of housing with pitched roofs. It is rare to find contemporary extensive green roofs in Scandinavian countries, with the exception of Norway and Sweden. Southern European countries, such as Greece, Italy, Spain, and Portugal, have less green roof development partly because of their hot, dry weather. Russia has made little progress in green roof development except for the ongoing movement to produce rooftop food (Dunnett and Kingsbury 2008).

North America is heavily influenced by European green roof activities. Chicago and Portland, Oregon were the first two cities to become known for green roof implementation, followed by Minneapolis, Boston, New York, and Washington, D.C. In 2003, the Ford Motor Company in Dearborn, Michigan completed the world's largest green roof in an industrial complex, because of the belief of the former Ford chairman that the sustainability of green roofs reflects sustainable manufacturing overall. Significant green roof activities have also taken place in Canada, especially in Toronto, the home of Green Roofs for Healthy Cities, and the well-known demonstration project on top of Toronto City Hall (Dunnett and Kingsbury 2008).

In Southeast Asia and parts of South America, green roofs are mainly installed for stormwater management because of the regions' heavy rainfall and evapotranspiration rates, but the vegetation may attract mosquitoes, increasing a possibility of malaria transmission (Köhler et al. 2001). Singapore has become closely involved with research related to and applications of green roofs. While China and South Korea have begun to facilitate green roofs, green roof technology in Japan has grown enormously, mostly through government promotions. In South America, Brazil has consistently been always a front-runner in green roofing partly because of Roberto Burle Marx, a famous landscape architect, and Mexico has begun to pursue research as well. In Australia, green roofs have developed rapidly, given much of the native vegetation thrives in shallow, dry and low-nutrient soil, making it well-suited to survive on extensive green roofs (Dunnett and Kingsbury 2008).

Acknowledging the benefits of green roofs to the public is important since it will help decision-makers, who are elected by the public, to promote green roofs through government policies and incentives. Such measures often fall into three categories: direct financial aid, maybe in the form of subsidies for construction; stormwater fee discounts; and requirements for green roofs in local development plans (Dunnett and Kingsbury 2008). Serious unavoidable environmental problems are often the main force in promoting green roof policy. Japan made it possible to offer subsidies to build green roofs in over 40 cities by 2008, starting with Tokyo's regulations promoting the building of green roofs to reduce the heat island effect in 2001 (Nagase 2008). Energy saving is another major driving factor for green roofs. A new energy code, passed in Chicago, required all of the new roofs to meet minimum guidelines of reflectivity by installing green roofs or solar panels to reduce the heat from traditional roofs (Nagase 2008). Special stormwater taxes have been implemented in many towns in Germany for a while, and this makes the responsible parties contribute to disposal costs, and drives individuals and businesses to pursue more sustainable stormwater management methods. Implementing green roofs will help reduce fees up to 50%, perhaps even 100%, if no stormwater runoff flows into the sewage system (The International Green Roof Association 2016). Switzerland's promotion of green roofs originally arose from the pursuit of biodiversity, creatures such as birds, lizards and rare insects were observed on roofs; and 3% of the existing flat-roof buildings in Basel became green roofs within 18 months after the government started a green roof support campaign (Brenneisen 2004).

Incentives are often based on evaluations of improvement in performance. Many cities, such as Seattle, have set up programs for long-term monitoring and simulation of green roof performance (Wachter et al. 2007). Policymakers need data on green roof contributions to improving environmental health in different locations before making policy changes. Geographic Information System (GIS) is usually used for determining the priority of green roof application (Buckland-Nicks 2015).

To increase public awareness, stimulate fund-raising, showcase the benefits of green roofs and evaluate their effects, governments will at times install demonstration projects, such as those in the City Halls of Toronto and Chicago. The demonstration projects are always a part of wider efforts focused on the overall environmental improvement of the local community.

In 1999, the Green Roof for Healthy Cities coalition (GRHC) was founded by six Toronto-based companies, and integrated both public and private organizations in promoting markets for green roofs. In North America, GRHC green roof accreditation program aims to provide the highest possible profit to clients by combining building and site design while reducing expenses.

Evaluations of green roof materials have been undertaken by the American Society for Testing and Materials, which published a series of guidelines in 2005. Guidelines, courses, and examinations for "Accredited Green Roof Professionals" were first set up by industry leading professionals in 2007 with the first examination in 2009.

Private and Public Benefits of Green Roofing

Despite green roofs are often not installed because of their requirements of regular maintenance, certain load-bearing capacity, necessary irrigation and drainage system, and relatively higher costs, there are a great number of ecological, psychological and social benefits provided by green roof systems. The specialized benefits of green roofs may be differentiated in public and private applications: public benefits are accessible and beneficial to all members of the community, while other private benefits are only accessible to a particular individual or group of people. From a public perspective, green roofing helps to counteract the Urban Heat Island (UHI) effect, improve air quality, facilitate improved stormwater management, increase biodiversity, promote urban agriculture, create educational opportunities, enhance aesthetic experiences, nurture human health and well-being, and stimulate local economies. From a private standpoint, it promotes energy efficiency, roofing membrane durability, fire retardation, reduction of electromagnetic radiation and noise, and is good for the future marketing value of the property (Green Roofs for Healthy Cities 2014)

Table 2.2 Private and public benefits of green roofing (Source from Green Roofs for Healthy Cities, table from author)

	Benefits
Private benefits	Reduce noise
	Promote energy efficiency
	Prolong roofing membrane durability
	Enhance fire retardation
	Reduce of electromagnetic radiation
	Stimulate the future marketing value of the property
Public benefits	Reduce Urban Heat Island (UHI) effect
	Improve air quality
	Facilitate improved stormwater management
	Increase biodiversity
	Promote urban agriculture
	Create educational opportunities
	Enhance aesthetic experiences
	Nurture human health and well-being
	Stimulate local economies

Private Benefits:

Unlike the reflection and transmission of sound from a conventional hard surface roof, the thick layers of green roof systems absorb, attenuate and bar acoustical noises, such as traffic, airplanes, and construction noises, from being heard throughout the building. A noise reduction of 40 decibels is accomplished by an extensive green roof, while an intensive one ensures a reduction of 46-50 decibels (Peck et al. 1999).

Similarly, green roofs' thick layers promote energy efficiency by reducing energy transmission through rooftops. Temperatures on green roofs in New York were found to have an average of 2°C (35.6 °F) differences between areas having most and least vegetation, saving energy consumption and air conditioning costs in summer. Research showed that an extensive green roof can reduce the daily energy demand for air conditioning in the summer by over 75% (Liu and Baskaran 2003).

Green roofs prolong the roofing membrane durability by covering it with vegetation. This prevents roof membrane exposure to ultraviolet radiation and day/night temperature changes, and so reduces daily expansion and contraction stress (GRHC). It is estimated that roof membrane durability can be extended by two to three hundred percent with green roof implementation (Peck, Callaghan, Kuhn, and Bass 1999).

In Germany, green roof systems were first established for fire retardation. A green roof system requires using inflammable materials, with stones and gravels used to maintain and protect the border. Often fire risk is lower with burn-resistant vegetation, such as succulent sedum, on site (Dunnett and Kingsbury 2008). According to Breuning's (2007) test in Stuttgart, he found the fire risk to be 15-20 times greater for a bitumen roof than for a green roof. He asserted there were no known fires on green roofs in Germany; at the time of his writing there were 200,000 m^2 (2 million ft^2) of extensive green roofs built up; in addition, there is also a 10-20% discount on fire insurance for qualified green roofs in Germany (Breuning 2007).

Even though it is debatable whether electromagnetic radiation is harmful to human health and well-being, green roofs able to reduce the transmission of electromagnetic radiation by 99.4% (Herman 2003).

Although the initial investment in green roofs is greater than that of conventional roofs, it pays off in the long run if it is well-maintained. Green roofs protect the roof from exposure to ultraviolet and other harmful radiation; the amount spent on energy declines enormously with the green roof thick layers; on-site food production has economic benefits if applicable; financial incentives are offered by many cities with policies and regulations to promote green roof establishment. With all of the economic benefits for the user, it raises the price for the future marketing value of the property as well.

Public Benefits:

It is widely believed that green roofs planted on a large scale would help with mitigating the UHI effect, a phenomenon common to urban environments, in which major cities are several degrees warmer than suburban or rural areas. In summer this effect can reach nearly 10 °C (The International Green Roof Association 2016). The excess heat is mainly either generated from urban structures or from anthropogenic heat sources (Rizwan, Dennis, and Chunho 2008). Green spaces and parks can absorb up to 80% of the energy input (The International Green Roof Association 2016). For dense, heavy-populated spaces, the vegetation on green roofs, as a perfect alternative to green spaces on ground level, releases water through evapotranspiration to cool the ambient atmosphere, so the sensible heat flux on the green roof surface is small (Susca, Gaffin, and Dell'Osso 2011, Takebayashi and Moriyama 2007).

Air quality is also improved as the plants on roofs will filter the dust and intake air pollutants. Approximately 0.2 kg aerosol dust and smog particles can be filtered by one square meter of green roof per year. Moreover, harmful materials like nitrates in the air and from rainfalls are deposited in the growing medium (The International Green Roof Association 2016). Research show the annual removal of air pollutants per hectare of a green roof was effective in Chicago (Yang, Yu, and Gong 2008), Washington, D.C. (Fund and Limno-Tech 2005) and Toronto (Currie and Bass 2008), however, it cannot be used as the only method of air quality control.

In addition to their utility in maintaining air quality, there are many ways to take advantage of green roofs by integrating them into a system of stormwater management. Green roofs facilitate improved stormwater management. In the past, the aim of conventional stormwater infrastructure was to convey the stormwater off-site as soon as possible, which places a heavy burden on the civic sewer system. Green roofs can reduce and retain a certain amount of stormwater runoff, which decreases stress on sewer system peak flow periods (Bengtsson, Grahn, and Olsson 2005, Berndtsson 2010, Carter and Rasmussen 2006, Mentens, Raes, and Hermy 2006, VanWoert et al. 2005). A reduction of 50-90% of the immediate stormwater runoff can be achieved. Most of this water returns directly into the natural water cycle through the transpiration/ evaporation process on green roofs, with the excess stormwater filtered and drained off in a time delay (The International Green Roof Association 2016). The capacity of runoff to transport pollutants such as phosphorus, nitrogen, and heavy metals is also reduced (Carter and Jackson 2007).

Green roofs are the least competitive space in cities for creating habitats. The natural plant community is often found on green roofs providing habitats for insects, invertebrates, and birds. Dr. Stephan Brenneisen has been a pioneer and a major contributor to research in biodiversity on green roofs, especially in Switzerland. The varied depth of the soil provides different opportunities for biodiversity. Deeper areas are more likely to create a more diverse biodiversity environment because of the moisture held on site (Dunnett and Kingsbury 2008). Green roofs also have the potential to be hidden places for conserving the endangered plants through habitat restoration (Cantor 2008).

Urban centers import a significant amount of food to meet the needs of their large populations on a daily basis. Not only can local food production ameliorate the wasting of resources such as gas and water along the food transport network, but such production also benefits human health and well-being by providing fresher and more nutritious food, which creates natural sources of farm-fresh food and encourages a healthy lifestyle. Green roofs offer alternatives to conventional farming, promoting urban agriculture, creating local produce, and mitigating the pressure of urban food demands (Dunnett and Kingsbury 2008).

Green roofs offer educational opportunities to learn sustainable infrastructures. Especially for the green roofs on top of educational facilities, they provide easy access for students, faculties, and visitors showcasing the benefits of green roofs systems and technologies (Green Roof for Healthy Cities 2016).

Many art-oriented students will appreciate the aesthetic enhancements that green roofs can offer. The roofscapes in most cities are far from pleasant, with extensive dark asphalt or bitumen covers. Visual access to plants and nature adds enjoyment to the property, and such an environment is believed to have positive effects on human health and well-being such as mental restoration, stress reduction, and lowering blood pressure (Ulrich and Simons 1986).

The local economy is stimulated by green roof development as well. The construction and maintenance of green roofs can create many job opportunities. Lush, local produce on green roofs also enriches the local economy. Surrounding properties' market prices will rise in reaction to the beautification of neighborhoods' roofscapes (Dunnett and Kingsbury 2008).

Green roofs' effects on air and water quality improvement will benefit human physical well-being. Green roof vegetation and space arrangement will often encourage mental restoration to enhance mental well-being. Green roofs can also be a community gathering space to encourage social interactions promoting social well-being. Hospital studies show the increase in recovery rate with the visual access to green spaces including green roofs (Ulrich 1984).

Former German FLL Vice President Klaus Neumann suggested that green roofs should be dedicated to promoting public health beyond the sustainable environmental benefits (Werthmann 2007). Since roofs constitute 40-50% of the impermeable surfaces in urban areas (Dunnett and Kingsbury 2008), there are numerous opportunities for green roofs to have an enormous effect on overall improvement of human quality of life.

CHAPTER 3

HUMAN HEALTH AND WELL-BEING

Definition of Health

People tend to identify different aspects of being healthy as important (Scriven 2010), and such guidelines may differ according to individuals' cultural and political backgrounds, and may change over time (Thomas and Petersen 2003). Overall health is a multidimensional concept, what constitutes "good" health in one perspective, may be "bad" in another. Those with serious diseases are likely to admit they are unwell. Other times, people may call themselves as "healthy" even when they are ill. Depression can be characterized as a symptom of ill health, despite one's good physical condition, but some people don't realize it until it's too late. Because of the complexity of the human life, it is difficult if not impossible, to assess overall health with a single metric (Blaxter 2003).

The World Health Organization (1948) defines health as "a state of complete physical, mental and social well-being and not merely the absence of disease or infirmity" (Tzoulas, Korpela, Venn, Yli-Pelkonen, Kaźmierczak, Niemela, and James 2007). The WHO definition has been criticized, however, for its vagueness (Callahan 1973, Jadad and O'Grady 2008); as Smith (2008) stated, it is "a ludicrous definition that would leave most of us unhealthy most of the time." Bircher (2005) further emphasizes that "Health is a dynamic state of well-being characterized by a physical, mental and social potential, which satisfies the demands of a life commensurate with age, culture, and personal responsibility. If the potential is insufficient to satisfy these demands the state is disease." Despite this controversy, this thesis uses the WHO definition of health, since some researchers, such as Engel (1977), agree that as the nature of human existence lies in its bio-psycho-social aspects, they are essential elements of a definition of health. The WHO definition has been widely recognized and remained unchanged since 1948, mainly because it captures the basic essence of health, and there have been no other definitions developed in consensus that can replace their existing one. The WHO's definition can serve as an aspirational point of reference while acknowledging the varying degrees of health that can characterize individuals. Ideally, an individual is considered healthy if he achieves physical, mental and social well-being as stated above in the WHO's definition of health.

Physical well-being is defined as an individual's physical fitness, an indispensable part of overall health (Australian Bureau of Statistics 2006). Physical well-being is measured on a range from severe disability to high energy level, that is, a comparative level of capacity for vigorous activity, without chronic conditions or symptoms (Belloc and Breslow 1972). Physical well-being is determined by physical environment and personal living habits such as smoking, diet, work habits, sedentary lifestyle, and frequency of exercise (Australian Bureau of Statistics 2006). Physical well-being can be achieved by performing physical activities from regular light or intense exercise to household chores (Penedo and Dahn 2005).

Mental well-being is defined by WHO (2014) as "a state of well-being in which every individual realizes his or her own potential, can cope with the normal stresses of life, can work productively and fruitfully, and is able to make a contribution to her or his community." Other research have defined mental well-being according to various criteria, such as subjective well-being, perceived self-efficacy, autonomy, competence, intergenerational dependence, and self-actualization of one's intellectual and emotional potential, and so forth. It is considered nearly impossible to arrive at a holistic definition of mental well-being from a cross-cultural perspective.

However, it is generally agreed that mental well-being is based on mental functioning, and includes preventing mental disorders through mental restoration (World Health Organization 2001). Individuals with mental health problems are often afraid of seeking treatments because of stigma and discrimination against patients and families (World Health Organization 2014). Lifestyle transformations, particularly physical activity, have been demonstrated to improve mental well-being conditions (Lynn, Morrone, and Toran 2013), and vigorous physical activity is related to a higher health-related quality of life and general liveliness (Conte et al. 2015, Pucci et al. 2012)

Social well-being is often associated with a society which provides equal opportunities and full accessibility to citizens at the level of the society as a whole or of a particular population (McDowell 2006). From an individual's perspective, social well-being is described as "that dimension of an individual's well-being that concerns how he gets along with other people, how other people react to him, and how he interacts with social institutions and societal mores (McDowell 2006)," which demonstrates the importance of elements such as personality and social skills (McDowell 2006). The extent of an individual's social network, as well as its stabilizing effect in helping the individuals deal with difficult life circumstances, can be measured through the Social Relationship Scale (SRS), a research instrument designed for studying the impact of life events in general population samples (McDowell 2006). Addictions involving drug abuse and tobacco, for example, have been shown to be closely associated with the reduction or prevention of one's normal social interactions. Social isolation and lack of community interactions are strongly related to reduced mental and physical well-being (McDowell 2006, Wilkinson and Marmot 2003). Social support, along with recent positive shifts in how treatment is perceived (e.g., the removal of the stigma associated with treatment), has been shown to help ameliorate individuals' health problems (McDowell 2006).

Based on definitions of physical, mental and social well-being, the WHO's definition of health can be understood to encompass physical fitness, efficient mental functioning, and effective social interaction.

Reasons for Selecting SITES

There are several popular alternative rating systems that can be used for green roofs to promote human health and well-being. The LEED® (short for Leadership in Energy and Environmental Design) green building certification system is not preferred for valuing a green roof site because it emphasizes overall building sustainability performances (U.S. Green Building Council 2016), rather than sustainable sites such as green roofs. The WELL Building Standard®, as one of the first guidelines of its kind that focuses on human health and well-being, was developed based on the effects of indoor spaces on individuals, most of which are not applicable to outside landscapes like green roofs. SITES (The Sustainable Sites Initiative™) is designed to focus on mitigating the negative impact of human behaviors on the built environment and enhance overall landscape performances and values. Even The U.S. General Services Administration (GSA), the government's largest civilian landlord, has recently decided to incorporate SITES into their program because of its effective and efficient approach to achieving federal goals for environmental performance on diverse capital project types. Nancy Somerville, Hon. ASLA, executive vice president and CEO of ASLA has indicated that the American people and the environment will benefit from this adoption of SITES (The American Society of Landscape Architects 2016).

Introduction of SITES

The Sustainable Sites Initiative™ (SITES), a broad, but detailed, set of guidelines and rating system, aims to define sustainable sites, monitor their performance and eventually promote landscape values. It is a program based on the appreciation of land as a necessary component to be carefully designed to mitigate, if not avoid, the harmful impacts of human behaviors (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

SITES is a multidisciplinary collaboration between The United States Botanic Garden, the Lady Bird Johnson Wildflower Center at The University of Texas at Austin, the American Society of Landscape Architects and numerous allied stakeholders, organizations and individuals. The initiative developed and set national voluntary guidelines to facilitate design teams with an understanding that any landscape has the opportunity to contribute to protecting the environment and addressing urgent environment problems if it is accordingly designed and managed (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

SITES is organized with prerequisites and credits over an evaluation process. Prerequisites are the premises to follow if the projects would like to be considered for this voluntary rating system. The accomplishment of the credits is elective, but a certain number of credits must be achieved in order to be considered a sustainable site. While some credits are valued as a range of points according to the level of achievement, others are achieved with settled points. SITES is formulated in sections to comply with the typical project development process (Calkins 2011). The sections are as follows:

- Pre-design Assessment + Planning
- Site Design – Water

- Site Design – Soil + Vegetation
- Site Design – Materials Selection
- Site Design – Human Health + Well-being
- Construction
- Operations + Maintenance
- Education + Performance Monitoring
- Innovation or Exemplary Performance

Methodology of the Selection of Health-promoting Guidelines

Based on the WHO's definition of health, I have selected guidelines from SITES according to their closeness to categories including physical fitness, efficient mental functioning, and effective social interactions, to enhance understanding of the relationship between green roofs and human health. First, all of the potential health-promoting guidelines are selected according to their relationship with physical, mental or social health in design processes for green roof site users, and a table (see Table 3.1) is then developed below based on the SITES v2 scorecard. Later, the recommended strategies are adapted from SITES, and have been discussed and modified to address to specific green roofs promoting health. Last but not least, design strategies are classified into different program elements (based on contents of *Landscape Architectural Graphic Standards*) for the convenience of general design considerations for future green roofs. Some guidelines are not discussed below. Although these affect human health and well-being, it was hard to control these in a design process. Those guidelines include "Control and retain construction pollutants", "Protect air quality during construction", "Plan for sustainable site maintenance", "Minimize pesticide and fertilizer use", and "Protect air quality during landscape maintenance". By doing this, I am developing a set of preliminary guidelines so green roofs may better contribute to human health and well-being.

Table 3.1 Green roof design guidelines checklist based on SITES v2 scoreboard

Key	
√	This well-being can be achieved through this guideline.
◯	Vacant space means it is not applicable to this thesis.
×	This well-being cannot be achieved through this guideline.
	Guidelines highlighted in this color are the ones that can promote human health and well-being on green roofs for site users

SITES v2 Scorecard Summary						
Physical Well-being	**Mental Well-being**	**Social Well-being**	**Desgin Metrics**			**Discussed**
			1: SITE CONTEXT	**Possible Points:**	**13**	
◯	◯	◯	**CONTEXT P1.1**	Limit development on farmland (Required)		
◯	◯	◯	**CONTEXT P1.2**	Protect floodplain functions (Required)		
◯	◯	◯	**CONTEXT P1.3**	Conserve aquatic ecosystems (Required)		
◯	◯	◯	**CONTEXT P1.4**	Conserve habitats for threatened and endangered species (Required)		
◯	◯	◯	**CONTEXT C1.5**	Redevelop degraded sites	**3 to 6**	
◯	◯	◯	**CONTEXT C1.6**	Locate projects within existing developed areas	**4**	
√	×	√	**CONTEXT C1.7**	Connect to multi-modal transit networks	**2 to 3**	
			2: PRE-DESIGN ASSESSMENT + PLANNING	**Possible Points:**	**3**	
√	√	√	**PRE-DESIGN P2.1**	Use an integrative design process (Required)		
◯	◯	◯	**PRE-DESIGN P2.2**	Conduct a pre-design site assessment (Required)		
◯	◯	◯	**PRE-DESIGN P2.3**	Designate and communicate VSPZs (Required)		
√	√	√	**PRE-DESIGN C2.4**	Engage users and stakeholders	**3**	
			3: SITE DESIGN - WATER	**Possible Points:**	**23**	
◯	◯	◯	**WATER P3.1**	Manage precipitation on site (Required)		
◯	◯	◯	**WATER P3.2**	Reduce water use for landscape irrigation (Required)		
◯	◯	◯	**WATER C3.3**	Manage precipitation beyond baseline	**4 to 6**	
◯	◯	◯	**WATER C3.4**	Reduce outdoor water use	**4 to 6**	
×	√	×	**WATER C3.5**	Design functional stormwater features as amenities	**4 to 5**	
◯	◯	◯	**WATER C3.6**	Restore aquatic ecosystems	**4 to 6**	
			4: SITE DESIGN - SOIL + VEGETATION	**Possible Points:**	**40**	
◯	◯	◯	**SOIL+VEG P4.1**	Create and communicate a soil management plan (Required)		
◯	◯	◯	**SOIL+VEG P4.2**	Control and manage invasive plants (Required)		
√	√	×	**SOIL+VEG P4.3**	Use appropriate plants (Required)		
◯	◯	◯	**SOIL+VEG C4.4**	Conserve healthy soils and appropriate vegetation	**4 to 6**	
◯	◯	◯	**SOIL+VEG C4.5**	Conserve special status vegetation	**4**	
◯	◯	◯	**SOIL+VEG C4.6**	Conserve and use native plants	**3 to 6**	

○	○	○	**SOIL+VEG C4.7**	Conserve and restore native plant communities	**4 to 6**	
○	○	○	**SOIL+VEG C4.8**	Optimize biomass	**1 to 6**	
√	×	×	**SOIL+VEG C4.9**	Reduce urban heat island effects	**4**	
○	○	○	**SOIL+VEG C4.10**	Use vegetation to minimize building energy use	**1 to 4**	
○	○	○	**SOIL+VEG C4.11**	Reduce the risk of catastrophic wildfire	**4**	
			5: SITE DESIGN - MATERIALS SELECTION	**Possible Points:**	**41**	
○	○	○	**MATERIALS P5.1**	Eliminate the use of wood from threatened tree species (Required)		
○		○	**MATERIALS C5.2**	Maintain on-site structures and paving	**2 to 4**	
○		○	**MATERIALS C5.3**	Design for adaptability and disassembly	**3 to 4**	
○	○	○	**MATERIALS C5.4**	Use salvaged materials and plants	**3 to 4**	
○	○	○	**MATERIALS C5.5**	Use recycled content materials	**3 to 4**	
○	○	○	**MATERIALS C5.6**	Use regional materials	**3 to 5**	
○	○	○	**MATERIALS C5.7**	Support responsible extraction of raw materials	**1 to 5**	
√	×	×	**MATERIALS C5.8**	Support transparency and safer chemistry	**1 to 5**	
○	○	○	**MATERIALS C5.9**	Support sustainability in materials manufacturing	**5**	
○	○	○	**MATERIALS C5.10**	Support sustainability in plant production	**1 to 5**	
			6: SITE DESIGN - HUMAN HEALTH + WELL-BEING	**Possible Points:**	**30**	
×	√	√	**HHWB C6.1**	Protect and maintain cultural and historic places	**2 to 3**	
×	√	√	**HHWB C6.2**	Provide optimum site accessibility, safety, and wayfinding	**2**	
×	√	√	**HHWB C6.3**	Promote equitable site use	**2**	
×	√	×	**HHWB C6.4**	Support mental restoration	**2**	
√	√	×	**HHWB C6.5**	Support physical activity	**2**	
×	√	√	**HHWB C6.6**	Support social connection	**2**	
√	√	√	**HHWB C6.7**	Provide on-site food production	**3 to 4**	
√	×	×	**HHWB C6.8**	Reduce light pollution	**4**	
○	○	○	**HHWB C6.9**	Encourage fuel efficient and multi-modal transportation	**4**	
√	×	×	**HHWB C6.10**	Minimize exposure to environmental tobacco smoke	**1 to 2**	
○	○	○	**HHWB C6.11**	Support local economy	**3**	
			7: CONSTRUCTION	**Possible Points:**	**17**	
○	○	○	**CONSTRUCTION P7.1**	Communicate and verify sustainable construction practices (Required)		
√	×	×	**CONSTRUCTION P7.2**	Control and retain construction pollutants (Required)		
○	○	○	**CONSTRUCTION P7.3**	Restore soils disturbed during construction (Required)		
○	○	○	**CONSTRUCTION C7.4**	Restore soils disturbed by previous development	**3 to 5**	
○	○	○	**CONSTRUCTION C7.5**	Divert construction and demolition materials from disposal	**3 to 4**	
○	○	○	**CONSTRUCTION C7.6**	Divert reusable vegetation, rocks, and soil from disposal	**3 to 4**	
√	×	×	**CONSTRUCTION C7.7**	Protect air quality during construction	**2 to 4**	

			8. OPERATIONS + MAINTENANCE		**Possible Points:**	**22**	
√	×	×	**O+M P8.1**	Plan for sustainable site maintenance (Required)			
○	○	○	**O+M P8.2**	Provide for storage and collection of recyclables (Required)			
○	○	○	**O+M C8.3**	Recycle organic matter		**3 to 5**	
√	×	×	**O+M C8.4**	Minimize pesticide and fertilizer use		**4 to 5**	
○	○	○	**O+M C8.5**	Reduce outdoor energy consumption		**2 to 4**	
○	○	○	**O+M C8.6**	Use renewable sources for landscape electricity needs		**3 to 4**	
√	×	×	**O+M C8.7**	Protect air quality during landscape maintenance		**2 to 4**	
			9. EDUCATION + PERFORMANCE MONITORING		**Possible Points:**	**11**	
×	√	√	**EDUCATION C9.1**	Promote sustainability awareness and education		**3 to 4**	
○	○	○	**EDUCATION C9.2**	Develop and communicate a case study		**3**	
○	○	○	**EDUCATION C9.3**	Plan to monitor and report site performance		**4**	
			10. INNOVATION OR EXEMPLARY PERFORMANCE		**Bonus Points:**	**9**	
√	√	√	**INNOVATION C10.1**	Innovation or exemplary performance		**3 to 9**	
			TOTAL ESTIMATED POINTS		**Total Possible Points:**	**200**	
Key					**SITES Certification levels**	Points	
√	This well-being can be achieved through this guideline.				**CERTIFIED**	70	
○	Vacant space means it is not applicable to this thesis.				**SILVER**	85	
×	This well-being cannot be achieved through this guideline.				**GOLD**	100	
					PLATINUM	135	

Table 3.2 Concluded green roof design guidelines checklist based on SITES v2 scoreboard

Green Roof Health-promoting Design Guidelines					
Physical Well-being	**Mental Well-being**	**Social Well-being**	**Desgin Metrics**		**Points**
√	×	√	CONTEXT C1.7	Connect to multi-modal transit networks	2 to 3
√	√	√	PRE-DESIGN P2.1	Use an integrative design process (Required)	
√	√	√	PRE-DESIGN C2.4	Engage users and stakeholders	3
×	√	×	WATER C3.5	Design functional stormwater features as amenities	4 to 5
√	√	×	SOIL+VEG P4.3	Use appropriate plants (Required)	
√	×	×	SOIL+VEG C4.9	Reduce urban heat island effects	4
√	×	×	MATERIALS C5.8	Support transparency and safer chemistry	1 to 5
×	√	√	HHWB C6.1	Protect and maintain cultural and historic places	2 to 3
×	√	√	HHWB C6.2	Provide optimum site accessibility, safety, and wayfinding	2
×	√	√	HHWB C6.3	Promote equitable site use	2
×	√	×	HHWB C6.4	Support mental restoration	2
√	√	×	HHWB C6.5	Support physical activity	2
×	√	√	HHWB C6.6	Support social connection	2
√	√	√	HHWB C6.7	Provide on-site food production	3 to 4
√	×	×	HHWB C6.8	Reduce light pollution	4
√	×	×	HHWB C6.10	Minimize exposure to environmental tobacco smoke	1 to 2
×	√	√	EDUCATION C9.1	Promote sustainability awareness and education	3 to 4
√	√	√	INNOVATION C10.1	Innovation or exemplary performance	3 to 9

Studies on Health-promoting Guidelines and Recommended Health-centered Green Roof Design Strategies

Connect to Multi-modal Transit Networks

Multi-modal transit networks normally involve elements such as roadways, sidewalks, bicycle lanes, pedestrian pathways, and mass public transportation systems. Projects accessible by various kinds of transportation services are more readily accessible. Connecting to multi-modal transit networks will promote human health and well-being by providing healthy lifestyle alternatives, minimizing the potential negative influences of car-dependent habits, such as obesity and the inherent risk of automotive accidents (Pratt, Macera, and Wang 2000). It also reduces pollution by using personal vehicles less and encouraging the use of public transportation, which benefits human health and well-being physically in the long run. Green roofs can be located near—if not directly connected to—public transit services. In this way, they are more accessible to pedestrians, bicyclists and others using public transit services.

Table 3.3 Health-centered design guideline and strategies for green roofs on connecting to multi-modal transit networks

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Connect to Multi-modal Transit Networks	Prioritize establishing green roofs at areas with existing multi-modal transit networks including roadways, sidewalks, bicycle lanes, and mass public transportation systems.	Accessibility
	Inspect and take into consideration any new plans on transportation and transit systems within two years of project completion. Keep up to date with the progress made on transportation service development by establishing and maintaining relationships with related departments and agencies.	Site planning
	Use surveys to identify the transportation needs of future users of the site.	Site planning
	Facilitate ease of access to the roof from transport options.	Accessibility

Use an Integrative Design Process

An integrative design process is a collaborative design process based on the requirements and demands of stakeholders and site users using sustainability principles and performance goals with considerations of construction oversight and site maintenance strategies by an integrated design team. A typical integrated design team includes members with particular expertise contributing to the site such as the owners, clients, and design, construction and maintenance professionals (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

Collaborative communications will ensure the project be viewed from multiple perspectives, and innovative ideas and solutions may be created through effective collaborations. The earlier the sustainability principles and performance goals are considered, the easier and better they will be implemented in the project as well. The engagement of stakeholders and site user groups will help maximize site benefits to local people and the environment. Effective construction oversight and site maintenance strategies will guarantee the site is consonant with the design and exhibits optimal landscape performance. The integrated design will facilitate a better understanding of the project since professionals in different disciplines are acknowledged to have different requirements and constraints, which can be identified early in the process (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

Green roofs should be designed integratively, like any other landscape design. However, because of green roofs' special characteristics, limitations should be considered early. Green roof and public health professionals should be included in the integrative design team. Detailed short and long-term maintenance plans should consider conditions like extreme weather, climate, and wear and tear, since the roof environment is poorer than ground-level landscapes and less resistant to hazardous changes. Charrettes can be organized to facilitate more suggestions and ideas from the site users to better serve local populations, and in particular, address issues such as physical and visual accessibility. The aforementioned public health experts, moreover, would evaluate the green roofs' potential effects on the local populations.

Table 3.4 Health-centered design guideline and strategies for green roofs on using an integrative design process

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Use an Integrative Design Process	Identify project goals on physical, mental and social well-being	Project administration
	Coordinate cooperative communications between professionals regularly from various backgrounds, including at least one green roof and one public health professional.	Human factors
	Make short and long term maintenance plans according to the site conditions and the existing and potential resources (e.g., budget, staff, volunteers, equipment, materials, educational programs, and classes).	Project administration
	Organize activities like a charrette to engage stakeholders and site user groups in formulating more site specific designs meeting the requirements of site users.	Human factors

Engage Users and Stakeholders

Engaging future site users and stakeholders can contribute to shaping and fulfilling specific project goals, in a form of collaboration that integrates local perspectives as a supplement to professional knowledge. A site designed with various voices in mind will balance the benefits of different parties. In this way, individuals will get the most out of the site (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

In order to engage site users and stakeholders in green roof designs, the process normally starts with a site assessment identifying the local needs and requirements, particularly analyzing the weight that the structure can hold. Next, a program plan must be made according to the specific site conditions and suggestions from users and stakeholders. Later, participants from among site users and stakeholders should be invited to design and review a project development presentation. Lastly, the design should be presented to the public in different formats, such as a website, community meeting, newspaper article, etc.

Table 3.5 Health-centered design guideline and strategies for green roofs on engaging users and stakeholders

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Engage Users and Stakeholders	Approach and recruit potential site users and stakeholders to participate in different ways, such as through websites, surveys, and charrettes, workshops, community meetings, etc.	Human factors

Design Functional Stormwater Features as Amenities

A stormwater feature is a stormwater management element which uses precipitation as its main source. Stormwater features can take in the form of pools, fountains, stormwater BMPs, water gardens, channels for local conveyance, rain gardens, and water art. Functional stormwater features will help individuals gain access to the water visually and physically, and have a stronger connection with water (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

Stormwater features like impressive stormwater management systems or simply the sound of running water can enhance individuals' aesthetic experience of the site (Calkins 2011). Water on-site is often associated with psychological effects, such as mental restoration and reflection, which potentially functions as stress relieving and increasing work productivity factor (Bowers 2003, Burmil, Daniel, and Hetherington 1999). The physical interactions with water can create recreational opportunities as well. For example, a dry detention pond can be potentially used as a space to play between storms (Calkins 2011).

Green roofs often provide stormwater management features working on water quantity and quality, which slows down the peak flow frequency and duration, at the same time filtering the pollutants on site. Bio-retention, infiltration, and water harvesting system could possibly be implemented on green roofs, depending on the roof's carrying capacity if it is not exceeded (Calkins 2011).

Table 3.6 Health-centered design guideline and strategies for green roofs on designing functional stormwater features as amenities

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Design Functional Stormwater Features as Amenities	Design and sustain stormwater features to mimic natural ecosystem features by using native plant communities and other aquatic organisms.	Stormwater management
	Plan for additional treatment, such as ozonation or thermal control, for water features with which human contact is expected.	Stormwater management
	Collaborate between artists, craftsmen and designers to create stormwater features with sound functionality and entrancing aesthetics.	Experiential factors, Human factors
	Design stormwater features with maximized functional and health-promoting attributes, such as physical, mental and social well-being, by utilizing low impact development strategies and providing physical or visual accessibility.	Accessibility
	Design sustainable stormwater harvesting and infiltration systems for on-site food production.	Stormwater management

Use Appropriate Plants

An appropriate plant species is vegetation that is adaptable to site conditions and design intent; features like cold hardiness, heat tolerance, salt tolerance, soil moisture range, plant water use requirements, soil volume requirements, soil pH requirements, sun and shade requirements, pest susceptibility, and maintenance requirements should be considered in advance to decide whether it is appropriate to the site. Both native and non-native plants can be appropriate to the site once they meet the standard above and if they are not identified as invasive or ecologically detrimental (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

Using appropriate plants will promote mental restoration by encouraging humans' visual and physical interactions with plants (Calkins 2011). Plants can also be therapeutic, and produce on-site food production. Using appropriate plants helps with conserving water and creating habitats; it reduces the need for fertilizers, pesticides and maintenance efforts (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

Although any given plants can grow on green roofs with sufficient growing media, water and building carrying capacity, designers should take account of variable site considerations. Some shrubs and trees can be well-suited to green roof conditions, while many cannot. Chosen vegetation species should be ecologically feasible, which are tolerant of both dry and saturated conditions; typical successful species are succulents, bulbs and corms, biannual or annual self-seeders, bunch and stoloniferous graminoids, and many model wetland species, which work perfectly on all types of roofs. There are limitations and factors to consider when planting some shrubs and tall trees on semi-extensive and intensive green roofs, such as carrying capacity, water availability, available depth and type of growing media, wind velocity, soil temperature, solar access, and climate (Calkins 2011).

Table 3.7 Health-centered design guideline and strategies for green roofs on using appropriate plants

Health-promoting Guideline	Health-centered Design Strategies	Program Elements
Use Appropriate Plants	Select plants that are adaptable to site conditions. Invasive species that threaten the balance of the local ecosystem should be avoided.	Planting
	Consult local governmental agencies, educational facilities, and native plant societies for plant selection. Refer to local authoritative plant recommendation list. Inspect frequently to exclude state and federal noxious weeds and invasive plants	Human factors
	Select low-maintenance vegetation species	Planting
	Prevent potential insect and disease pests by using diverse plants; as a general guide for larger sites, any specific plant species should not exceed 10 percent of the total, and any particular plant genus should not exceed 20 percent of the total. Similarly, any specific plant family should not exceed 30 percent of the total. For smaller sites, plant diversity can be achieved by selecting appropriate species from a local or regional area	Planting
	Selecting plants that provide food, nesting sources for appropriate native wildlife	Planting

Reduce Urban Heat Island Effect

Urban heat island effect refers to the phenomenon of man-made urban areas being hotter than nearby rural areas. It can increase the summertime peak energy demand, air-conditioning costs, levels of air pollution, water quality, and instances of illness and death relating to heat and pollution (U.S. Environmental Protection Agency 2016). The excess heat is mainly either generated from the reduction of original on-site vegetation and the addition of new urban structures and pavement (Gray and Finster 1999, Rizwan, Dennis, and Chunho 2008). Urban air quality is degraded because the raised temperature increases the formation rate of ground-level ozone, which is the main concern associated with the heat island effect (Gray and Finster 1999), since ozone can cause diseases and conditions associated with the respiratory system (U.S. Environmental Protection Agency 2006).

Vegetative covers—including green roofs, which have vegetation such as trees, shrubs, and other plants—provide shade for rooftops by reducing solar radiation and cool the ambient air by evapotranspiration through their leaves (Susca, Gaffin, and Dell'Osso 2011, Takebayashi and Moriyama 2007). In this way, vegetation on green roofs can lower the local temperature, improve air quality, and mitigate UHI effects so as to reduce the rate of human diseases related to respiratory system.

Table 3.8 Health-centered design guideline and strategies for green roofs on reducing Urban Heat Island Effect

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Reduce Urban Heat Island Effect	Maximize the percentage of vegetated areas on roofs	Environmental factors
	Use shade from proper trees, dense shrubs, vegetated trellises, walls or other shading structures reasonably.	Environmental factors
	Provide light color covers and surfaces for pedestrian areas as an alternative to traditional dark ones to reduce building temperature.	Environmental factors
	Consider the use of photovoltaic cells to shade impervious surfaces.	Environmental factors
	Consider employing shady plants or the structures mentioned in the previous strategies if a roof functions as a parking lot.	Environmental factors

Support Transparency and Safer Chemistry

Transparency and safer chemistry products and materials can be checked by chemical hazard assessment, which helps evaluate their "greenness" and safety by identifying product composition and determining their effects on human and environmental health. Such assessment looks for the connection between chemical products and possible hazards such as reproductive toxicity, neurotoxicity, persistence etc (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014). With health protections in place, not only will the site users benefit from transparency and safer chemistry products and materials, but the manufacturing and construction workers will benefit as well. Promoting materials that have minimized effects on environment and human health on green roofs requires continuous efforts (Calkins 2011).

Table 3.9 Health-centered design guideline and strategies for green roofs on supporting transparency and safer chemistry

Health-promoting Guideline	Health-centered Design Strategies	Program Elements
Support Transparency and Safer Chemistry	Avoid using materials with finishes (e.g., dye, paint, gloss) or other chemical additives if possible.	Material
	Make use of certification systems using guidelines that promote transparency and safer chemistry in products.	Material
	Prioritize low-risk products that meet the highest affordable safety guidelines.	Material
	Communicate clear expectations to suppliers regarding transparency and safer chemistry needs for current and future projects.	Human factors

Protect and Maintain Cultural and Historic Places

Cultural landscapes and historical sites are often referred to cultural and historical places. According to the National Park Service, a cultural landscape is a geographic area, along with its indigenous animals and natural resources, that has a unique or significant cultural, historical, or aesthetic value. And a historic site is defined as a place of historical significance, such as battlefields or the residences of influential individuals (Birnbaum 1994). Preserving cultural landscapes and historical sites is a continuous process, as often the site itself has been long neglected and suffered from a lack of attention, and thus has the potential for improvement (Melnick 2000).

Protecting and maintaining cultural and historical places can enhance mental and social well-being. It enriches individuals' knowledge and enhances the experience of landscape evolution, cultivating individuals' attention to and affections for cultural and historic places. It will also encourage people to respect and remember the spaces with cultural and historical backgrounds. It engages individuals together to appreciate these places and foster a closer community (The Lady Bird Johnson Wildflower Center of the University of Texas at Austin, the U.S. Botanic Garden, and the American Society of Landscape Architects 2014).

Most historical and cultural buildings' structures are old and fragile, they were built with outdated techniques and methods, and if they can support green roofs at all, such roofs would mostly be of the extensive variety. Green roofs can enhance sustainability and energy performance of historic buildings. Building energy use is reduced by covering the roof membrane so as to extend the life-cycle of roofs as well. However, preserving cultural and historic buildings is the priority, any potential negative effects on the historic character of the building should be avoided.

Table 3.10 Health-centered design guideline and strategies for green roofs on protecting and maintaining cultural and historic places

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Protect and Maintain Cultural and Historic Places	Maintain site selection and design practices that reflect sensitivity to any concerns relating to the cultural, historic, and religious significance of potential sites.	Cultural factors
	Obtain inspiration from local history and culture for green roof designs on non-historical structures	Cultural factors
	Prioritize preserving historic features to sustainable benefits gained from building green roofs.	Cultural factors

Providing Optimum Site Accessibility, Safety, and Wayfinding

There are three ways to define site accessibility. The first according to Merriam-Webster dictionary is to be "capable of being reached or appreciated". In other words, it means physical or visual access. The 2010 Americans with Disabilities Act (ADA) Guidelines for Accessible Design, as said by US Department of Justice, define it as providing accessibility to individuals with disabilities to sites, facilities, and buildings (Department of Justice 2010). The final way would be to adopt a social equity standpoint using universal design, which is a holistic human-centered design approach (Ostroff 2011).

Integrating design with considerations of site accessibility, safety, and wayfinding will promote a sense of safety, and support social interaction. Furthermore, it will yield an enhanced quality of life by lessening anxiety concerning crime and expedite movement for all types of people (Huelat 2007). Many studies have reported that green spaces play an important part in producing beneficial health effects (Lee and Maheswaran 2011). Several studies have shown that access to green spaces can be psychologically and physiologically restorative (Hartig et al. 2003, Pretty et al. 2005), and possibly encourage quicker recovery after surgery (Ulrich 1984). While clear wayfinding helps individuals to gain access to the resources and amenities which benefit health, site safety can largely influence the site use frequency (Calkins 2011).

Most green roofs have limitations on accessibility, for example in the physical domain, there are limits to the extra weight the building can hold besides the green roof system. Besides that, the physical accessibility of the site also varies because of other factors, such as different building ownership, building hours and building use. Visually, accessibility depends on whether the roof can be viewed from surrounding structures. Safety issues are always a subject of concern: structures with appropriate heights, such as tall walls or fences, should be implemented to limit physical activities on site, if it is accessible to the public. Semi-enclosure spaces are encouraged, to avoid the risks associated with completely enclosed spaces, but at the same time, the spaces should be kept relatively independent. Easy navigation to the green roof site should be provided to maximize its effects on human health and well-being.

Table 3.11 Health-centered design guideline and strategies for green roofs on providing optimum site accessibility, safety, and wayfinding

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Providing Optimum Site Accessibility, Safety, and Wayfinding	Provide evident site accessibility and wayfinding to green roofs.	Accessibility
	Identify techniques to improve green roof legibility by understanding the building and its roofs' layout and site expectations.	Site planning
	If the green roof is physically accessible, plan for equitable site uses early using universal design strategies, such as handicap ramps, moveable furniture, and materials, etc.	Accessibility
	Provide opportunities, such as educational programs and social events, for visual or physical access to green roofs.	Accessibility
	Address safety concerns during site design by identifying approaches to avoid safety problems according to green roof types and site users.	Security considerations
	Design seating areas with low walls, fences, vegetation, or topography to invoke a sense of safety.	Security considerations

Promoting Equitable Site Use

Equitable site use requires access to the site as a prerequisite, allowing people to experience and enjoy the site equally, including expanding site use to those who normally don't have access to a site (Calkins 2011). Universal design should be considered at the beginning of the design process rather than as an afterthought (Ostroff 2011).

Inequitable urban development and the uneven separation of natural amenities has led to the unequal distribution of green spaces, mostly for low-income and minority residents (Heynen, Perkins, and Roy 2006, Wendel, Downs, and Mihelcic 2011). Such individuals often have less contact with the green spaces, which to some degree causes distinctions in health-related behaviors and obesity (Kipke et al. 2007, Powell, Slater, and Chaloupka 2004).

This factor only affects green roofs with physical accessibility. On-site events, amenities, or programs can be provided to engage different site users. Local communities should also use this green roof resource as an opportunity to promote social interactions between majority and minority site users.

Table 3.12 Health-centered design guideline and strategies for green roofs on promoting equitable site use

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Promoting Equitable Site Use	Identify needs and provide options for site users by actively engaging with the local community.	Human factors
	Provide free public site access to selected site elements (amenities, activities, facilities, programs, or events), which meet the needs of the local community	Accessibility
	Balance the use of permanent elements and temporary installations to provide options for a wider range of site users.	Accessibility

Supporting Mental Restoration

Although 450 million people in 2001 were estimated to suffer from mental or neurological disorders or from psychological problems, many of whom have alcohol and drug abuse (World Health Organization 2001), many studies have demonstrated the beneficial mental restorative effects of nature for urban residents (Berman, Jonides, and Kaplan 2008, Kaplan 1995, Taylor, Kuo, and Sullivan 2001). According to Stephen and Rachel Kaplan's Attention Restoration Theory (ART) (Kaplan and Kaplan 1989), a cognitive framework focused on recovery from mental fatigue or Directed Attention Fatigue (DAF) (Kaplan 2001), people prefer being in nature more than urban area physically and psychologically. DAF affects an individual's fragility, perceptions, thoughts and actions (Kaplan 1995). ART suggests natural environments can help to build up directed, sustained attention to help people recover from this fatigue (Kaplan

2010). Natural environments create a type of effortless attention or fascination that gives directed attention a chance to rest and restore (Berto 2005).

Looking out at a green roof also calmed participants' feelings and helped them gain perspectives in their work and to creatively solve problems (Loder 2014). As individual perceptions of what constitutes nature vary, so too do assessments of green roofs beneficial effects. As such it is impossible to generalize about what level of vegetation is appropriate for all locations. Even so, green roofs should be located in a place that is physically or visually accessible and provide on-site furniture, such as seating and shade structures for rest and meditation.

Table 3.13 Health-centered design guideline and strategies for green roofs on supporting mental restoration

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Supporting Mental Restoration	During the site assessment process, look for space that has the potential to optimize mental health benefits. Consider elements like shade trees, relaxing or appealing views on site, or those from surrounding structures and buildings.	Experiential factors
	During site planning and design, identify site users' needs according to communications with stakeholders and potential site users.	Human factors
	Provide views to distant vegetation or human activities	Experiential factors
	Avoid obstructed views by placing structures or vegetation carefully.	Experiential factors
	Aim for a plan incorporating a number of mentally beneficial spaces of small size, instead of one expansive space.	Experiential factors
	Acknowledge the site's integration with nature by linking exterior green roof spaces with interior spaces for public use through the placement of objects like potted plants or through constructed spaces like greenhouses.	Experiential factors

	Keep the roof space free from distractions, such as noise from mechanical systems, building and facility operations, and traffic. Using dense foliage, barriers or screens can help minimize noise. Schedule maintenance activities only when site users are not present.	Experiential factors
	Place seating areas with low walls, fences, vegetation, or topography to create a sense of enclosure.	Security considerations
	Design different seating options with comfortable, movable furniture in both sun and shade.	Experiential factors
	Design certain structures and vegetation for shade and windbreak protection. Walls, fences, and vegetation can provide shade and be used to guide winds with different effects.	Experiential factors
	Use a variety of vegetation and artworks to provide a multi-sensory aesthetic experience.	Experiential factors

Supporting Physical Activity

Plentiful research has documented the health benefits of physical activity, such as its effects on obesity, cardio- and cerebro-vascular disease, diabetes, colorectal cancer, osteoporosis, depression and fall-related injuries (Foster et al. 2005, Gast et al. 2007, Gregg, Pereira, and Caspersen 2000, Kahn et al. 2002, Meisinger et al. 2007, Penedo and Dahn 2005, Shaw et al. 2006, Thomas, Elliott, and Naughton 2006, Williams 2001). Physical activity, from regular light or intense exercise to household chores, is beneficial to bodily and mental health (Penedo and Dahn 2005). Individuals who exercise regularly are reported to have lower mortality than ones who don't (Blumenthalet al. 2004).The sites which provide spaces for physical activity can also offer opportunities for beneficial "green exercise" like walking (Pretty et al. 2003).

In addition, extensive research illustrates mood improvement and depression and anxiety reduction effects from physical activity (Ross and Hayes 1988, Stephens 1988). Evidence shows that a 50-60-minute exercise session per week, with a warm-up, aerobics, upper-extremity strength and cool-down phases improves health-related quality of life (American Association of Cardiovascular and Pulmonary Rehabilitation: Guidelines for Cardiac Rehabilitations and Secondary Prevention Programs. 3rd ed. Champaign, IL: Human Kinetics; 1999cite). Even a seated exercise program is found to be beneficial towards lightening mental burdens (Headley, Ownby, and John 2004). Aerobic exercise works better on heavily depressed individuals than receiving psychotropic treatment (Babyak et al. 2000). It is believed that depression can be improved with constant physical activity (Paffenbarger, Lee, and Leung 1994). Besides aerobic practices, studies show less conventional exercises such as African dance or Hatha yoga can have a positive effect on mental well-being as well (West et al. 2004).(Penedo and Dahn 2005)

Green roofs have the potential to provide space for physical activities. Due to the characteristics of extensive green roofs, they can’t support public uses such as exercise. However, some researchers argue intensive and semi-intensive green roofs are places where individuals can perform physical activity with privacy, safety and security (Rashid, Ahmed, and Khan 2010).

Table 3.14 Health-centered design guideline and strategies for green roofs on supporting physical activity

Health-promoting Guideline	Health-centered Design Strategies	Program Elements
Supporting Physical Activity	Design the green roofs according to site users with adequate, accessible and comfortable spaces for potential physical activities.	Accessibility
	For smaller sites, design innovative meandering pathways to increase the opportunity for on-site physical activities.	Circulation
	For larger sites, consider addressing the site map and walking routes to enhance safety protection.	Security considerations
	Consider pedestrian lighting for public green roofs accessible at night.	Site amenities
	Utilize elevated light sources only when space is used for more intensive physical activities.	Site amenities
	Divide space wisely with separation between a quiet mental restoration area and an active physical area.	Experiential factors
	Provide movable seating furniture on-site for rest after on-site physical activities.	Experiential factors

Supporting Social Connection

Social connections take different forms, such as having conversations, engaging in public activities and paying visits (Maas et al. 2009). It is widely known that social relationships have an impact on diverse health outcomes (Berkman et al. 2000). Individuals who actively take part in communities or socially interact with others tend to live longer (Kawachi et al. 1997) and are comparatively healthier physically as well as mentally (Kawachi and Berkman 2000, Leyden 2003).

On-site events, activities, programs are encouraged to engage the community. The green roof should be located in a place that is accessible and provides on-site furniture like seating and shade structures for rest and communicating.

Table 3.15 Health-centered design guideline and strategies for green roofs on supporting social connection

Health-promoting Guideline	Health-centered Design Strategies	Program Elements
Supporting Social Connection	During site planning and design, identify site users' needs according to communications with stakeholders and potential site users.	Human factors
	Look for large shaded areas as potential spaces to accommodate moderate to large groups.	Human factors
	Aim for a plan incorporating a number of mentally beneficial spaces of small size, instead of one expansive space.	Experiential factors
	Design different seating options with comfortable, movable furniture in both sun and shade.	Experiential factors

Providing On-site Food Production

Providing food production on green roofs can potentially help with human health and well-being by encouraging community involvement, and providing education about managing food production and nutrition on site. Growing the food on-site can improve the quality and freshness of the produce (Kortright and Wakefield 2011, Story et al. 2008). Foods like nuts, fruits, herbs, and vegetables are necessary, and generally beneficial for human health and well-being. Growing and distributing on-site food will inspire social connections, encourage community engagement and provide promising places for recreation, exercise, therapy and education (Guitart, Pickering, and Byrne 2012).

Table 3.16 Health-centered design guideline and strategies for green roofs on providing on-site food production

Health-promoting Guideline	Health-centered Design Strategies	Program Elements
Providing On-site Food Production	Select appropriate vegetation that are adaptable to site specific conditions with shallow roots and lower maintenance	Planting
	Manage and maintain the site with the cooperation of local communities and programs, with necessary assistance in irrigation and pollination	Human factors
	Use organic and healthy soil for on-site vegetation in a relatively thin system	Material
	Lessen the impact of harmful chemicals on human consumption by utilizing organic gardening techniques.	Project administration
	Consider different gardening techniques, such as greenhouses, raised beds, and container gardens, to provide separate spaces for food production and lower the risk of contamination.	Education
	Design sustainable stormwater harvesting and infiltration systems for on-site food production.	Stormwater management
	Consider using on-site food waste and vegetation trimmings as composting materials.	Project administration

Reducing Light Pollution

From the International Dark-sky Association, light pollution is any adverse effect of artificial light, including sky glow, glare, light trespass, light clutter, decreased visibility at night, and energy waste. Light pollution reduction can help minimize its adverse effects on human health and functioning in both nocturnal and daytime environments (Falchi et al. 2011, Stevens 2006). Reducing the artificial lights to reasonable numbers will help preserve the night environment, as they can disturb nocturnal species through sky glow, and potentially disturb the functioning of an entire ecosystem (Kempenaers et al. 2010, Longcore 2010, Longcore and Rich 2004, Navara and Nelson 2007, Rich and Longcore 2013).

Access to green roofs at night should be limited, because it has potential safety problems. If it is publically accessible at night, low wayfinding lights should be placed strategically on site only as necessary areas to restrict the light pollution.

Table 3.17 Health-centered design guideline and strategies for green roofs on reducing light pollution

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Reducing Light Pollution	Retain pedestrian way-finding light levels based on site lighting criteria, avoiding off-site lighting and night sky pollution.	Site amenities
	Regulate the vectors and dispersal of light through a selection of specific light fixtures. Illuminating Engineering Society (IES) "full cut off" or "fully shielded" are among the most effective for this purpose as they restrict visible light to the lowest luminous portion of the fixture.	Site amenities
	Consider temporary lighting installations on public green roofs with no consistent night-time public accessibility.	Site amenities
	Based on the recommendations of the Dark Sky Society, cooperate with professional lighting designers to place fixtures strategically, so that they reach necessary areas such as site maps and walking routes, especially when they are over 15,000 lumens.	Human factors

Minimizing Exposure to Environmental Tobacco Smoke

Environmental tobacco smoke (ETS) has a heavy influence on individuals' health (Brownson et al. 1997). ETS causes acute and chronic diseases on otherwise healthy nonsmokers, including lung cancer in nonsmokers, childhood disorders, and perhaps heart disease (Jinot and Bayard 1992, Samet, Lewit, and Warner 1994). Minimizing exposure to ETS will benefit the working and public environment (Fielding 1991, Mudarri 1994), as well as possibly decrease the smoking rate (Borland et al. 1990, Longo et al. 1996, Petersen et al. 1988, Sorsensen et al. 1991).

Smoking can be generally phased out by ordinances, and it is easier to restrict smoking on green roofs than on ground-level public spaces. What's more, vegetation on green roofs help purify the air as well, all of which will contribute to minimizing exposure to ETS on green roofs.

Table 3.18 Health-centered design guideline and strategies for green roofs on minimizing exposure to environmental tobacco smoke

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Minimizing Exposure to Environmental Tobacco Smoke	Prohibit smoking on green roofs	Experiential factors
	If smoking must be allowed, then: Strategically place smoking areas with the consideration of dominant wind directions and microclimate effects	Experiential factors
	If smoking must be allowed, then: Consider innovative methods to limit the exposure to environmental tobacco smoke such as putting air filters around the smoking area	Experiential factors

Promote Sustainability Awareness and Education

Promote the understanding of sustainability enriches individuals' knowledge, and it will improve their appreciation of the sustainable features and influence individuals towards more responsible choices, which all contribute to individuals' mental health development (SITES v2 Reference Guide).

Green roofs provide a perfect opportunity to showcase sustainable features such as habitat for biodiversity, on-site food production, energy efficiency, stormwater retention, and infiltration and harvesting systems. Green roof demonstration projects will help the public raise awareness on sustainability, promote more attentions on green roofs, and encourage more future green roof projects.

Table 3.19 Health-centered design guideline and strategies for green roofs on promoting sustainability awareness and education

Health-promoting Guideline	**Health-centered Design Strategies**	**Program Elements**
Promote Sustainability Awareness and Education	For any educational or other explanatory materials, make use of clear and concise language well-tailored to the intended audience, outlining important points and employing visual or verbal illustrations	Education
	Provide information on green roofs' sustainable and health-promoting features in a variety of formats (e.g., maps, models, brochures, electronic kiosks, MP3-based or cell phone tours), perhaps including translated materials in other languages	Education
	Connect to local schools and organizations with programs to stimulate green roof learning interest.	Human factors
	Encourage individuals' interactions with characteristic site elements by providing observable on-site sustainable features for demonstration.	Education
	Plan activities and programs on the green roofs, or in a nearby building which has visual access to the green roof.	Accessibility

Innovation or Exemplary Performance

Keep an open mind to innovations for site design to promote better potential for the site. Innovative designs will stimulate site users' imaginations on the way of site use, and in turn, inspire designers. Exemplary performance will help encourage others to be creative in design, and set up a demonstrative featured case for later designs, which will keep the market thriving. Innovations or exemplary performances of green roof will help generate green roof exposure to the public and help make the green roofing more popular and widespread.

Table 3.20 Health-centered design guideline and strategies for green roofs on innovation or exemplary performance

Health-promoting Guideline	Health-centered Design Strategies	Program Elements
Innovation or Exemplary Performance	Conduct research on similar past projects' performances	Site planning
	Explore the possibility of extending the benefits or raise the performances by using innovative strategies or tools.	Education
	Consider new and /or unique strategies and technologies to promote human health and well-being	Education

Health-promoting Guidelines Summary

The discussion above concerned 18 different guidelines selected from SITES, based on whether, or how, they meet the WHO's definition of health, which addresses physical fitness, efficient mental functioning, and effective social interactions.

Each is developed with a set of design strategies from different program elements (see Appendix A) to help green roofs promote human health and well-being. Most of the guidelines can work for all three types of green roofs, with a few exceptions for extensive green roofs (see Table 3.21). The discussion enhances the understanding of the relationship between green roofs and human health and offer an opportunity for future green roof designers to develop health-promoting spaces.

Table 3.21 Green roof design guidelines checklist for different roof types based on SITES

Green Roof Health-promoting Design Guidelines									
Physical Well-being	**Mental Well-being**	**Social Well-being**	**Desgin Metrics**		**Points**	**Intensive**	**Semi-intensive**	**Extensive**
√	×	√	**CONTEXT C1.7**	Connect to multi-modal transit networks	**2 to 3**	√	√	√
√	√	√	**PRE-DESIGN P2.1**	Use an integrative design process (Required)		√	√	√
√	√	√	**PRE-DESIGN C2.4**	Engage users and stakeholders	**3**	√	√	√
×	√	×	**WATER C3.5**	Design functional stormwater features as amenities	**4 to 5**	√	√	√
√	√	×	**SOIL+VEG P4.3**	Use appropriate plants (Required)		√	√	√
√	×	×	**SOIL+VEG C4.9**	Reduce urban heat island effects	**4**	√	√	√
√	×	×	**MATERIALS C5.8**	Support transparency and safer chemistry	**1 to 5**	√	√	√
×	√	√	**HHWB C6.1**	Protect and maintain cultural and historic places	**2 to 3**	×	√	√
×	√	√	**HHWB C6.2**	Provide optimum site accessibility, safety, and wayfinding	**2**	√	√	×
×	√	√	**HHWB C6.3**	Promote equitable site use	**2**	√	√	×
×	√	×	**HHWB C6.4**	Support mental restoration	**2**	√	√	√
√	√	×	**HHWB C6.5**	Support physical activity	**2**	√	√	×
×	√	√	**HHWB C6.6**	Support social connection	**2**	√	√	×
√	√	√	**HHWB C6.7**	Provide on-site food production	**3 to 4**	√	√	×
√	×	×	**HHWB C6.8**	Reduce light pollution	**4**	√	√	√
√	×	×	**HHWB C6.10**	Minimize exposure to environmental tobacco smoke	**1 to 2**	√	√	√
×	√	√	**EDUCATION C9.1**	Promote sustainability awareness and education	**3 to 4**	√	√	√
√	√	√	**INNOVATION C10.1**	Innovation or exemplary performance	**3 to 9**	√	√	√

CHAPTER 4

GREEN ROOFS CASE STUDIES

This chapter reviews three green roof cases out of many outstanding ones on their performances in promoting human health and well-being. A brief introduction of each case is presented at first, followed with an analysis of how each case promotes health via applying the guidelines listed earlier. The case studies selected have varied sizes and it is organized and discussed in an order according to their types, respectively, intensive, semi-intensive, and extensive green roofs.

Case 1 Millennium Park

Table 4.1 Millennium Park basic information

Project Name	Millennium Park
Year	2004
Location	Chicago, USA
Type	Intensive
Designer	Cooperation between many leading architects, landscape architects, artists, planners.
Size:	24.5 acres (99,000 m2)
Access:	Accessible daily, 6 a.m. to 11 p.m.

Basic information

The Millennium Park, nearly half of which is a “green roof” with energy efficiency and universal accessibility, is located between Lake Michigan and the historic Chicago Loop business area, with lakefront parks in the west; the Art Institute of Chicago in the south; and high-rise, commercial, and residential buildings on both the west and north sides (City of Chicago 2016).

Figure 4.1 Millennium Park bird’s eye view
(Source: photograph by City of Chicago, 2016)

Although famous now, the Park used to be an industrial wasteland covered with unattractive railroad tracks and parking lots from the 1850s to 1997. The original project was envisioned by Mayor Richard M. Daley in late 1997. It grew more complicated but more comprehensive with the participation of the leading architect Frank Gehry. Additionally, many more architects, artists, planners, and landscape architects have put effort into this project since.

Nowadays, the 24.5-acre Millennium Park is a symbol for exceptional public-private partnership, and it received the 2009 Rudy Bruner Award (RBA) for Urban Excellence (City of Chicago 2016), an award that aims to facilitate ingenious thinking about the built environment and to encourage effective conversations among interested parties in order to build better cities (The Bruner Foundation, Inc. 2014) .

The project was developed through continuous fundraising since it went on longer and became larger than expected. With art pieces added to the site, the structures needed additional stabilization requiring more investment, so part of the tax funds intended for business development were used to support this project instead. Luckily, the framework of the park plan from Skidmore, Owings & Merrill (SOM), an architecture and urban planning firm, was really flexible and all-inclusive, so the art pieces were included easily on site. The art pieces and various events attract tourists with different backgrounds and interests year-round (The Bruner Foundation 2009)

Strengths

The site is fully accessible to all visitors, with key features and services like gradual slope ramps, wheelchair seating, elevators, wheelchair accessible restrooms, assistive listening devices, and audio tour scripts. The Crown Fountain is also designed at grade providing accessibility to all visitors. The Park is open from 6 a.m. to 11 p.m. to guarantee the best site experience and minimize the possibility of crime. Wifi service is available on site. And park maps are distributed at reasonable distances for wayfinding. Drinking and smoking are prohibited in certain areas and conditions with few exceptions (City of Chicago 2016). The features mentioned provide optimum site accessibility, safety, and wayfinding, and minimize exposure to environmental tobacco smoke.

Different transit alternatives are available and provide access to the park. Underground transit options and parking lots were set up, replacing the previous ground-level ones. An accessible modernized train depot was developed underneath the Park, offering transit through Chicago and to southern Illinois. The Park also connects to important roadways and public transportation, such as buses, elevated trains, and subway trains, within walking distance if not directly connected. A bicycle center, the McDonald’s Cycle Center, was built to provide service including lockers and showers besides regular heated, indoor bicycle parking facilities. The Park

Figure 4.2 Millennium Park general plan
(Source: graphic by City of Chicago, 2016)

emphasizes the pedestrian flow connectivity, especially with two bridges linking the Art Institute of Chicago in the south and Grant Park in the east to Millennium Park (The Bruner Foundation 2009). In these ways, Millennium Park fulfills the criteria for connection to multi-modal transit networks.

This project has fulfilled the goal of promoting equitable site use, supporting social connection, promoting sustainability awareness, and education. The site supports private events like wedding ceremonies, corporate and non-profit fundraising events, with 500 free tours, social events and concerts in the park each year, as well as numerous opportunities for educational introductions on site sustainability (City of Chicago 2016), which all more or less promote social interactions, equitable site use, and visitors' sustainability awareness and education.

The project engaged users and stakeholders by inviting public and private investments, so the park grew naturally, even without a set, detailed, and developed plan. Additional innovative ideas were developed representing individuals' own perspectives, multiple additions were integrated into the site, and it ended up attracting diverse groups of visitors (The Bruner Foundation 2009).

Various innovative art pieces and exhibitions are set up around the park, bringing people together and pushing the limits of creative green roof designs. Though some of these works, such as the Cloud Gate and the Crown Fountain (see Figure 4.3), were very challenging to build on site, the donors were unconditionally cooperative in their support of the unique arts, which have become significant landmarks and among the most popular destinations around the world (The Bruner Foundation 2009).

The water features in the park are not specifically focused on stormwater management, but can perform such functions when needed. At the same time, features such as the pond in front of the Millennium Monument and the stepped pools under the boardwalk in Lurie Garden all contribute to the distinctive experience of the park. Crown Fountain especially provides an unusual space for both adults and children. It was designed by famous sculptor Jaume Plensa, and is located in the southwest corner of the park. It is composed of two fifty-foot tall glass towers showing 1,000 rotating photographs of normal Chicagoans' faces on two LED screens facing each other, with a small fountain outlet on each screen pouring water out of the mouth area. In between the towers, a shallow (a quarter of an inch deep) reflecting pool provides space for recreation. It is popular among different people of diverse backgrounds and ages; families are often seen coming with towels and bathing suits to enjoy the fountain on warm days (The Bruner Foundation 2009).

Figure 4.3 Millennium Park Cloud Gate and Crown Fountain
(Source: photograph by City of Chicago, 2016)

Besides the enjoyment of physical contact with water, the park provides adequate space for potential physical activities on site. Recreational activities like ice skating are provided at the McCormick Tribune Plaza and Ice Rink (see Figure 4.4) in winter time, and the plaza operates as a food venue in summer (The Bruner Foundation 2009). However, skating, rollerblading, and skateboarding is not allowed in the park out of safety concerns (City of Chicago 2016).

The 5-acre Lurie Garden (see Figure 4.4), in the southeast part of the Park, was designed by Gustafson Guthrie Nichol Ltd., Piet Oudolf, and Robert Israel. The garden, as both a visually attractive and ecologically habitat-friendly space, contains 138 varieties of perennial plants, which cooperate harmoniously on site. The 14-foot "big shoulder" hedge is a living wall designed to protect the delicate perennials in the middle from heavy pedestrian traffic and wind. The lush dark plate area represents the history of Chicago, with most of its plants cool and dark in color, while the light plate area suggests the future with warm, bright, dry-weather plants (Gustafson Guthrie Nichol Ltd. 2009). Such a garden is an excellent example of the city's motto, "Urbs in Horto" (City in a Garden), which refers to Chicago's transformation from a distant and empty area to a modern and vibrant city (City of Chicago 2016).

Figure 4.4 Millennium Park ice rink and Lurie Garden
(Source: photograph by City of Chicago, 2016)

Most of the elements discussed above such as water, plants, physical activities and social events help restore human minds and support mental restoration. The arrangements of the seating around the park inspire social interactions as well as individual meditation. Activities like people watching, playing in the Crown Fountain, or taking part in events all have the potential to refresh the mind.

Vegetation in the Park provide shades and mitigate the ULI effect by reducing solar radiation and cool the ambient air by evapotranspiration through their leaves. Light-colored pavements reflect the light and decrease the temperature on the ground-level surface. Water features on site make a difference as well by cooling the air. The Park was designed to provide a sustainable and comfortable space for human health and well-being.

Weakness

The Park could have been better planned at an earlier stage by using an integrative design process. The flexible planning made the site tolerant of subsequent additions, but it's hard to coordinate diverse visions and expectations with limited time and money (The Bruner Foundation 2009). Although the Park is currently completed, the entire process took a total of seven years with continuous fundraising, which frustrated many Chicagoans. Moreover, it is weak in protecting and maintaining cultural and historic places, even though the Millennium Monument, with the donors' names, establishes the connection between the past and future by memorializing the generous contributions of local Chicagoans (Bruner Foundation, Inc. 2009).

Successful as the Park may be, it lacks transparency regarding certain key features related to human health and well-being, such as pesticide and fertilizer use and the effects of landscape maintenance on air quality. Furthermore, there is little information concerning the on-site food production, light pollution reduction and the sustainability of the Park's many building materials.

Lesson learned

The Millennium Park has become a perfect example showcasing a multi-functional green roof connecting the history and present of the city and incorporating private and public endeavors. It promotes human health and well-being in the ways listed below:

Table 4.2 Millennium Park health-promoting design guidelines checklist

The Millennium Park		
	Guidelines	Yes(√) / No(×)
1	Connect to multi-modal transit networks	√
2	Use an integrative design process (Required)	×
3	Engage users and stakeholders	√
4	Design functional stormwater features as amenities	√
5	Use appropriate plants (Required)	√
6	Reduce urban heat island effects	√
7	Support transparency and safer chemistry	×
8	Protect and maintain cultural and historic places	√
9	Provide optimum site accessibility, safety, and wayfinding	√
10	Promote equitable site use	√
11	Support mental restoration	√
12	Support physical activity	√
13	Support social connection	√
14	Provide on-site food production	×
15	Reduce light pollution	×
16	Minimize exposure to environmental tobacco smoke	√
17	Promote sustainability awareness and education	√
18	Innovation or exemplary performance	√

Case 2 Rooftop of Covenant House Toronto

Table 4.3 Rooftop of Covenant House Toronto basic information

Project Name	Covenant House Toronto
Year	2008
Location	Toronto, Canada
Type	Semi-intensive
Designer	Roth & Associates
Size	7200 sq.ft.(670 m^2)
Slope	1%
Access	Accessible, By Appointment

Basic information

Covenant House, as the largest youth center in Canada, has helped over 50,000 estranged young individuals improve the quality of their lives (Covenant House 2016) . It opens doors to homeless youth offering 24/7 crisis care and a variety of services, such as education, counseling, healthcare, and employment assistance.

The roof garden, designed by Roth & Associates, on Covenant House Toronto is used as an outdoor classroom to educate, mentor, heal, and inspire youth. The building was opened in 1982, and the green roof was complete in August of 2008. The community came together, raising funds to promote youth development. This case has been selected because of its successful education of youths in sustainability, and tremendous health-promotion effect on young individuals, which leaves an important social impact on society as well.

Figure 4.5 Covenant House Toronto green roof bird's eye view
(Source: graphic by Roth & Associates, 2016)

Strengths

The site is located in downtown Toronto, right across the Ryerson University, and easily accessible by multiple transit options, such as buses, bicycles, taxis, and walking. Originally 80 percent of the annual budget comes from private individuals, corporations, and organizations to help with sustaining of Covenant House. Because the green roof was designed to comply with the Eco-Roof Incentive Program in Toronto, the city offered \$6.97/ ft^2 (\$75/ m^2) up to a maximum of \$100,000. At the same time, the community has been really generous and supporting by donating $250,000. This engagement of the users and stakeholders all contribute to the success of this green roof (Greenroofs.com 2015).

5,000 perennials and sedums were planted on site, with on-site food production including tomatoes, peppers, and herbs in raised planters. An irrigation system was applied to the 6 in (15 cm) deep mixed growing medium produced by Bioroof to enhance plant health, which is also protected by the efficient drainage system from passive water. The extensive green roof area is focused on stormwater retention and designed to manage a 25-year storm event without runoff. The whole system is capable of retaining up to 1.1 gallons per square foot, and even more over a typical 25-year storm event for the city of Toronto, which earns one of the top retention values in the industry. Not only does the site include a green roof that manages the stormwater, but it also features a wetland area and a fish pond with a fountain. This flowing fountain on the site, a feature not often included on regular roofs, provides an innovative multi-sensory experience on site. The vegetation and water features also have an impact on mitigating the ULI effect (Greenroofs.com 2015).

Figure 4.6 Covenant House Toronto green roof water feature
(Source: photograph by greenroof.com, 2015)

Figure 4.7 Covenant House Toronto green roof plants
(Source: photograph by greenroof.com, 2015)

Figure 4.8 Covenant House Toronto green roof raised planters
(Source: photograph by greenroof.com, 2015)

The youth are encouraged to work on the rooftop garden. This work habit not only improves physical health but also promotes mental restoration. The vegetation itself helps refresh the mind, and additional therapeutic benefits come from the physical activity and the development of gardening skills. All of these benefits contribute positively to the establishment of the young people's confidence in their lives. Many features on site work multi-functionally not only to help with mental restoration but also to foster social interactions between individuals. An overhead trellis offers a shelter where individuals can meditate and also creates a perfect space for group gatherings in the shade during hot summers. The raised planters are used as both the vegetable garden and seating areas. All of the features mentioned above contribute to the social interactions between each other (Greenroofs.com 2015).

The roof is both a sustainable site offering science classes like biology and an inspirational space having art and creative writing classes, all of which can earn credits for high school studies. Additional study opportunities are provided for youth to get into sustainable industries, such as horticulture, landscape architecture, and the green roof industry, with the collaboration of Ryerson University. Graduate students and the young individuals work together in earth science field as well, such as environmental studies, ecology, and green roof ecosystems. Besides being an outdoor classroom to study science, the rooftop garden gives a live show of how vegetation transits over time. Not only does it allow the youth and staff to get involved with the green, but it also improves sustainability awareness (Greenroofs.com 2015).

Materials used on site promote the idea of sustainability. All plastic and/or composite components are from 100% recycled materials. All materials were supplied from local areas within 500 km radius. A minimum of 90% were obtained from sustainable sources for the cultivation of the growing media. The soil was formed not to use mined products and the associated energy (agricultural peat moss, expanded shale, pumice, lava rock and other similar sourced materials) (Greenroofs.com 2015).

Weakness

The green roof of Covenant House Toronto offers impressive additional benefits on the estranged youths' health and well-being. However, it lacks detailed descriptions of the integrative design process. Furthermore, there is little information concerning aspects such as protecting and maintain cultural and historical places, the light pollution reduction and minimizing exposure to environmental tobacco smoke.

Lesson learned

Covenant House Toronto green roof benefits the homeless young people greatly by providing an outdoor classroom to educate and heal young individuals, it also provides a successful example of urban farming on rooftop, which makes the wasted roof spaces into food production area. It is an excellent example of a health-promoting green roof with the achievement of health-promoting guidelines as shown below:

Table 4.4 Covenant House Toronto health-promoting design guidelines checklist

Covenant House Toronto		
	Guidelines	Yes(√) / No(×)
1	Connect to multi-modal transit networks	√
2	Use an integrative design process (Required)	×
3	Engage users and stakeholders	√
4	Design functional stormwater features as amenities	√
5	Use appropriate plants (Required)	√
6	Reduce urban heat island effects	√
7	Support transparency and safer chemistry	√
8	Protect and maintain cultural and historic places	×
9	Provide optimum site accessibility, safety, and wayfinding	√
10	Promote equitable site use	√
11	Support mental restoration	√
12	Support physical activity	√
13	Support social connection	√
14	Provide on-site food production	√
15	Reduce light pollution	×
16	Minimize exposure to environmental tobacco smoke	×
17	Promote sustainability awareness and education	√
18	Innovation or exemplary performance	√

Case 3 The American Society of Landscape Architects (ASLA) Headquarters Green Roof

Table 4.5 ASLA headquarters green roof basic information

Project Name	The American Society of Landscape Architects (ASLA) Headquarters Green Roof
Year	2006
Location	Washington D.C., USA
Type	Mostly Extensive, with limited semi-intensive and intensive areas
Designer	Michael Van Valkenburgh Associates, Inc. (MVVA)
Size	3000 sq.ft.(280m^2)
Access	Accessible, By Appointment

Background Information

The green roof, located on the rooftop of the ASLA headquarters in the center of Washington D.C., was designed by Michael Van Valkenburgh Associates, Inc. (MVVA), and was installed in April 2006. It transformed an existing 3,000 square foot barren roof into a socially interactive space surrounded with green roof sustainable features, showcasing the leadership of landscape architects in green roof promoting. It has attracted more than 5,000 visitors from various backgrounds and interests (Greenroofs.com 2015).

Figure 4.9 ASLA headquarters green roof before and after
(Source: photograph by LAF, 2016)

The site is almost fully-greened, with the exception of the wood deck area found when first entering the roof. Two 25-foot-wide elevated “waves”—the sloping surfaces at the north and south ends of the roof—planted with a green roof system, were created to cover the relocated HVAC systems. Taller vegetation was planted on top of the new stairwell structure and elevator shaft. Aluminum gratings were set up covering an extensive green roof system, which maximized both the green roof sustainable performances and human activity space and increased the green area on the roof by 30% (Greenroofs.com 2015).

The green roof contains all three types of the system—intensive, semi-intensive, and extensive—with the growing medium ranging from 3-21 inches. Intensive plantings are implemented on top of the stairwell structure and elevator shaft because they can support heavier weight. The north elevated wave was planted with a semi-intensive system, while the extensive green roof is implemented on the south elevated wave and under most of the walking terrace gratings (Greenroofs.com 2015).

The comprehensive roof is designed specifically to meet future needs in green roof research and education, with monitor systems on stormwater retention, temperature, water quality, and plant performance.

Strengths

The whole design and installation process went smoothly using an integrative design process with the collaborations between the users and stakeholders, including ASLA employees, landscape architects, engineers, horticulturists, and material suppliers. Challenges have been carefully considered at an earlier stage of the design and have been innovatively solved in the end. A monitoring system has assured the control of the sustainable features of the site. Adaptive management methods have been utilized on the site for better green roof performance (Greenroofs.com 2015).

The green roof is located in the center of Washington D.C. and is accessible by various transits like subway trains, buses, cars, and bikes. It is accessible with elevators and stairs by appointments. Necessary safety structures are provided, and the existing low parapet has been elevated by adding railings. The aluminum gratings are using the specific Slip-Not abrasive surface out of safety concerns as well (ASLA 2016).

Figure 4.10 ASLA headquarters green roof site plan and elevation
(Source: graphic by MVVA, 2007)

Even though the ASLA green roof is not fully greened, 100% of the stormwater can be retained on site when the precipitation is less than 1 inch in 24 hours. Roof performance was collected and monitored through flow meters and rain gauges on runoff reduction and concentration of contaminants leaving the roof. Data collected showed that it had retained 67.71% of 20.09 inches of rain from July 2006 to January 2007. Concentrations of nutrients and heavy metals are found to be reduced after going through the green roof system (ASLA 2016).

The ASLA headquarters green roof can be 43 Fahrenheit degrees (about 6.1 Celsius degrees) cooler than the neighboring normal building roofs, according to the data collected on site (ASLA 2016) . Implementing more green roofs on a city-wide and worldwide scale will have a greater impact on helping mitigate the urban heat island effect.

Selecting the right plants is never a one-time choice; continuous efforts on the research of the plant species through monitoring are necessary, with appropriate following adjustments and supplements. Individual plants were tagged, and light and temperature meters were put at different locations to test plant performances under different microclimate and locations. Specific sedums at a certain height were used on site and had been monitored over the first growing season. Some native plant species that are rarely used on green roofs were tried at first. The previous planting strategies were reconsidered and adjusted by using more typical plant species with denser coverage of soil surface in the fall for planting supplement (Werthmann 2007).

The two elevated “waves” provide a pleasant environment for mental restoration. They create a better view on the roof by weakening the influence of the urban foreground and leading the view to faraway Washington D.C. cityscape background. Secondly, the waves mitigate the noises from the normal HVAC systems, providing a comfortable rooftop environment that invites individuals to enjoy themselves. The mind also gets refreshed by the enclosed space provided by the waves with various appropriate plants. Moreover, movable colorful chairs are provided on site for personal meditation or group discussions, which all contribute to the improvement of mental restoration, more or less through watching the green roof vegetation, or communicating with other individuals (ASLA 2016).

Figure 4.11 ASLA headquarters green roof plants
(Source: photographs by ASLA, 2016)

The roof creates a good balance between displaying sustainable features and providing interactive social spaces. It maximizes both the sustainable features and human activity space to encourage social interactions by setting up the aluminum gratings on the green roof system. Social events and physical activities, such as educational tours, cocktail parties, yoga classes, and meetings for ASLA employees, have been held on the rooftop. Although it has limited space for physical activity on account of the size of the roof, it opens one’s mind to develop the abandoned roof area into a potential urban getaway space for resting (ASLA 2016).

The roof is a demonstration project aiming to promote green roof development. It is a living classroom designed with sustainability monitoring and research intent. A more diverse plant palette is expected to be created with the on-site monitoring and data collection. Data on temperature and water are also collected and recorded for future research. Tours are available for groups and individuals by appointments. More than 5,000 people has visited and learned from the site. Documentation and educational resources provided via ASLA’s dedicated green roof website has been viewed over 35,000 times per year (ASLA 2016). A book called "Green Roof: A Case Study: Michael Van Valkenburgh Associates' Design for the Headquarters of the American Society of Landscape Architects", written by Christian Werthmann, is also available for details on the ASLA headquarters green roof.

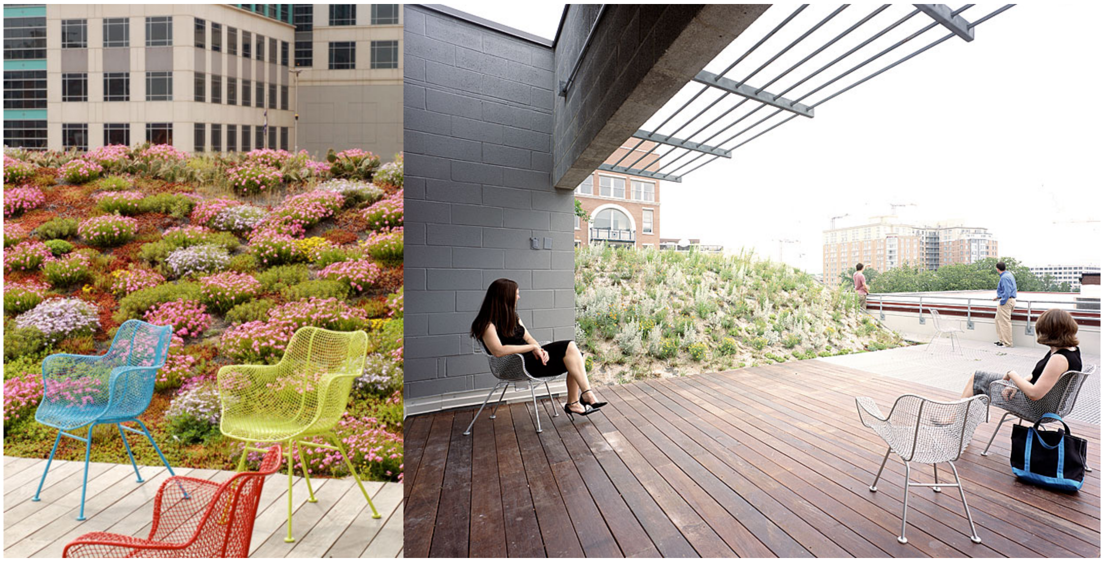


Figure 4.12 ASLA headquarters green roof social spaces
(Source: photographs by ASLA, 2016)

The ipe wood selected to build the decking area was furnished by Forest World, with the certification of the Forest Stewardship Council as sustainably harvested wood, which meet the guideline on supporting transparency and safer chemistry.

One of the most distinctive and inspiring features on site is the implementation of aluminum gratings covering the extensive green roof system, which largely extends the human activity space without cutting back the “green” areas on the roof. Another innovative idea is the elevated waves, which effectively block the views and noises from HVAC systems. Moreover, it provides a more diversified habitat by creating different potentials with different microclimates. It also offers a peek for the individuals on the ground-level attracting their interests (ASLA 2016).

Weaknesses

The green roof is built on a three-story ASLA headquarters building, which was purchased brand new by ASLA in 1997. The greening of the ASLA headquarter cannot fulfill the criteria as protecting and maintaining cultural and historic places because a twenty-year-old building cannot be considered as a cultural and historic place. Still, it helps preserve the existing roof by extending the roof life expectancy from more pinhole leaks and create a space for human activities and enjoying the cityscape (LAF 2016). Moreover, the ASLA green roof has functional stormwater features, and green roofs are typically thought of as fancy stormwater management practices, but none of them works as amenities.

Furthermore, there is little information on meeting other guidelines that can also promote human health and well-being, such as providing on-site food production, reducing light pollution, minimizing exposure to environmental tobacco smoke, minimizing pesticide and fertilizer use, and protecting air quality during landscape maintenance.

Lesson Learned

The ASLA headquarters green roof is not only a perfect demonstration project for sustainable features on green roofs but also an excellent example of a health-promoting green roof with the achievement of certain health-promoting guidelines as shown below. This case is a more useful reference since it is relatively same size as the site to be designed.

Table 4.6 ASLA headquarter health-promoting design guidelines checklist

ASLA Headquarters Green Roof		
	Guidelines	Yes(√) / No(×)
1	Connect to multi-modal transit networks	√
2	Use an integrative design process (Required)	√
3	Engage users and stakeholders	√
4	Design functional stormwater features as amenities	×
5	Use appropriate plants (Required)	√
6	Reduce urban heat island effects	√
7	Support transparency and safer chemistry	√
8	Protect and maintain cultural and historic places	×
9	Provide optimum site accessibility, safety, and wayfinding	√
10	Promote equitable site use	√
11	Support mental restoration	√
12	Support physical activity	√
13	Support social connection	√
14	Provide on-site food production	×
15	Reduce light pollution	×
16	Minimize exposure to environmental tobacco smoke	×
17	Promote sustainability awareness and education	√
18	Innovation or exemplary performance	√

Summary of Case Studies

Table 4.7 Summary health-promoting design guidelines checklist of all three case studies

NO.	Guidelines	Millennium Park	Covenant House Toronto	ASLA Headquarters Green Roof
1	Connect to multi-modal transit networks	√	√	√
2	Use an integrative design process (Required)	×	×	√
3	Engage users and stakeholders	√	√	√
4	Design functional stormwater features as amenities	√	√	×
5	Use appropriate plants (Required)	√	√	√
6	Reduce urban heat island effects	√	√	√
7	Support transparency and safer chemistry	×	√	√
8	Protect and maintain cultural and historic places	√	×	×
9	Provide optimum site accessibility, safety, and wayfinding	√	×	√
10	Promote equitable site use	√	√	√
11	Support mental restoration	√	√	√
12	Support physical activity	√	√	√
13	Support social connection	√	√	√
14	Provide on-site food production	×	√	×
15	Reduce light pollution	×	×	×
16	Minimize exposure to environmental tobacco smoke	√	×	×
17	Promote sustainability awareness and education	√	√	√
18	Innovation or exemplary performance	√	√	√

CHAPTER 5

DESIGN APPLICATION

Site Inventory and Analysis

The site for the green roof is located on the ground-level roof of the Boyd Graduate Studies Building (the "Boyd Building"; 33.943°N, 87.375°W) on the University of Georgia (UGA) campus in Athens, Georgia (see Figure 5.1). Athens is in northeast Georgia, approximately 65 miles northeast of Atlanta (see Figure 5.2). Athens has hot, humid summers with mild to gently cold winters, because it is within the humid subtropical climate zone. Average annual precipitation is 49.7 inches (1260 mm) with a chance of light snow in winters (see Table 5.1). There were 123,000 people, 39,239 households, and 19,344 families residing in the city as of the census (City-data.com 2016) of 2010, with an addition of many visitors each year, the green roof design can potentially influence and benefit many people. Most people who come to the site are students, faculty members and staff. These groups can use and potentially maintain this frequented area. They could create and participate in academic programs to support site maintenance.

The Boyd Building contains the mathematics department and the office of the Vice President of Research. Even though there are 3 other existing green roofs on UGA main campus (see Figure 5.3), the site was selected because of its high visibility, accessibility, favorable location for sustainable education applications, appropriate size, and ability to hold additional weight with the removal of the existing five planters. The west wing of the complex is the Science Library, a specialized satellite library of the main library. The site is enclosed by one six-floor tower on its eastern side (Boyd) and a three-floor tower on its western side (the Science Library), which limits the sunlight exposure at the site. In its current state, the roof site features a hydrology test site, a pipe system, and machinery. On the south side, behind a dinosaur exhibit, there is a paved downward slope that leads to staff parking and maintenance rooms beneath the site. This hollow space made between the roof and Soul Street could allow for easy maintenance and upkeep of the site. Designers and staff could use the staff parking lot to bring in materials and tend to the space.

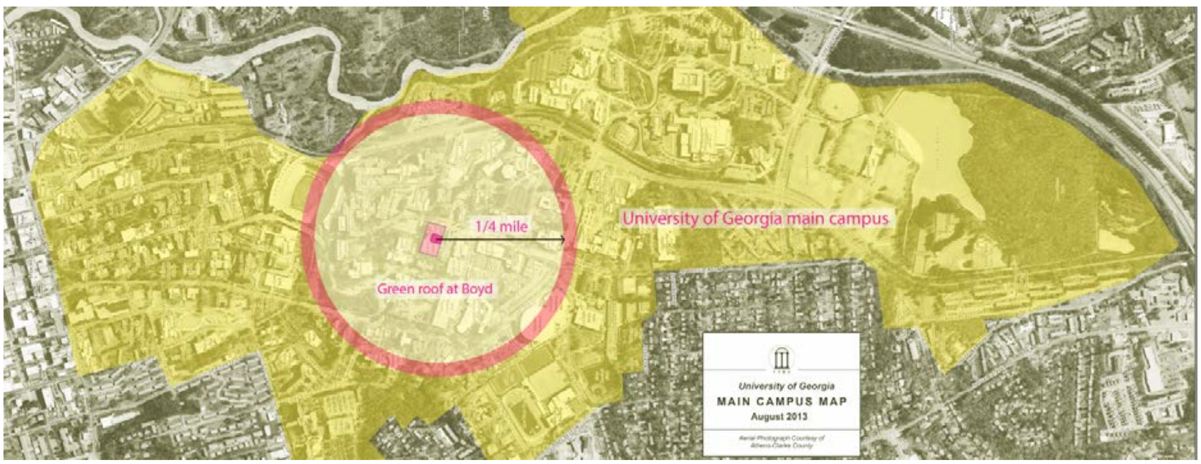


Figure 5.1 Boyd green roof location map

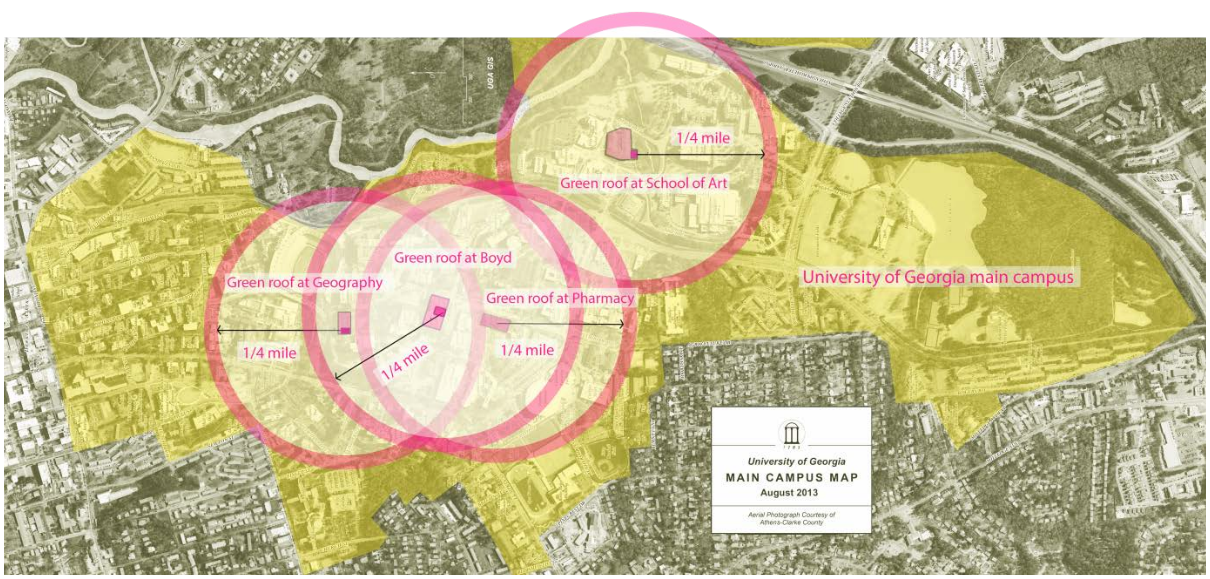


Figure 5.2 Athens existing green roofs map

Table 5.1 Athens climate data (Source: NOAA (extremes 1884–present)

Climate data for Athens, Georgia (Ben Epps Airport), 1981–2010 normals													
Month	**Jan**	**Feb**	**Mar**	**Apr**	**May**	**Jun**	**Jul**	**Aug**	**Sep**	**Oct**	**Nov**	**Dec**	**Year**
Record high °F (°C)	80 -27	81 -27	89 -32	97 -36	100 -38	109 -43	108 -42	107 -42	108 -42	98 -37	86 -30	80 -27	109 -43
Average high °F (°C)	53.9 -12.2	58.2 -14.6	66.2 -19	74 -23.3	81.8 -27.7	88.7 -31.5	91.4 -33	89.9 -32.2	84 -28.9	74.4 -23.6	65.2 -18.4	55.7 -13.2	73.6 -23.1
Average low °F (°C)	33.1 -0.6	36.3 -2.4	42.5 -5.8	49.3 -9.6	58.2 -14.6	66.4 -19.1	69.8 -21	69.3 -20.7	62.7 -17.1	51.5 -10.8	42.4 -5.8	35 -1.7	51.4 -10.8
Record low °F (°C)	−4 (−20)	3 (−16)	11 (−12)	26 (−3)	37 -3	45 -7	55 -13	53 -12	36 -2	24 (−4)	7 (−14)	2 (−17)	−4 (−20)
Average precipitation inches (mm)	4.05 -102.9	4.48 -113.8	4.42 -112.3	3.14 -79.8	3 -76.2	4.18 -106.2	4.47 -113.5	3.52 -89.4	3.94 -100.1	3.55 -90.2	3.82 -97	3.73 -94.7	46.29 -1,175.80
Average snowfall inches (cm)	1.6 -4.1	0.8 -2	0.9 -2.3	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0 0	0.3 -0.8	3.5 -8.9
Average precipitation days (≥ 0.01 in)	10.4	9.5	9.3	8.2	8.7	10.8	10.5	9.1	7.7	6.8	8.6	9.9	109.6
Average snowy days (≥ 0.1 in)	0.8	0.5	0.2	0	0	0	0	0	0	0	0	0.3	1.8

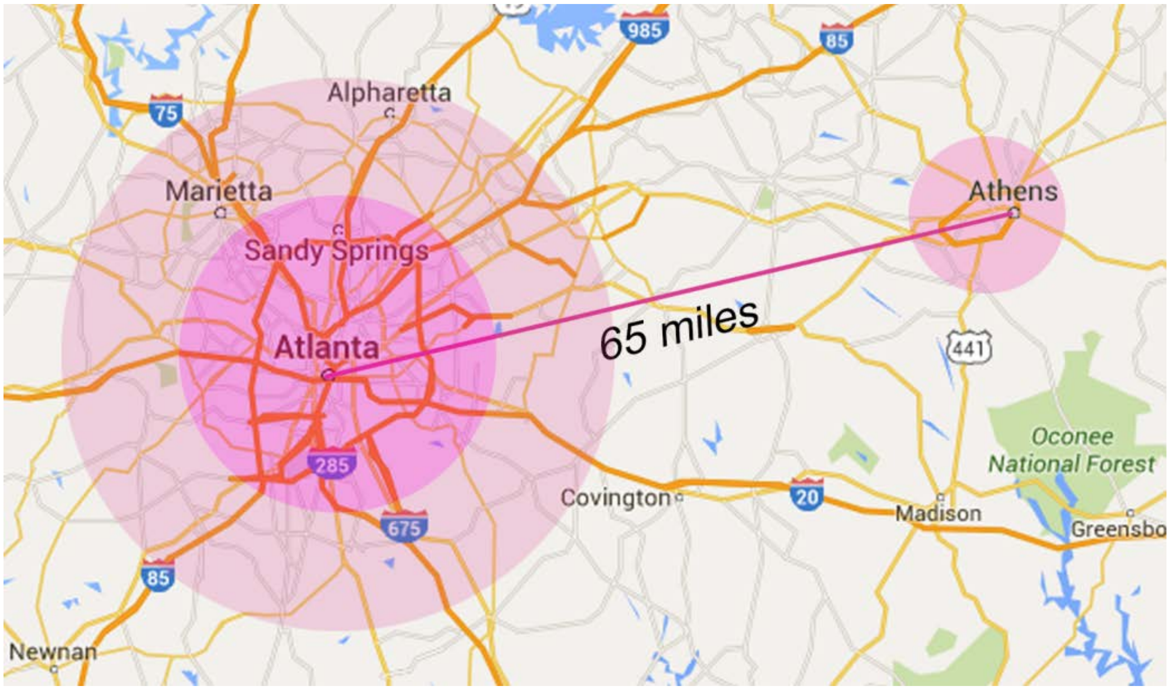


Figure 5.3 Athens location map

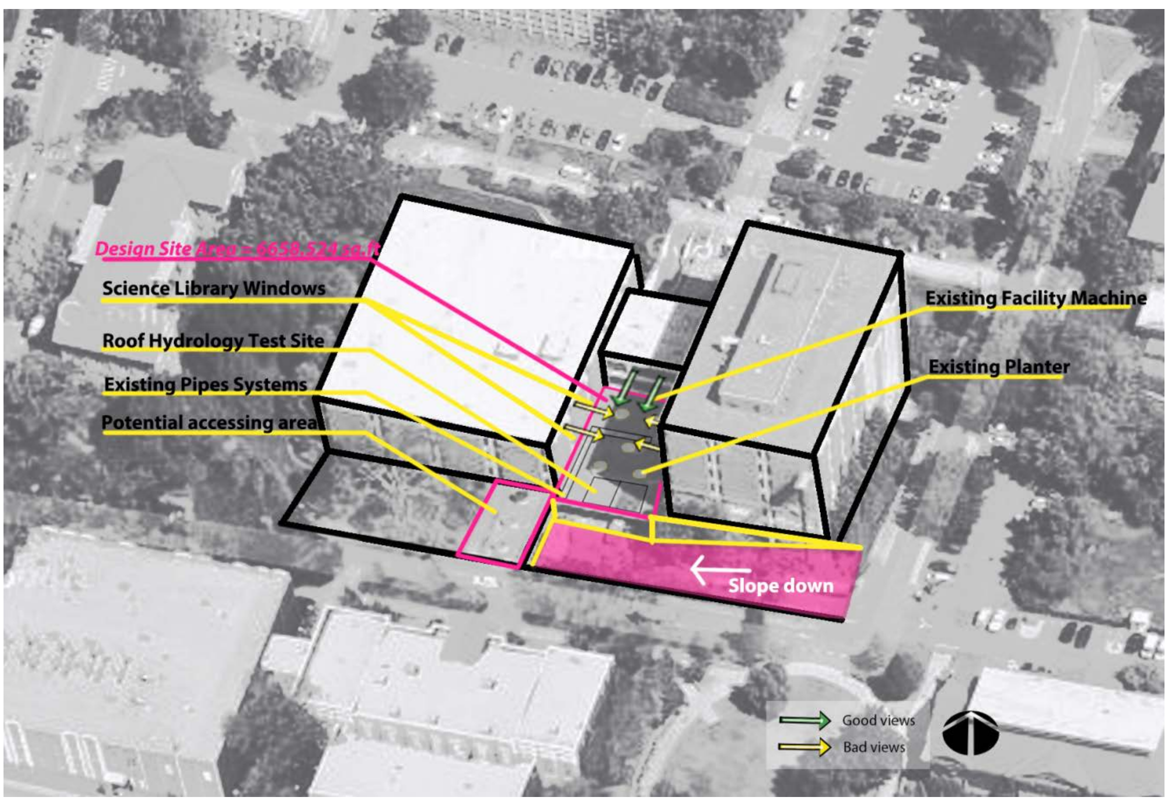


Figure 5.4 Boyd building green roof existing site analysis

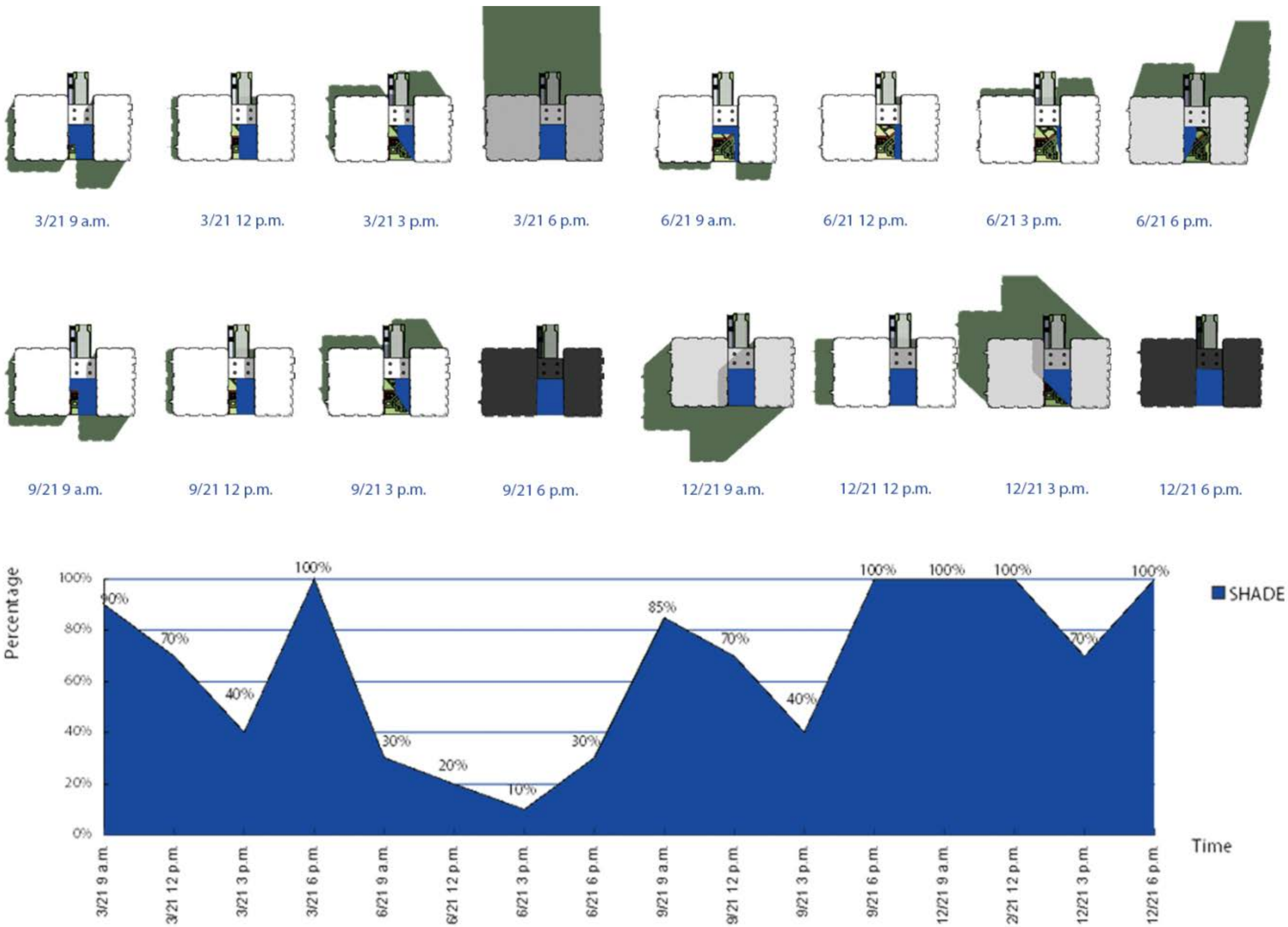


Figure 5.5 Boyd building green roof shade analysis

Figure 5.6 Boyd building green roof existing elevation

The views for one standing in the site vary; to the north is Boyd's lobby and to the south is Soul Street. This road is one-way and pedestrian-friendly, which allows site users to observe pedestrians and vice versa. Standing in the site and looking east or west means looking at the sides of Boyd and the science library, respectively. Faculty and staff in these buildings currently look across the site into parallel offices (not a particularly appealing view). A green roof would improve the view considerably. All of these features create possibilities for applying the design strategies to the site, adding special character to the roof.

Previous Research and Results

Two test plots (one with vegetation and one with black gravel) for comparing the effectiveness of green roof stormwater management were constructed at the Boyd Building for collecting ecology data from November 2003 to November 2004. During this period, 31 precipitation events were monitored, ranging in depth from 0.28 to 8.43 cm. It was reported that the green roofs retained less stormwater with the increasing depth of precipitation, fluctuating from 90 percent for small storms of fewer than 2.54 cm to little less than 50 percent for larger storms, which were over 7.62 cm. They found that the runoff had been delayed, and the average runoff lag time was over two times greater in the green plot than in the black gravel plot (34.9

and 17 min., respectively). The curve number, CN=86, was concluded by the precipitation and runoff data collected.

Proposed Design

The design application is a conceptual design based on considerations of existing site conditions of the Boyd Building, and aims to promote site users' health and well-being with the use of design strategies from the 18 health-promoting guidelines (see Appendix A). In order to achieve the goals, a physically, mentally, and socially health-beneficial green roof space is proposed for the Boyd Building, with practical/functional design features.

Most of the 18 guidelines are applied in the site design. The integrative design process involved consulting a science librarian, Chandler Christoffel, and the former director of the grounds department, Dexter Adams. Dr. Todd Rasmussen, a professor of Hydrology & Water Resources, who participated in the effort to set up the test plots and conduct stormwater research at my selected design site, was also consulted. Several anonymous visitors were randomly asked to offer their suggestions for the Boyd Building roof. More professionals in diverse field will be consulted, such as industries in green roof, structural engineering, irrigation, horticulture, and lighting, to refine the design details. Most areas in Athens are connected with multiple bus transit options to bus stops within a five-minute walk to the site.

In my proposed design, the five existing planters and test plots (see Figure 5.4) are removed to reduce the weight on the roof, allowing for further development. The pipe system is maintained but protected with a rectangular covering made from recycled plastic; the machinery near the lobby is relocated and placed near the air conditioner. Green walls will surround this machinery and screen it from view, in order to enhance the aesthetic appeal of the roof without reducing the functionality of the building.

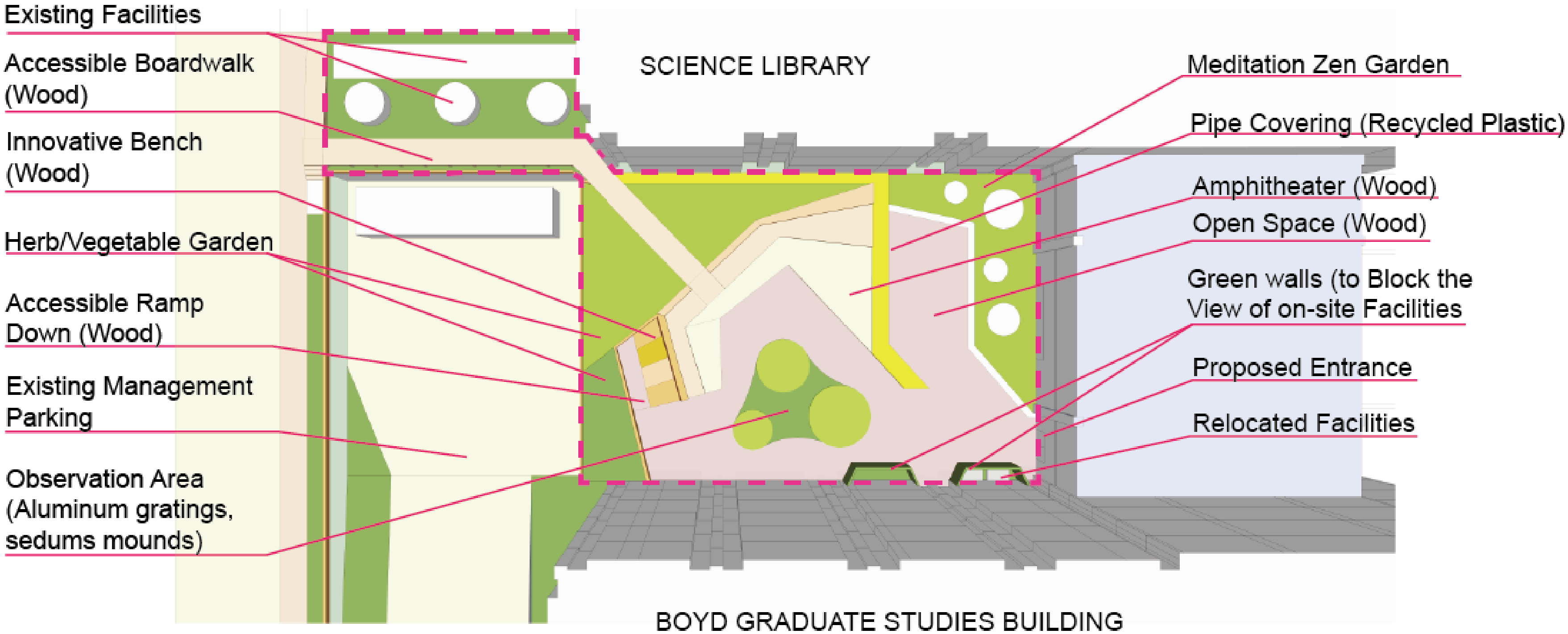
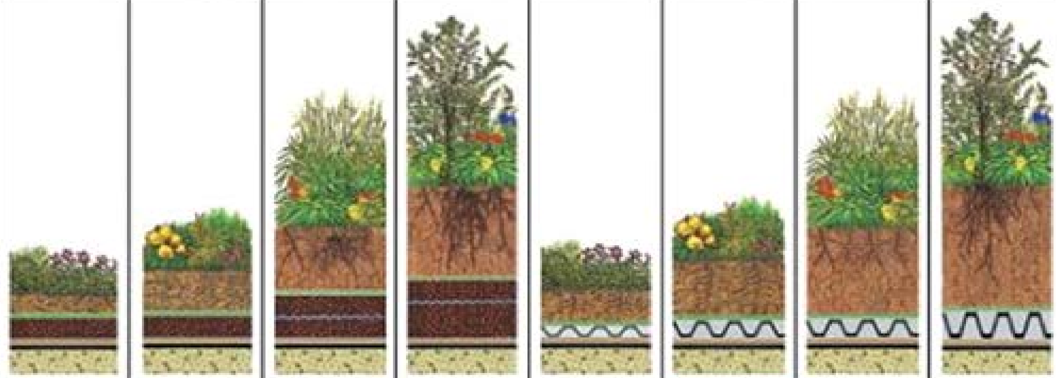


Figure 5.7 Boyd green roof proposed plan

Table 5.2 Green roof system selected for the design application highlighted in pink. (Source: www.greenroofservice.com, highlighted by author)



GREEN ROOF SYSTEMS according FLL	SYSTEMS WITH GRANULAR DRAINAGE				SYSTEMS WITH DRAINAGE PLATES			
system designation	G1	G2	G3	G4	P1	P2	P3	P4
typical plants	sedum herbs	sedum herbs perennials	perennials grasses shrubs	grasses shrubs trees	sedum herbs	sedum herbs perennials	perrenials grasses shrubs	grasses shrubs trees
extensive soil mix	2"	4"	-	-	3"	5"	-	-
intensive soil mix	-	-	6"	9"	-	-	8"	12"
separation fabric	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"	1/8"
granular drainage	2"	2"	4"	6"	-	-	-	-
drainage plate	-	-	-	-	1"	1-1/2"	1-1/2"	2-1/2"
drainage mat	-	-	-	-	-	-	-	-
protection mat	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"	1/4"
nominal thickness	4"	6"	10"	15"	4"	7"	10"	15"
dry weight	19 lbs/ft²	28 lbs/ft²	45 lbs/ft²	69 lbs/ft²	14 lbs/ft²	23 lbs/ft²	34 lbs/ft²	52 lbs/ft²
saturated weight	26 lbs/ft²	41 lbs/ft²	70 lbs/ft²	105 lbs/ft²	23 lbs/ft²	37 lbs/ft²	57 lbs/ft²	85 lbs/ft²
minimum slope	0:12	0:12	0:12	0:12	1/4:12	1/4:12	1/4:12	1/4:12
maximum slope	1:12	1:12	1:12	1:12	1:12	1:12	1:12	1:12
water retention/Year*	50%	60%	70%	80%	50%	60%	70%	80%
irrigation system	-	-	subsurface	subsurface	-	-	surface	surface

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* conservative numbers

A wooden, two-tiered, angular amphitheater is proposed for the site, focused inward toward a central location on the roof. This area could function as an outdoor classroom for classes and programs that promote sustainability awareness. It is also designed to be a social gathering place and a relaxing space for individuals to sit, lie down, or meditate when there is no class being held on the site. The southern side of the amphitheater features a standing-height counter/table for users to enjoy snacks or lunch while looking out from the amphitheater area, doubling as the back of a set of innovatively designed benches.

This short wooden divider (i.e., the counter/table) serves as the border between an ergonomically designed seating area and the amphitheater area. These innovative benches, located on the south side of the roof, offer a relatively independent semi-enclosed space (wheelchair-accessible via a wooden ramp) for relaxing and possibly even napping. These wooden benches are ergonomically designed with comfortable curves and promote users' physical and mental restoration, matching the contours of a human body in a reclining position (similar to tanning benches at swimming pools).

Three mounds of succulents in different sizes will be showcased near the focal center of the amphitheater as an observation area. To provide a space for individuals to observe the plants closely, aluminum grating (similar to that used on the ASLA headquarters green roof) will serve as a walkway in the middle of the three mounds, with roof plants visible underneath the grating. Also, the foot traffic across the top of the grating will serve to keep the plants underneath trimmed to the appropriate height. This multifunctional use of space shows the potential for green roofs to be accessible and fully greened at the same time.

Signs will be posted next to featured design elements on the green roof to explain their function(s) and recount the prior history of the roof, along with any projects or studies that were conducted at the site. For example, in past years, the site has been occupied by two large test plots, which will be removed to make space for the proposed design. Explanatory signs posted around the green roof in this way will preserve some continuity with past projects carried out on the site.

Herb and vegetable gardens are included in the design to address multiple guidelines and offer multiple benefits. Food harvested from on-site food production in the gardens can be made available to students or other site users who are responsible for the plants or conducting research.

The gardens also promote physical health by providing individuals with an opportunity to take care of the plants and herbs growing there. Appropriate plants will be selected to meet the climate and site conditions, but changes may be made according to the results obtained from continuous monitoring and research. Plant identification and observation will offer a relaxing place where students and faculty can feel refreshed and reinvigorated at the same time, it will inform people about the plants through placards installed next to each species. The proposed herb and vegetable gardens on the green roof will also be a great way to promote the idea of roof farming. These roof gardens will incorporate such guidelines as providing on-site food production, promoting physical activities, promoting mental restoration, and promoting sustainability education and awareness.

15 herbs and/or vegetables are conceptually proposed on the roof (see Table 5.3, 5.4), along with 10 other roof plants in observation area and meditation Zen Garden area. The herb and vegetables were selected according to their multiple uses referring to ATL Urban Farms. The Sedums and perennials were selected from Southeast Green Roofs, most of which are native, adapted to local conditions and/or pollinator-friendly. An irrigation system is provided in the herb and/ or vegetable garden because of the key function of steady water in growing and maintaining the vegetation. Suggested summer and fall vegetable lists are suggested separately for different seasons.

Safety barriers, accessibility ramps and stairs will be installed at the site. Individuals can access the site either from the 1% sloped ramp from the Boyd building at the north side of the site, or from Soule Street via the stairs or ramp. A wooden boardwalk is proposed to connect Soule Street to the site along the roof of a separate wing of the Boyd building. Safety barriers line either side of the stairs and ramp, as well as the outer boundary of the green roof (next to the herb and vegetable garden), to prevent injury.

Table 5.3 Vegetable plants list (Source: ATL urban farms and http://localfoods.about.com/od/searchbyregion/a/georgiaseasons.htm, selected and reorganized by author.)

Vegetable/ Fruit Plants			GOOD USE IN							BEST USE			HARVEST TIME											
	Common Name	Description	Salad	Sandwich	Stir Fry	Steamed	Grilled	Roast	Soup	Alone	Raw	with other ingredients	January	Feburary	March	April	May	June	July	August	September	October	November	December
												WINTER												
1	ARUGULA	Young leaves less peppery. Mature leaves strong peppery flavor.	×	×					×	×	×	×												
2	BROCCOLI RAAB	Leaves have bitter, pungent taste, adds a lot of flavor to soups and stews. Plant forms tiny broccoli florets as well.	×		×	×	×	×	×	×		×												
3	BRUSSELS SPROUTS	Plant forms tiny cabbages 1– 1½" dia., Use heads only – leaves and stems not good. Great steamed alone or stir fried with bacon and peppers, Yum!	×		×	×	×	×	×	×		×												
4	CABBAGE,Chinese	Ruffled, lighter leaf, mild flavor.	×	×	×	×	×		×	×		×												
5	COLLARD GREENS	Assertive acerbic taste.	×		×	×			×	×		×												
6	KALE	Leafy green. Young crisp leaves can be used raw in salads. Mature leaves typically cooked. Great in smoothies.	×	×	×	×	×	×	×	×		×												
7	LETTUCES	All lettuce varieties great in salads, sandwiches, wraps, dips and as garnish. Too tender to cook. Use raw. Young and tender leaves are best tasting.	×							×	×	×												
8	PAC CHOI	Flavor between mild cabbage and spinach. Cook stems first, add leaves last. Best when lightly cooked. Very young leaves chopped in salads.	×		×	×	×		×	×		×												
9	SPINACH	Tangy flavor perfect raw in salads & sandwiches or cooked. Recommend boiling or steaming to bring out sweeter tastes.	×	×	×	×			×	×		×												
10	SWISS CHARD	Young leaves in salad. Mature leaves typically cooked. Slightly bitter taste - fades when cooked.	×		×	×	×		×	×		×												
												SUMMER												
1	CUCUMBER,Traditional	Slightly bitter skin, great taste.	×	×					×	×	×	×												
2	EGGPLANT, Italian	Use mostly cooked, mild flavor, good breaded and fried.		×	×		×		×	×		×												
3	PEPPER, bell	Great raw and cooked. Spicier when green, milder when red.	×	×	×	×	×	×	×	×		×												
4	PEPPER, jalapeño, early	Seeds and membranes hold hottest heat flavor. Discard and use pepper for mild spice addition. Adds great flavor and mild heat to dishes. Use raw or cooked. Can be pickled.	×	×	×		×	×	×	×		×												
5	PEPPER, Lunchbox	Sweet and flavorful. Great as snacks or delicious in salad or sautéed.	×	×	×		×	×	×	×		×												
6	SQUASH, summer	All parts edible, great raw or roasted. Can be used in breads.	×	×	×	×	×	×	×	×		×												
7	TOMATO, 'Boxcar Willie' hrlm	Red slicer tomato with distinctly delicious well-balanced rich sweet flavor. Perfect for juice, sauce or canning.	×	×			×	×	×	×		×												
8	TOMATO, Roma	Low acid and sugary mild flavor with subtle sweetness amplified when cooking. Great for use in sauces.	×	×	×	×	×	×	×	×		×												
9	WATERMELON, 'Sugar Baby'	Very sweet red firm with few seeds. 7-8" dia.	×				×			×	×	×												
10	ZUCCHINI	All parts edible, great raw or roasted. Can be used in breads.	×	×	×	×	×	×	×	×		×												

Table 5.4 Herb plants list (Source: http://atlurbanfarms.com/wp-content/uploads/2016/02/Veggie-Use-Guide-Rev-10-15.pdf, reorganized by author)

Herb Plants			GOOD USE IN							BEST USE		
	Common Name	Description	Salad	Sandwich	Stir Fry	Steamed	Grilled	Roast	Soup	Alone	Raw	with other ingredient
1	BASIL, Italian, pesto	Clove accent flavor, good with tomatoes or sauces.	×	×	×				×	×		×
2	CHIVES	Flavor enhancer, chop fine and freeze	×		×				×	×		×
3	FENNEL	Sweet anise taste, adds flavor to all, chop thin for salad, great roasted.	×		×	×	×	×	×	×		×
4	LEMON BALM	Herb. Scent of lemon with hint of mint., great in salad, tea, and with fish.	×			×	×	×				×
5	OREGANO	Herb. Aromatic spicy flavor mostly used in Italian cooking. Great with veggies, in sauces, soups, and on pizza.	×						×			×
6	PARSLEY	Herb. Flavoring agent. Brightens all dishes. Add near end of recipe for best flavor. Good in salads, dips, veggies and meats.	×		×				×			×
7	ROSEMARY	Herb. Pungent flavor. Use with meat or potatoes, fish, chicken. Only use leaves.			×		×	×	×			×

Figure 5.8 Sedum plants
(Source: http://www.southeastgreenroofs.com/plants.html, reorganized by author)

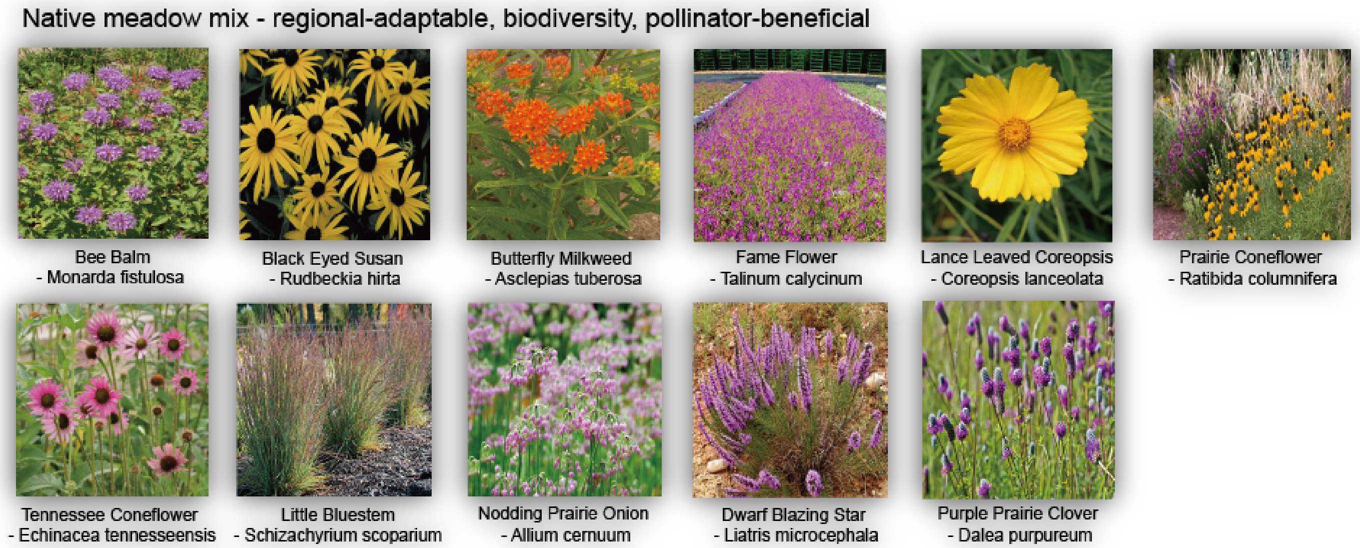

Figure 5.9 Native meadow plants list
(Source: http://www.southeastgreenroofs.com/plants.html, reorganized by author)

The meditation area will contain a combination of pleasant-looking plants and Zen garden sand and rocks. Concentric circles in the gravel will inspire mental restoration. The plants surrounding these designs are planted to recall a natural mountainous landscape. The meditation area will inspire mental restoration for individuals both inside the building and on the roof. It functions as an innovative feature on this roof as well.

The space next to the meditation Zen garden is for light physical activities like yoga classes. It can also serve as an alternative space for outdoor social events when reorganized with temporary installations.

Except for the areas containing plants, the roof will be mostly covered with ipe wood, including the elevated and non-elevated pavement areas as well as the boardwalk and access ramp. The only exception will be the observation area, which will be covered with aluminum grating.

The site meets the remaining four guidelines previously outlined. Minimal lighting is proposed at ground level throughout the site, which will prevent user injury while avoiding excessive light pollution. As UGA is a non-smoking campus, the roof will be tobacco-free as well, ensuring minimal exposure to environmental tobacco smoke. Transparency and chemical safety are assured through tracing the material back from the very first step and the using of recycled materials.

Figure 5.10 Boyd green roof conceptual planting design

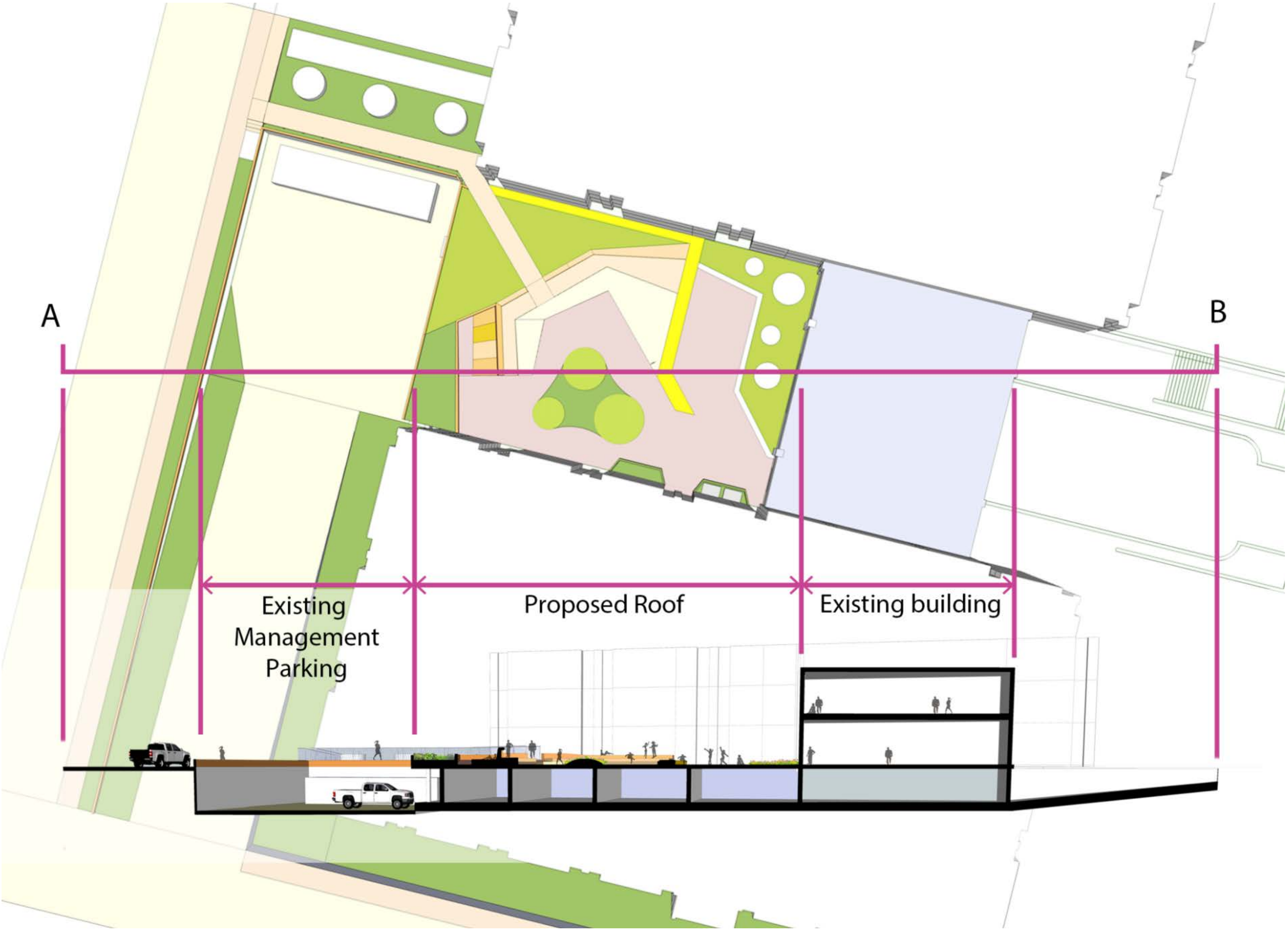

Figure 5.11 Boyd green roof section A-B

Figure 5.12 Boyd green roof bird’s eye view

Design Evaluation

All of the design features are proposed according to design guidelines to promote physical, mental and social well-being.

Some features on site help with physical well-being (see Figure 5.13). Areas with features such as meditation Zen garden, herb and vegetable garden, observation area, and green walls promote physical well-being mainly from plant maintenance work. The open space area provides opportunities for health-beneficial classes and activities such as yoga. Moreover, aspects including materials selection, on-site lighting selection and tobacco-free environment play an important part in building a physically health-beneficial site.

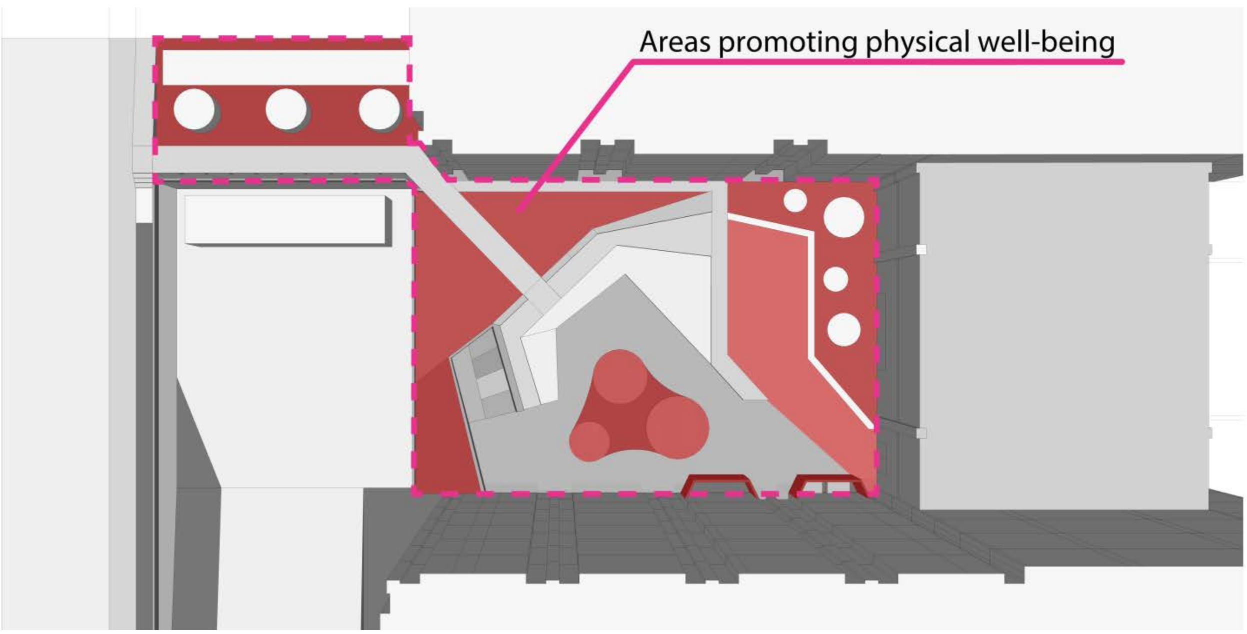

Figure 5.13 Boyd green roof design features emphasized on physical well-being

Many features on site promote mental well-being (see Figure 5.14) as well. Some areas encourage mental restoration by providing plants to observe, including features such as meditation Zen garden, herb and vegetable garden, green walls, and observation area. Some other areas provide spaces for possible mind resting, such as amphitheater /outdoor classroom, innovative benches, and open space. Furthermore, education opportunities, such as the use of materials, and signs introducing featured design elements, are offered on site about the sustainability of green roofs which facilitate full development of individuals' minds.

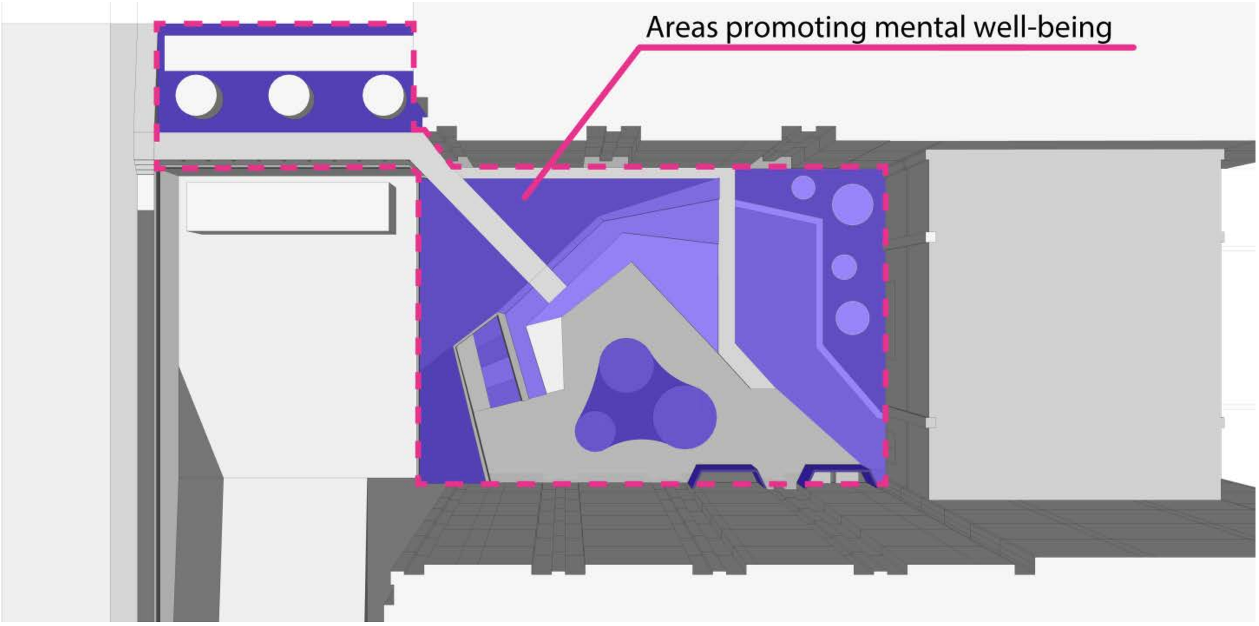

Figure 5.14 Boyd green roof design features emphasized on mental well-being

While social well-being is addressed through design features (see Figure 5.15) such as meditation Zen garden, herb and vegetable garden, observation area, green walls, and signs introducing featured design elements, which can invoke socially communications through green roof related educations. Other areas with features such as amphitheater /outdoor classroom, open space, innovative benches, boardwalk and accessible ramps provide spaces and opportunities for social interactions.

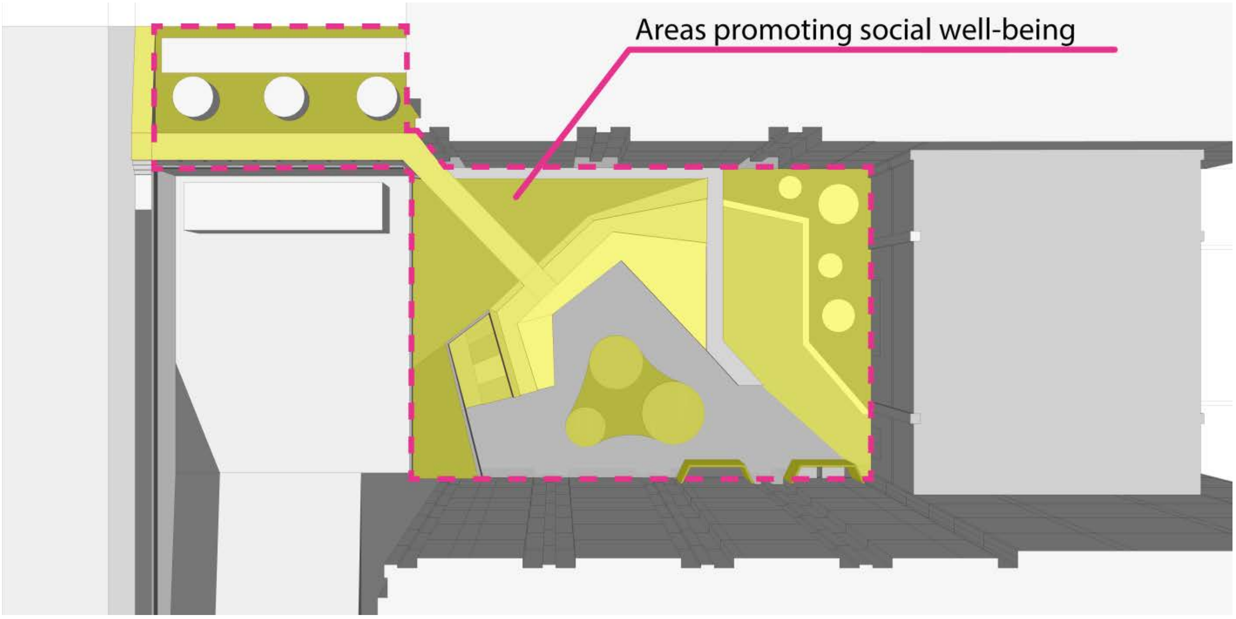

Figure 5.15 Boyd green roof design features emphasized on social well-being

However, the proposed design applies most, but not all, of the 18 health-promoting guidelines to the site. Though green roofs generally function well as stormwater management systems, the Boyd Building green roof suffers from a lack of opportunity to create pleasant and innovative stormwater amenities on site, as the site contains no downspouts or similar drainage pipes.

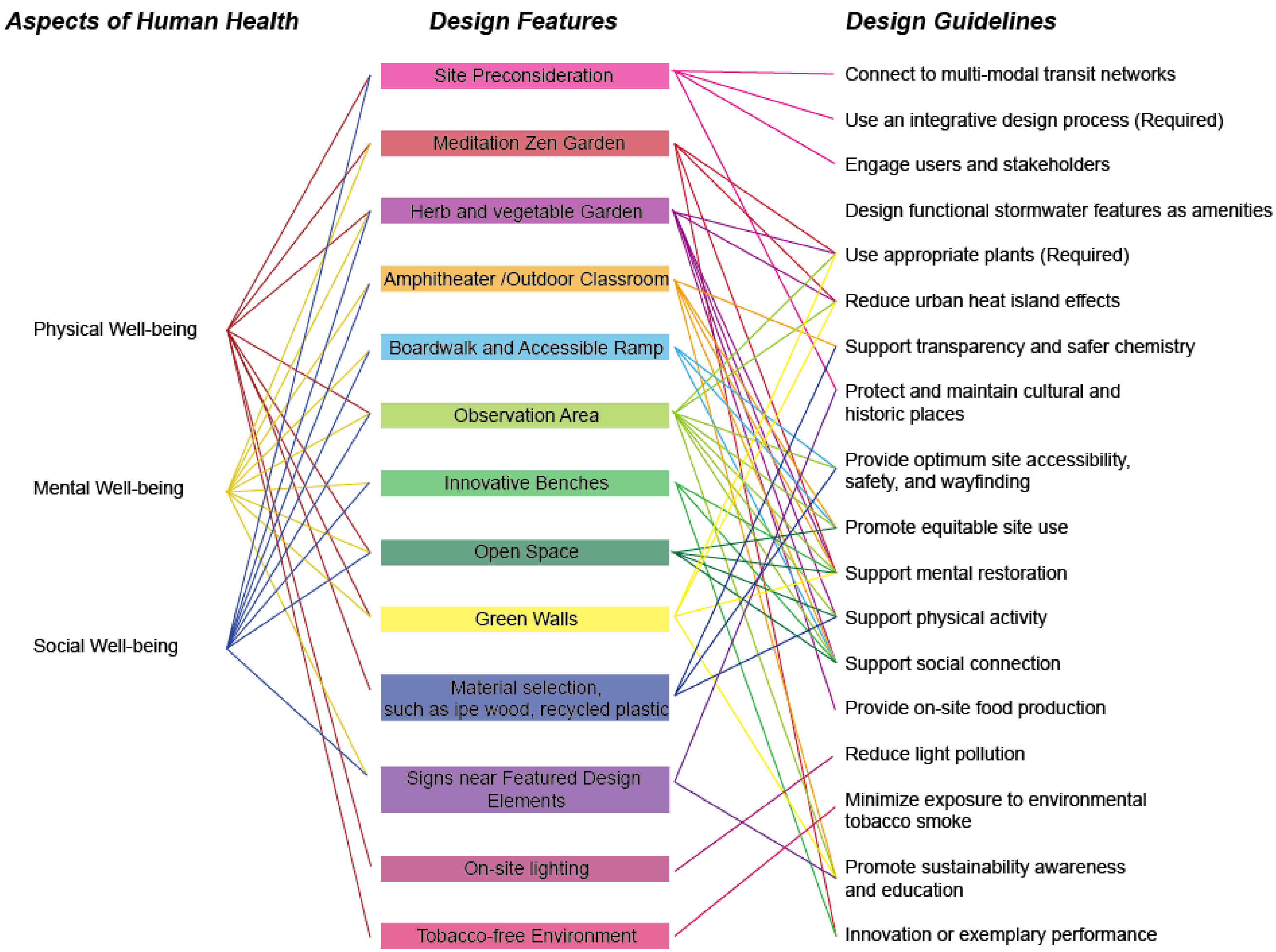

Figure 5.16 Evaluation of Boyd green roof design on promoting health and well-being

CHAPTER 6

CONCLUSION

Conclusion

Although existing research has put great effort into promoting performance and education on the sustainability of green roofs, there has been little mention of methods and applications for improving the health-promoting functions of green roofs. My thesis aimed to explore possible guidelines for designing green roofs with an emphasis on promoting human health and well-being. Promoting human health and well-being is a comprehensive topic, which involves different degrees and aspects of health improvement. The most crucial purpose of this thesis is looking at green roof design with a focus on health and well-being, rather than (but not to the exclusion of) sustainability, which is different from most of the existing studies. Different sustainable landscape design rating systems were researched, and SITES was selected as the base resource for selecting applicable guidelines. The selection of the design guidelines was based on their applicability for green roof users and the definitions of physical, mental and social well-being. In order to maximize promoting human health and well-being, the author looked beyond the health and well-being section in SITES, integrating guidelines from other sections to expand the number of health-promoting design strategies. The author's research has led to a set of design strategies and program elements for designers as a reference for designing health-promoting green roofs. Designers have to select appropriate guidelines and strategies for specific sites, because the purpose of the guidelines is to provide a toolbox of all the possible solutions. Cases are discussed and analyzed from a health-promoting perspective, analyzing how they either meet or fail to meet certain guidelines discussed in this thesis, as well as how this influenced of their performance. The design strategies highlighted in Chapter 3 (see also Appendix A) are applied in the conceptual green roof design for the Boyd Graduate Studies Building in Athens, Georgia, testing the effectiveness of the guidelines. This thesis will help designers to think in a comprehensive way to serve human health and well-being, enhancing the health-promoting guidelines and strategies, without sacrificing the sustainable features of green roofs.

For future green roof designers, there are several program elements concluded from each of the design strategies (see Appendix A). Designers should consider elements such as site planning, human factors, experiential factors, environmental factors, cultural factors, security considerations, project administration, site amenities, education, stormwater management, plants and materials while designing green roofs (see Appendix B).

A health-promoting green roof design could involve an integrative design process, incorporating a team of professionals, site users and stakeholders from the very beginning. This would mean designing with community-wide considerations in mind, such as connecting to multi-modal transit networks, protecting and maintaining cultural and historical places, site accessibility, safety and wayfinding, equitable site use, supporting physical, mental and social activities, reducing light pollution, minimizing exposure to environmental tobacco smoke, promoting sustainability awareness and education, and innovation. Moreover, design teams will discuss appropriate features, such as stormwater amenities, appropriate plants, transparency and safe materials, and on-site food production.

The present study has not done a full analysis of the degree to which particular factors help with promoting health. While this thesis provides a metric for evaluating the number of different strategies utilizing on a particular green roof, currently there is limited ability to effectively measure the actual health benefits of each individual guideline. Future study in the area of green roofing might further analyze these factors and suggest additional factors and considerations. Another limitation may be found in the lack of specific suggestions for improving sites discussed in the case studies, which would require an in-depth investigation of costs and specific community characteristics, including which design features should be prioritized based on the value of the features in terms of their health benefits, as well as cost and community health considerations. Thus, there is a wide range of possibilities in pursuing in-depth case studies dedicated to improving particular sites according to established guidelines, taking into account site-specific information on structural and cost constraints, etc.

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APPENDIX A

SUMMARY OF HEALTH-PROMOTING GREEN ROOF DESIGN GUIDELINES, STRATEGIES, AND PROGRAM ELEMENTS

Health-promoting Guidelines	Health-centered Design Strategies	Program Elements
Connect to Multi-modal Transit Networks	Prioritize establishing green roofs at areas with existing multi-modal transit networks including roadways, sidewalks, bicycle lanes, and mass public transportation systems.	Accessibility
	Inspect and take into consideration any new plans on transportation and transit systems within two years of project completion. Keep up to date with the progress made on transportation service development by establishing and maintaining relationships with related departments and agencies.	Site planning
	Use surveys to identify the transportation needs of future users of the site.	Site planning
	Facilitate ease of access to the roof from transport options.	Accessibility
Use an Integrative Design Process	Identify project sustainability and performance goals.	Project administration
	Coordinate cooperative communications between professionals regularly from various backgrounds, including at least one green roof and one public health professional.	Human factors
	Make short and long term maintenance plans according to the site conditions and the existing and potential resources (e.g., budget, staff, volunteers, equipment, materials, educational programs, and classes).	Project administration
	Organize activities like a charrette to engage stakeholders and site user groups in formulating more site specific designs meeting the requirements of site users.	Human factors

Engage Users and Stakeholders	Approach and recruit potential site users and stakeholders to participate in different ways, such as through websites, surveys, and charrettes, workshops, community meetings, etc.	Human factors
Design Functional Stormwater Features as Amenities	Design and sustain stormwater features to mimic natural ecosystem features by using native plant communities and other aquatic organisms.	Stormwater management
	Plan for additional treatment, such as ozonation or thermal control, for water features with which human contact is expected.	Stormwater management
	Collaborate between artists, craftsmen and designers to create stormwater features with sound functionality and entrancing aesthetics.	Experiential factors, Human factors
	Design stormwater features with maximized functional and health-promoting(expand this-what does this mean?) attributes by utilizing low impact development strategies and providing physical or visual accessibility.	Accessibility
	Design sustainable stormwater harvesting and infiltration systems for on-site food production.	Stormwater management
Use Appropriate Plants	Select plants that are adaptable to site conditions. Invasive species that threaten the balance of the local ecosystem should be avoided.	Planting
	Consult local governmental agencies, educational facilities, and native plant societies for plant selection. Refer to local authoritative plant recommendation list. Inspect frequently to exclude state and federal noxious weeds and invasive plants.	Human factors
	Select low-maintenance vegetation species.	Planting
	Prevent potential insect and disease pests by using diverse plants; as a general guide for larger sites, any specific plant species should not exceed 10 percent of the total, and any particular plant genus should not exceed 20 percent of the total. Similarly, any specific plant family should not exceed 30 percent of the total. For smaller sites, plant diversity can be achieved by selecting appropriate species from a local or regional area.	Planting

	Selecting plants that provide food, nesting sources for appropriate native wildlife.	Planting
Reduce Urban Heat Island Effect	Maximize the percentage of vegetated areas on roofs.	Environmental factors
	Use shade from proper trees, dense shrubs, vegetated trellises, walls or other shading structures reasonably.	Environmental factors
	Provide light color covers and surfaces for pedestrian areas as an alternative to traditional dark ones to reduce building temperature.	Environmental factors
	Consider the use of photovoltaic cells to shade impervious surfaces.	Environmental factors
	Consider employing shady plants or the structures mentioned in the previous strategies if a roof functions as a parking lot.	Environmental factors
Support Transparency and Safer Chemistry	Avoid using materials with finishes (e.g., dye, paint, gloss) or other chemical additives if possible.	Material
	Make use of certification systems using guidelines that promote transparency and safer chemistry in products.	Material
	Prioritize low-risk products that meet the highest affordable safety guidelines.	Material
	Communicate clear expectations to suppliers regarding transparency and safer chemistry needs for current and future projects.	Human factors
Protect and Maintain Cultural and Historic Places	Maintain site selection and design practices that reflect sensitivity to any concerns relating to the cultural, historic, and religious significance of potential sites.	Cultural factors
	Obtain inspiration from local history and culture for green roof designs on non-historical structures.	Cultural factors
	Prioritize preserving historic features to sustainable benefits gained from building green roofs.	Cultural factors
Providing Optimum Site Accessibility, Safety, and Wayfinding	Provide evident site accessibility and wayfinding to green roofs.	Accessibility
	Identify techniques to improve green roof legibility by understanding the building and its roofs' layout and site expectations.	Site planning

	If the green roof is physically accessible, plan for equitable site uses early using universal design strategies, such as handicap ramps, moveable furniture, and materials, etc.	Accessibility
	Provide opportunities, such as educational programs and social events, for visual or physical access to green roofs.	Accessibility
	Address safety concerns during site design by identifying approaches to avoid safety problems according to green roof types and site users.	Security considerations
	Design seating areas with low walls, fences, vegetation, or topography to invoke a sense of safety.	Security considerations
Promoting Equitable Site Use	Identify needs and provide options for site users by actively engaging with the local community.	Human factors
	Provide free public site access to selected site elements (amenities, activities, facilities, programs, or events), which meet the needs of the local community.	Accessibility
	Balance the use of permanent elements and temporary installations to provide options for a wider range of site users.	Accessibility
Supporting Mental Restoration	During the site assessment process, look for space that has the potential to optimize mental health benefits. Consider elements like shade trees, relaxing or appealing views on site, or those from surrounding structures and buildings.	Experiential factors
	During site planning and design, identify site users' needs according to communications with stakeholders and potential site users.	Human factors
	Provide views to distant vegetation or human activities	Experiential factors
	Avoid obstructed views by placing structures or vegetation carefully.	Experiential factors
	Aim for a plan incorporating a number of mentally beneficial spaces of small size, instead of one expansive space.	Experiential factors

	Acknowledge the site's integration with nature by linking exterior green roof spaces with interior spaces for public use through the placement of objects like potted plants or through constructed spaces like greenhouses.	Experiential factors
	Keep the roof space free from distractions, such as noise from mechanical systems, building and facility operations, and traffic. Using dense foliage, barriers or screens can help minimize noise. Schedule maintenance activities only when site users are not present.	Experiential factors
	Place seating areas with low walls, fences, vegetation, or topography to create a sense of enclosure.	Security considerations
	Design different seating options with comfortable, movable furniture in both sun and shade.	Experiential factors
	Design certain structures and vegetation for shade and windbreak protection. Walls, fences, and vegetation can provide shade and be used to guide winds with different effects.	Experiential factors
	Use a variety of vegetation and artworks to provide a multi-sensory aesthetic experience.	Experiential factors
Supporting Physical Activity	Design the green roofs according to site users with adequate, accessible and comfortable spaces for potential physical activities.	Accessibility
	For smaller sites, design innovative meandering pathways to increase the opportunity for on-site physical activities.	Circulation
	For larger sites, consider addressing the site map and walking routes to enhance safety protection.	Security considerations
	Consider pedestrian lighting for public green roofs accessible at night.	Site amenities
	Utilize elevated light sources only when space is used for more intensive physical activities.	Site amenities
	Divide space wisely with separation between a quiet mental restoration area and an active physical area.	Experiential factors
	Provide movable seating furniture on-site for rest after on-site physical activities.	Experiential factors

Supporting Social Connection	Look for large shaded areas as potential spaces to accommodate moderate to large groups.	Human factors
	During site planning and design, identify site users' needs according to communications with stakeholders and potential site users.	Human factors
	Aim for a plan incorporating a number of mentally beneficial spaces of small size, instead of one expansive space.	Experiential factors
	Design different seating options with comfortable, movable furniture in both sun and shade	Experiential factors
Providing On-site Food Production	Select appropriate vegetation that are adaptable to site specific conditions with shallow roots and lower maintenance.	Planting
	Manage and maintain the site with the cooperation of local communities and programs, with necessary assistance in irrigation and pollination.	Human factors
	Use organic and healthy soil for on-site vegetation in a relatively thin system.	Material
	Lessen the impact of harmful chemicals on human consumption by utilizing organic gardening techniques.	Project administration
	Consider different gardening programs, such as greenhouses, raised beds, and container gardens, to provide separate spaces for food production and lower the risk of contamination.	Education
	Design sustainable stormwater harvesting and infiltration systems for on-site food production.	Stormwater management
	Consider using on-site food waste and vegetation trimmings as composting materials.	Project administration
Reducing Light Pollution	Retain pedestrian way-finding light levels based on site lighting criteria, avoiding off-site lighting and night sky pollution.	Site amenities
	Regulate the vectors and dispersal of light through a selection of specific light fixtures. Illuminating Engineering Society (IES) "full cut off" or "fully shielded" are among the most effective for this purpose as they restrict visible light to the lowest luminous portion of the fixture.	Site amenities
	Consider temporary lighting installations on public green roofs with no consistent night-time	Site amenities

	public accessibility.	
	Based on the recommendations of the Dark Sky Society, cooperate with professional lighting designers to place fixtures strategically, so that they reach necessary areas such as site maps and walking routes, especially when they are over 15,000 lumens.	Human factors
Minimizing Exposure to Environmental Tobacco Smoke	Prohibit smoking on green roofs.	Experiential factors
	If smoking must be allowed, then: Strategically place smoking areas with the consideration of dominant wind directions and microclimate effects.	Experiential factors
	If smoking must be allowed, then: Consider innovative methods to limit the exposure to environmental tobacco smoke such as putting air filters around the smoking area.	Experiential factors
Promote Sustainability Awareness and Education	For any educational or other explanatory materials, make use of clear and concise language well-tailored to the intended audience, outlining important points and employing visual or verbal illustrations.	Education
	Provide information on green roofs' sustainable and health-promoting features in a variety of formats (e.g., maps, models, brochures, electronic kiosks, MP3-based or cell phone tours), perhaps including translated materials in other languages.	Education
	Connect to local schools and organizations with programs to stimulate green roof learning interest.	Human factors
	Encourage individuals' interactions with characteristic site elements by providing observable on-site sustainable features for demonstration.	Education
	Plan activities and programs hold on the green roofs, or in a nearby building which has visual access to the green roof.	Accessibility
Innovation or Exemplary Performance	Conduct research on similar past projects performances.	Site planning
	Explore the possibility of extending the benefits or raise the performances by using innovative strategies or tools.	Education
	Consider new and /or unique strategies and technologies to promote human health and well-being.	Education

APPENDIX B

SUMMARY OF HEALTH-PROMOTING GREEN ROOF DESIGN PROGRAM ELEMENTS, STRATEGIES, AND GUIDELINES

Program Elements	**Health-centered Design Strategies**	**Health-promoting Guidelines**
Accessibility	Prioritize establishing green roofs at areas with existing multi-modal transit networks including roadways, sidewalks, bicycle lanes, and mass public transportation systems.	Connect to Multi-modal Transit Networks
	Facilitate ease of access to the roof from transport options.	
	Design stormwater features with maximized functional and health-promoting (expand this-what does this mean?) attributes by utilizing low impact development strategies and providing physical or visual accessibility.	Design Functional Stormwater Features as Amenities
	Provide evident site accessibility and wayfinding to green roofs.	Providing Optimum Site Accessibility, Safety, and Wayfinding
	If the green roof is physically accessible, plan for equitable site uses early using universal design strategies, such as handicap ramps, moveable furniture, and materials, etc.	
	Provide opportunities, such as educational programs and social events, for visual or physical access to green roofs.	
	Provide free public site access to selected site elements (amenities, activities, facilities, programs, or events), which meet the needs of the local community.	Promoting Equitable Site Use
	Balance the use of permanent elements and temporary installations to provide options for a wider range of site users.	

	Design the green roofs according to site users with adequate, accessible and comfortable spaces for potential physical activities.	Supporting Physical Activity
	Plan activities and programs hold on the green roofs, or in a nearby building which has visual access to the green roof.	Promote Sustainability Awareness and Education
Circulation	For smaller sites, design innovative meandering pathways to increase the opportunity for on-site physical activities.	Supporting Physical Activity
Cultural factors	Maintain site selection and design practices that reflect sensitivity to any concerns relating to the cultural, historic, and religious significance of potential sites.	Protect and Maintain Cultural and Historic Places
	Obtain inspiration from local history and culture for green roof designs on non-historical structures.	
	Prioritize preserving historic features to sustainable benefits gained from building green roofs.	
Education	Consider different gardening programs, such as greenhouses, raised beds, and container gardens, to provide separate spaces for food production and lower the risk of contamination.	Providing On-site Food Production
	For any educational or other explanatory materials, make use of clear and concise language well-tailored to the intended audience, outlining important points and employing visual or verbal illustrations.	Promote Sustainability Awareness and Education
	Provide information on green roofs' sustainable and health-promoting features in a variety of formats (e.g., maps, models, brochures, electronic kiosks, MP3-based or cell phone tours), perhaps including translated materials in other languages.	
	Encourage individuals' interactions with characteristic site elements by providing observable on-site sustainable features for demonstration.	
	Explore the possibility of extending the benefits or raise the performances by using innovative strategies or tools.	Innovation or Exemplary Performance

	Consider new and /or unique strategies and technologies to promote human health and well-being.	
Environmental factors	Maximize the percentage of vegetated areas on roofs.	Reduce Urban Heat Island Effect
	Use shade from proper trees, dense shrubs, vegetated trellises, walls or other shading structures reasonably.	
	Provide light color covers and surfaces for pedestrian areas as an alternative to traditional dark ones to reduce building temperature.	
	Consider the use of photovoltaic cells to shade impervious surfaces.	
	Consider employing shady plants or the structures mentioned in the previous strategies if a roof functions as a parking lot.	
Experiential factors	During the site assessment process, look for space that has the potential to optimize mental health benefits. Consider elements like shade trees, relaxing or appealing views on site, or those from surrounding structures and buildings.	Supporting Mental Restoration
	Provide views to distant vegetation or human activities	
	Avoid obstructed views by placing structures or vegetation carefully.	
	Aim for a plan incorporating a number of mentally beneficial spaces of small size, instead of one expansive space.	
	Acknowledge the site's integration with nature by linking exterior green roof spaces with interior spaces for public use through the placement of objects like potted plants or through constructed spaces like greenhouses.	
	Keep the roof space free from distractions, such as noise from mechanical systems, building and facility operations, and traffic. Using dense foliage, barriers or screens can help minimize noise. Schedule maintenance activities only when site users are not present.	

	Design different seating options with comfortable, movable furniture in both sun and shade.	
	Design certain structures and vegetation for shade and windbreak protection. Walls, fences, and vegetation can provide shade and be used to guide winds with different effects.	
	Use a variety of vegetation and artworks to provide a multi-sensory aesthetic experience.	
	Divide space wisely with separation between a quiet mental restoration area and an active physical area.	Supporting Physical Activity
	Provide movable seating furniture on-site for rest after on-site physical activities.	
	Aim for a plan incorporating a number of mentally beneficial spaces of small size, instead of one expansive space.	Supporting Social Connection
	Design different seating options with comfortable, movable furniture in both sun and shade	
	Prohibit smoking on green roofs.	Minimizing Exposure to Environmental Tobacco Smoke
	If smoking must be allowed, then: Strategically place smoking areas with the consideration of dominant wind directions and microclimate effects.	
	If smoking must be allowed, then: Consider innovative methods to limit the exposure to environmental tobacco smoke such as putting air filters around the smoking area.	
	Collaborate between artists, craftsmen and designers to create stormwater features with sound functionality and entrancing aesthetics.	Design Functional Stormwater Features as Amenities
Human factors	Collaborate between artists, craftsmen and designers to create stormwater features with sound functionality and entrancing aesthetics.	Design Functional Stormwater Features as Amenities
	Coordinate cooperative communications between professionals regularly from various backgrounds, including at least one green roof and one public health professional.	Use an Integrative Design Process

	Organize activities like a charrette to engage stakeholders and site user groups in formulating more site specific designs meeting the requirements of site users.	
	Approach and recruit potential site users and stakeholders to participate in different ways, such as through websites, surveys, and charrettes, workshops, community meetings, etc.	Engage Users and Stakeholders
	Consult local governmental agencies, educational facilities, and native plant societies for plant selection. Refer to local authoritative plant recommendation list. Inspect frequently to exclude state and federal noxious weeds and invasive plants.	Use Appropriate Plants
	Communicate clear expectations to suppliers regarding transparency and safer chemistry needs for current and future projects.	Support Transparency and Safer Chemistry
	Identify needs and provide options for site users by actively engaging with the local community.	Promoting Equitable Site Use
	During site planning and design, identify site users' needs according to communications with stakeholders and potential site users.	Supporting Mental Restoration
	Look for large shaded areas as potential spaces to accommodate moderate to large groups.	Supporting Social Connection
	During site planning and design, identify site users' needs according to communications with stakeholders and potential site users.	
	Manage and maintain the site with the cooperation of local communities and programs, with necessary assistance in irrigation and pollination.	Providing On-site Food Production
	Based on the recommendations of the Dark Sky Society, cooperate with professional lighting designers to place fixtures strategically, so that they reach necessary areas such as site maps and walking routes, especially when they are over 15,000 lumens.	Reducing Light Pollution
	Connect to local schools and organizations with programs to stimulate green roof learning interest.	Promote Sustainability Awareness and Education

Material	Avoid using materials with finishes (e.g., dye, paint, gloss) or other chemical additives if possible.	Support Transparency and Safer Chemistry
	Make use of certification systems using guidelines that promote transparency and safer chemistry in products.	
	Prioritize low-risk products that meet the highest affordable safety guidelines.	
	Use organic and healthy soil for on-site vegetation in a relatively thin system.	Providing On-site Food Production
Planting	Select plants that are adaptable to site conditions. Invasive species that threaten the balance of the local ecosystem should be avoided.	Use Appropriate Plants
	Select low-maintenance vegetation species.	
	Prevent potential insect and disease pests by using diverse plants; as a general guide for larger sites, any specific plant species should not exceed 10 percent of the total, and any particular plant genus should not exceed 20 percent of the total. Similarly, any specific plant family should not exceed 30 percent of the total. For smaller sites, plant diversity can be achieved by selecting appropriate species from a local or regional area.	
	Selecting plants that provide food, nesting sources for appropriate native wildlife.	
	Select appropriate vegetation that are adaptable to site specific conditions with shallow roots and lower maintenance.	Providing On-site Food Production
Project administration	Identify project sustainability and performance goals.	Use an Integrative Design Process
	Make short and long term maintenance plans according to the site conditions and the existing and potential resources (e.g., budget, staff, volunteers, equipment, materials, educational programs, and classes).	
	Lessen the impact of harmful chemicals on human consumption by utilizing organic gardening techniques.	Providing On-site Food Production
	Consider using on-site food waste and vegetation trimmings as composting materials.	

Security considerations	Address safety concerns during site design by identifying approaches to avoid safety problems according to green roof types and site users.	Providing Optimum Site Accessibility, Safety, and Wayfinding
	Design seating areas with low walls, fences, vegetation, or topography to invoke a sense of safety.	
	Place seating areas with low walls, fences, vegetation, or topography to create a sense of enclosure.	Supporting Mental Restoration
	For larger sites, consider addressing the site map and walking routes to enhance safety protection.	Supporting Physical Activity
Site amenities	Consider pedestrian lighting for public green roofs accessible at night.	Supporting Physical Activity
	Utilize elevated light sources only when space is used for more intensive physical activities.	
	Retain pedestrian way-finding light levels based on site lighting criteria, avoiding off-site lighting and night sky pollution.	Reducing Light Pollution
	Regulate the vectors and dispersal of light through a selection of specific light fixtures. Illuminating Engineering Society (IES) “full cut off” or “fully shielded” are among the most effective for this purpose as they restrict visible light to the lowest luminous portion of the fixture.	
	Consider temporary lighting installations on public green roofs with no consistent night-time public accessibility.	
Site planning	Inspect and take into consideration any new plans on transportation and transit systems within two years of project completion. Keep up to date with the progress made on transportation service development by establishing and maintaining relationships with related departments and agencies.	Connect to Multi-modal Transit Networks
	Use surveys to identify the transportation needs of future users of the site.	
	Identify techniques to improve green roof legibility by understanding the building and its roofs’ layout and site expectations.	Providing Optimum Site Accessibility, Safety, and Wayfinding

	Conduct research on similar past projects performances.	Innovation or Exemplary Performance
Stormwater management	Design and sustain stormwater features to mimic natural ecosystem features by using native plant communities and other aquatic organisms.	Design Functional Stormwater Features as Amenities
	Plan for additional treatment, such as ozonation or thermal control, for water features with which human contact is expected.	
	Design sustainable stormwater harvesting and infiltration systems for on-site food production.	
	Design sustainable stormwater harvesting and infiltration systems for on-site food production.	Providing On-site Food Production