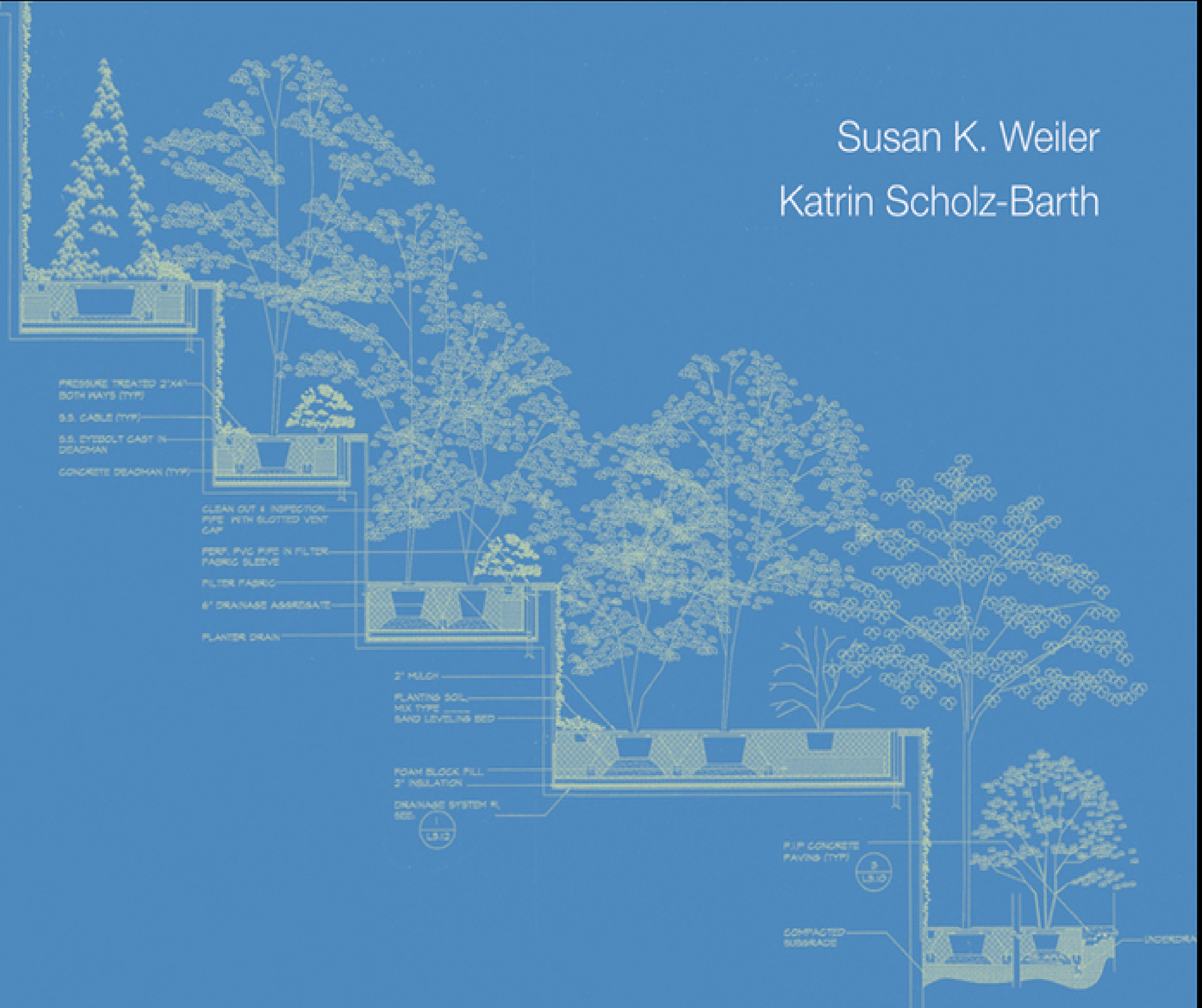
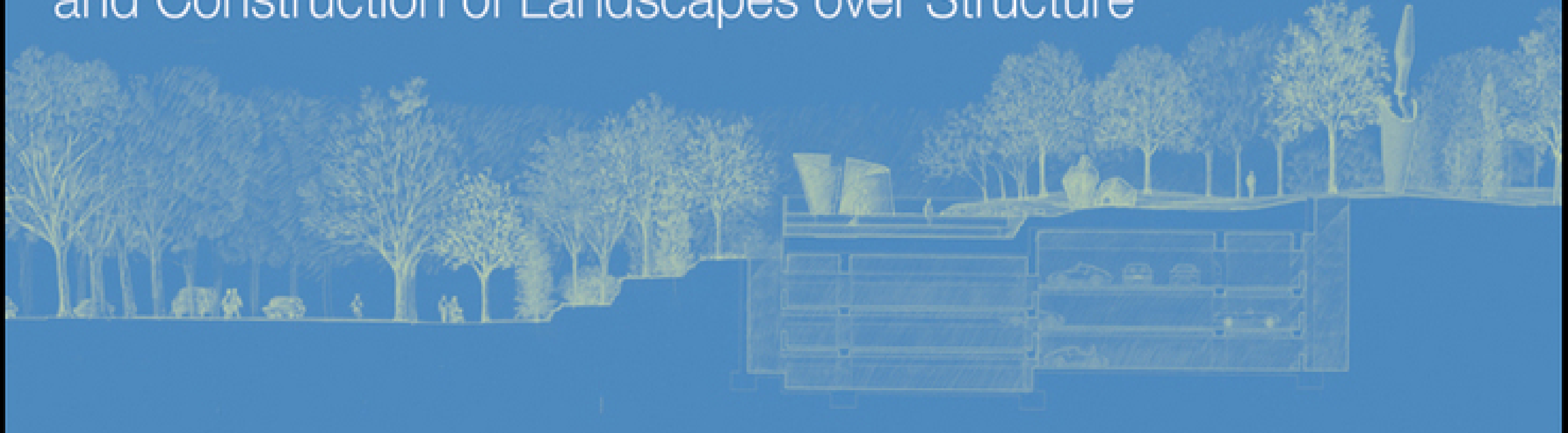


Susan K. Weiler

Katrin Scholz-Barth

Green Roof Systems

A Guide to the Planning, Design, and Construction of Landscapes over Structure



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Katrin Scholz Barth

Chapter 1

Replenishing Our Diminishing Resources: Integrating Landscape and Architecture

The world is a glorious bounty.

—Ian L. McHarg, Design with Nature

The technology and materials for vegetating roofs and creating usable open spaces over structure have been known for centuries. Since 4000 BC, practitioners of building and agriculture have utilized the knowledge and materials of their time to construct sacred places such as ziggurats, simple vegetated roofs, and remarkable gardens over elevated surfaces.

The *building green* movement is not new, nor is the practice of using natural resources responsibly to sustain life and encourage the regeneration of natural resources.

In the last five years, the term *green roof* has taken on ecological and social significance beyond its seemingly simplistic description. As commonly understood, the term has become an epithet for the reduction of pollution and urban heat islands, for large-scale mitigation of stormwater runoff, and for maximum utilization of urban land.

Justifiably, the concept of the green roof as a way to add pervious surface and usable open space without taking up additional land is easy to understand and should be equally easy to implement. Consequently, many clients, municipalities, architects, landscape architects, and planners have come to consider them as an integral element of sustainable building practice.

More recently, many European municipalities have mandated the incorporation of green roof systems as standard building practice. Even without legislative mandate, landscape architects and architects have, with the personal will and mandate of their clients, successfully built numerous green roofs as stormwater management systems and as comfortable, accessible, open spaces over structure. This has happened without fanfare, perhaps because many of these spaces have been imperceptibly integrated with the architecture and surrounding urban fabric, and perhaps because much of what sustains green roof functionality is invisible to the user.

Most roofs as we know them, however, are not invisible, and as cities grow so do the number and sizes of rooftops. So too does the amount of land used for roads, parking lots, and pavement. At issue is the fact that conventional rooftops and paved surfaces are impermeable, which in turn affects the quality of our water and air. The use of more and more land for building affects the way we live. As our cities grow we need to be thoughtful about how we use our limited natural assets.

FIGURE 1-1 Gardens at the United Nations, viewed from the East River, illustrate extensive portions built over the FDR Drive.

One of many strategies for replenishing our diminishing resources and integrating landscape and architecture is the green roof, and its wide-scale utilization is the focus of this book.

FIGURE 1-2 Outside Geneva, Switzerland, where vast meadows grow over the roof of a reservoir, a rich palette of plants provide a diversity of habitats for insects and small animals, as well as nesting places for birds.

FIGURE 1-3 Even a small individual effort can help ameliorate the negative impacts of unplanned development and urban growth in the Netherlands. (Photo: Joyce Lee)

This book aims to provide a comprehensive, systems-based approach to understanding, designing, and constructing green roof systems in an urban environment. The following chapters will:

- Broaden the reader's understanding of the deleterious effects that conventional roofs can have on the environment

FIGURE 1-4 West Ferry Circus, a lush garden of canopy trees, shrubs, lawns, and walkways, is one of the numerous interconnected open spaces at Canary Wharf in London. This part of the project was built over a highway, service roads, mechanical equipment rooms, and major utilities. Other open spaces were built over three to five stories of parking, a shopping center, and a tube stop.

- Challenge conventional thinking about the design and development of our built environment and foster innovative solutions that change the perception, appearance, and use of roofs for the benefit of our natural and cultural environment
- Identify the environmental, social, and economic benefits of turning the under-explored surfaces of roofs into multifunctional systems for stormwater management and the creation of usable landscapes over structure
- Provide detailed insight into their design, construction, and maintenance

Defining and Redefining the Roof: Traditional Roofs and Green Roof Systems

In traditional building terms, the roof is considered the lid or top of a habitable structure that keeps the unwanted weather elements outside and helps maintain the most comfortable conditions and temperatures for human habitation inside. For as long as there have been humans seeking shelter beyond a cave or a tree canopy, some type of protective weatherproofing material was overhead to provide protection from the sun, wind, rain, and snow. This has evolved from natural materials such as leaves, thatch, and sod to more durable materials such as slate, wood shingles, asphalt shingles, EPDM (ethylene propylene diene monomer) membranes—and contemporary green roof systems.

In traditional building terms, roofs can be sloped or flat. (Flat roofs actually have a slight slope to them even though to the naked eye they appear flat.) Regardless of its overall configuration and architectural type, a sloped roof sheds rainwater, snow, and ice more quickly than a flat roof, and it is generally more suited for the application of smaller overlapping units for weather protection such as slate, wood, or asphalt shingles, clay tiles, thatch, or sheet metal. Sloped roofs, for some, have greater aesthetic appeal, which may be attributed to a more interesting architecture, size, scale, and the richness of traditional building materials used for weatherproofing.

Flat roofs are more practical for covering long spans of horizontal surfaces, but they can also be used to cover smaller structures. Because of the simpler surface configuration, weather protection for flat roofs can be accomplished more economically through using large pieces of protective membrane.

Both sloped and flat roofs become extraordinarily hot in direct sun exposure, especially in summer. The variation in temperature of the roof surface, even in moderate climates, can cover more than 70 degrees from morning till afternoon. The heat gain is more severe on flat roofs because the entire roof is exposed to the sun at all times. Even so, it is generally easier to build, inhabit, and maintain green roof systems that are constructed on flat or slightly sloped roof decks (the surface supporting the roof) than on ones with slopes because on flat roofs the loosely laid soil and vegetation layer is not subject to gravity and shear forces that pull on them. The primary advantages of constructing green roof systems on low-sloped roof decks are their applicability as stormwater retention systems, their reduction of heat gain, and their ability to be developed for usable open spaces in urban areas without taking up more land.

The technologies of each age add to our ability to live more efficiently and productively. Just as city builders of 4000 BC used the technology of their age to build beautiful rooftop gardens and other needed places, contemporary practitioners of design and building use the knowledge and materials of this time to construct our needed places.

We just need to think more carefully about how we can build our needed places *and* replenish our diminishing resources. This requires thinking about roofs in a different way. The roof, usually a leftover space, sitting unused and absorbing heat, can be transformed into a floor—a platform for activity—while providing insulation for the living spaces below.

Designing with Nature

In the first pages of *Design with Nature,* a seminal treatise on the importance of understanding and integrating natural, economic, and social systems, Ian McHarg points out that “the world is a glorious bounty” from which we benefit and for which we must serve as guardians.

Land and the natural resources it yields have enormous value, but more often they are commodities that have a price; all can be owned, bought, and sold. Land as real estate has its price, water has its price, and energy has its price.

Assigning a Value to Open Space

It is more challenging to assign a dollar value to land as open space. Whether it is under public or private ownership, open space with its intricate, interconnected elements of earth, animals, plants, water, and air provides the armature for the way we live. Well-cared-for open space is itself a valuable commodity and must be envisioned as such. It plays a pivotal role in improving water and air quality. It positively influences real estate values, and it can help to diminish energy consumption in the surrounding area. Yet we seem to take it for granted, and the responsibility for its stewardship is not always taken at individual, municipal, federal, or global levels. Globally, the amount of open space continues to shrink and our natural resources continue to be diminished in extent and quality. Ozone depletion, air and water pollution, and acid rain have caused local and, cumulatively, global environmental problems. Deforestation and desertification, ground water depletion, and degradation of other natural resources have led to a loss of habitat and biodiversity.

FIGURE 1-5 Bryant Park provides enormous value as an urban open space and has significantly increased peripheral property values. The central lawn panel is built over the stacks of the New York Public Library.

As we develop land for building, we eat up at an alarming rate valuable open space that could be used for our own recreation or for providing connected corridors of habitat and a balanced diversity of vegetation and wildlife. More importantly, we are not carefully planning for the preservation of land we need for growing food or for the replenishment of clean water and air.

Unplanned development resulting from continued population growth may be seen as a root cause of consumption of land for building. This is not exclusively a problem in the developing world; North America has its very own disturbing track record. As an example, between 1973 and 1992 alone, metropolitan Atlanta, Georgia, grew at the expense of 380,000 acres of trees. This amounted to an average destruction of 55 acres every day for nineteen consecutive years. This rapid rate of urbanization in Atlanta prompted NASA to study the impact of development on the overall urban environment, focusing primarily on the regional climate and air quality. The study tied the development of the urban heat island phenomenon and elevated smog levels to the replacement of forests and agricultural land with dark surfaces of the built environment.[1] In our own country, which has some of the best agricultural soils in the world, farmland is being replaced at a rate of nearly 6,000 acres per day by housing, industry, and the services required to support them.

Cumulative Environmental Impacts of Urban Sprawl

When undisturbed forests, meadows, and prairies are replaced with buildings, along with asphalt and concrete roads and parking lots, the built surfaces become impervious to rainwater. Such a widespread trend has spiraling, deleterious consequences beyond removal of the plants and soils that act as natural sponges. Water and air quality is compromised directly and immediately by impervious surfaces. Water can no longer infiltrate the ground and is washed into streams and rivers when it rains, carrying with it nonpoint-source pollutants, nutrients such as phosphorus and nitrogen, and sediments deposited on the impervious surfaces. Dark, hard surfaces absorb solar radiation and store heat, making roofs and roads hot during the day; the stored radiant heat dissipates into the air at night, ultimately warming our globe. On a more recognizable level, regional climate changes can also be attributed to these significant changes in land cover and land use.

For example, Chesapeake Bay was once the most environmentally, socially, and economically diverse estuary in North America. In the last quarter century, unplanned development around the Washington, D.C., area has had deleterious effects on the health of the aquatic ecosystem, and in turn on the sociology and economy of the bay area. The leading cause of this has been the transformation of adjacent and regional open space to impervious surfaces, which has increased the amount of urban stormwater runoff into the bay. Sediment, nitrogen, and phosphorus input has degraded the water quality and with it the bay’s crab and oyster habitat. This means that the livelihood of fishermen and crab and oyster farmers along with their local history and traditions are at risk of disappearing—all as a direct result of increased pollution and diminished water quality stemming from development and urban runoff.

FIGURE 1-6 This graphic from the front page of *USA Today* shows that 13 million acres of farmland were lost in the United States between 2000 and 2006. This information is juxtaposed with an article about oil costing more than $100 a barrel for the first time.

USA TODAY Snapshots®

Farmland shrinks

Total acreage of farms in USA: (in millions of acres)

2000 945

2006 932

Crossword, Sudoku 5D
Editorial/Opinion 11, 13A
Lotteries 13C
Marketplace Today 5D
Market scoreboard 4B
State-by-state 9A

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Oil closes above $100 a barrel for first time

Prices at gas pump could surge to $3.75

By James R. Healey
USA TODAY

Oil closed above $100 a barrel Tuesday for the first time in history — a surprise price surge that leaves experts and motorists wondering if there's no limit.

The closing price of $100.01 a barrel, combined with gasoline prices that already had begun rising before the oil spike, could push the U.S. average for gasoline to $3.75 a gallon by Memorial Day — more than 50 cents higher than the record $3.227 set on May 24.

"You can make a much more legitimate case now for $3.50 to $3.75 a gallon as the spring peak," says Tom Kloza, veteran analyst at the Oil Price Information Service, a consultant. "But $4? No."

The about-face for prices is "unexpected, based on what appears to be falling consumption by consumers," says Geoff Sundstrom, spokesman for AAA.

Forecasts of petroleum demand this year have been lowered by the U.S. Energy Department and the International Energy Agency. "It shows we're still at the mercy of those who choose to supply our market, or not," he says.

"Wow. We were talking 12 days ago about going down into the $70s. Now we're talking about $105, $110," says Peter Beutel, president of Cameron Hanover, an energy risk management consultant.

Prices were in the high-$90 range most of the day, then zoomed as high as $100.10 after reports, later denied, that a Nigerian emancipation leader was shot and killed by Nigerian authorities. Unrest in oil-rich Nigeria can lead to shortages that drive prices up.

Also behind oil's record:

► A Monday explosion at Alon USA Energy's refinery in Big Spring, Texas, will keep the facility closed longer than expected. Alon's goal is to resume partial operations in about two months. Although it's not a huge refinery, the U.S. petroleum supply network is tight enough that it doesn't take much to create worries about supply shortages.

► Venezuelan President Hugo Chávez had threatened to cut oil to the USA over a dispute with ExxonMobil, although he said Sunday that he doesn't plan to do so. Exxon won a court judgment freezing $12 billion in Venezuelan assets in return for oil facilities Chávez nationalized.

► Representatives of the Organization of Petroleum Exporting Countries have suggested the cartel won't vote to increase production when OPEC meets in two weeks.

► Oil is priced worldwide in dollars. A weak dollar means it takes more to buy the same amount of oil.

The government's weekly survey showed the U.S. average for regular gas at $3.042 a gallon, up 8.2 cents in a week.

Familiar territory

The U.S. average gasoline price has bounced back above $3.

$3.00
$2.50
$2.00
0
$3.109
Tues.: $3.042
1/7/08
2/19/08

Vast and intact open spaces such as forests and prairie grasslands provide ecosystem services, the combined actions of the species in an ecosystem that perform services of value to society and that support the processes and functions on which human culture depends. Until recently, these were taken for granted and were not perceived as having value. Few people consider that our grocery stores are stocked with fruit because of the pollination services insects provide. In the nineteenth century, wetlands were viewed as disease-causing areas from which yellow fever and malaria emanated, and they were eliminated from the urban environment wherever possible. Now we marvel at wetlands’ water-storage capacity and their role in preventing flooding as well as their critical role as sources of rich biodiversity. Freshwater wetlands hold more than 40 percent of the world's species and 12 percent of all animal species. In the nineteenth century, elaborate infrastructure for supplying fresh water and removing stormwater and sanitary wastes were built in our urban areas to eliminate disease and improve the health of residents. They were indeed marvels that demonstrated humankind's technology and ingenuity. Nature was revered for her beauty but not for her ecosystem services. Recently that view has changed. Today, New Jersey estimates the value of those services at between $8.9 billion and $19.8 billion per year.[2] Green roof systems can be a part of ameliorating the consequences of urbanization—the decline or destruction of these ecosystem services, specifically water systems.

The depletion of our natural resources and the degradation of our ecological, social, and economic environments, if taken in toto, are serious enough to make you want to stay in bed with the covers pulled tightly over your head. But there are ways of breaking the spiral. Despite these alarming trends, many individuals and communities are beginning to recognize the diminution of our natural resources and are doing much to minimize and even reverse it.

It is unlikely that our populations and in turn our cities will stop growing. We can, however, be more cognizant of the adverse environmental impact of unbridled, unplanned development sprawling well beyond urban centers. In turn, the risks of concentrating the built environment can be mitigated by making our cities livable and vibrant as well as socially, economically, and environmentally sustainable. One way is to superimpose green spaces onto surfaces that would otherwise be impervious to natural and climatic occurrences. This book seeks to explore the positive impacts on our environment that can be derived from the singular and cumulative application of green roof systems and to consider issues involved in their design, construction, and maintenance.

Roof as Floor

The term “green roof” today is often used as an umbrella term for a number of sustainable systems built over a structural decking that serves as a roof to that specific portion of the structure. As a “roof garden,” “eco-roof,” “extensive green roof,” or “intensive green roof,” the system acts and is perceived as a roof or lid. As a “roof garden,” “open space over structure,” or “intensive green roof,” the system may serve as either a “roof” or a grade-level “floor.”

This ambiguity and confusion of terminology is exacerbated by current jargon derived from European usage of “extensive” and “intensive,” two words used within the fabrication, supply, and design industries. These terms, which may seem counterintuitive to English speakers, describe the depth of growing medium and level of effort required to maintain the green roof.

- *Extensive* is loosely used to describe a system that typically has a very shallow depth of soil or growing medium and is primarily used for its environmental benefits such as stormwater management and insulating properties. It is seldom irrigated; it is expected to require minimum maintenance; and it is not usually intended to be accessed directly for use as a garden or open space, though paved walkways and seating areas accommodate use as open space as well.
- *Intensive* is loosely applied to those systems that have a greater depth of soil or growing medium, which allows for a greater diversity in size and type of vegetation. This diversity usually implies a need for supplemental

irrigation and, overall, a more intensive level of maintenance.

A disadvantage to using “extensive” and “intensive” as blanket terms is that neither clearly reflects the system’s expected purpose or use nor adequately conveys design or maintenance requirements. Furthermore, a terminology-driven, rather than use-driven, approach to the design and construction of green roofs can lead to additional confusion and inaccuracy in design, documentation, and client expectations.

Ironically, in the design and construction of green roof systems, which comprise both living green roofs and landscapes over structure, the roof has to be thought of as a floor, above which a green roof system is built. If the definition of a roof is expanded to be a covering for any built structure at any elevation—such as a parking structure, academic or assembly facility, or any commercial or residential structure—and thought of as being programmed and designed for supporting a thin layer of vegetation to mitigate stormwater loss and heat gain or as usable, comfortable open space, the possibilities for beneficial uses of an otherwise vapid space become positively multiplied.

Coming to Terms with a Green Roof

While the generic term “green roof” already may have become too much a part of the green movement jargon for a clearer or new use of terms to take hold, describing specific applications of different types of green roofs is necessary.

Thus, for clarity, throughout this book, terms are defined as follows:

- *Green roof system* is used as an overarching description of a more environmentally, culturally, and economically sustainable use of a roof at any elevation.
- *Living green roof* is used to describe a thin-profile system where the growing medium is less than 8 inches deep and where the primary use is to effectively satisfy stormwater management requirements in lieu of conventional stormwater engineering methods.
- *Landscape over structure* describes a system where the growing medium is deeper than 8 inches; based upon programmatic requirements, it may be designed to accommodate its use as accessible open space. The combined depth of component parts may exceed several feet, and related systems required to support the uses often are more complex.

Living green roof and *landscape over structure* are not competing or contradictory strategies. Rather, large-scale ecological and social benefits can be recognized in the appropriate application of either, as well as their combined use to reduce stormwater runoff, bind dust and pollutant particulates, reduce energy consumption, increase biodiversity, improve the visual quality of conventional roofs, and provide valuable, beautiful, comfortable, usable open space. The selection of the most suitable application should be defined by varied use and design goals.

FIGURE 1-7a-b Living green roofs can merge landscape and architecture by expanding beyond the conventional notion of roof. (Photo: Kai-Hennik Barth)

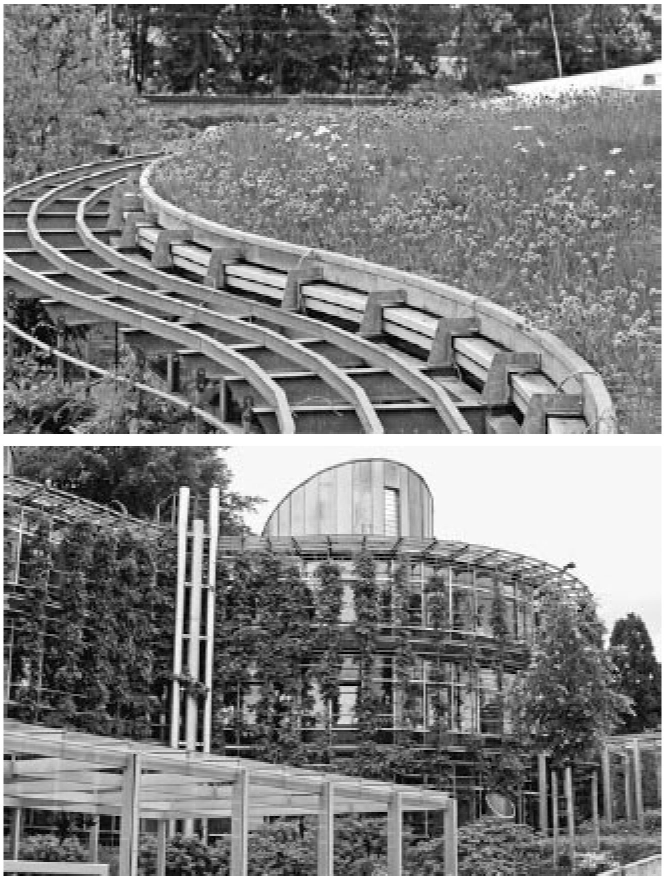


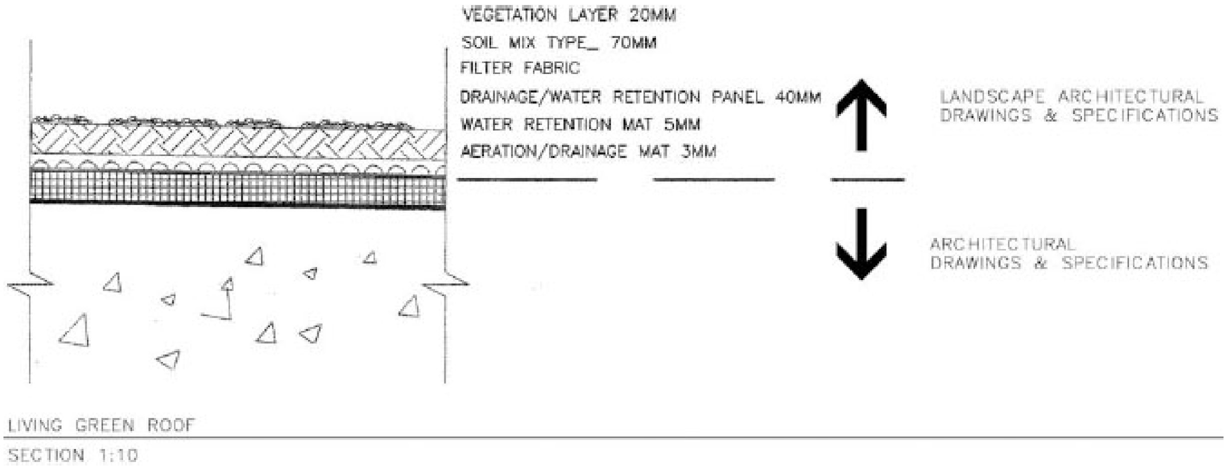
FIGURE 1-8 This is one of many gardens at the J. Paul Getty Center. All of them are over various structures used as garages, shipping and receiving facilities, storage areas, mechanical rooms, and portions of the scholars’ libraries and studies.

Application of Living Green Roofs

Living green roofs offer ecological, aesthetic, and economic advantages. From an ecological standpoint, a major benefit of a living green roof is that it slows and detains storm-water runoff by providing a pervious, vegetated surface, thus preserving water resources and eliminating the need for monetarily and environmentally costly stormwater management systems. The growing medium and vegetation cover also help to shade the roof surface, preventing solar heat gain or loss and thereby lowering consumption of energy to heat and cool the building below. The transpiration of the vegetation provides an evaporative cooling effect that can lower the air temperature locally to below ambient temperatures, helping to reduce the urban heat island effect locally with global implications.

From an aesthetic standpoint, a primary application of a living green roof is to provide a visually interesting vegetation layer of diverse texture and seasonal color, in contrast to a rock ballast or dark surface.

FIGURE 1-9 Detail section for a living green roof.



Economically, living green roofs may satisfy local governments' stormwater management requirements, which will reduce the cost of conventional methods of conveying stormwater from roof drains to ultimate outfall. This reduces not only owner construction costs but also the enormous costs to municipalities for infrastructure and operations associated with stormwater management. That is why today many municipalities offer incentives such as tax credits and larger allowable floor area ratios in exchange for implementation of living green roof systems.

FIGURE 1-10 Although a number of species of the genus *Sedum* may be utilized, a balanced matrix of genera should be included in the plant palette of a living green roof.

The depth of growing medium required for a living green roof is typically 3 to 6 inches but may be as thin as 1 inch. Since the primary purpose of a living green roof is to detain stormwater runoff, irrigation typically is not employed. The lack of consistent supplemental watering, shallow soil depth, and exposure to intense and desiccating sunlight and wind require vegetation capable of surviving these harsh, dry conditions. Low-growing, horizontally spreading, water-storing plants, which occur naturally in alpine environments, have proved to be the hardiest and most suitable for these conditions. Generically this type of plant is known as a succulent: a plant that can store water in its leaves and stems for extended periods of drought conditions. Most often, but not exclusively, plants are selected from the hundreds of species in the genus *Sedum,* many of which are succulents. The dominance of their use in the overall plant selection of living green roofs has led to the occasional use of the misnomer “sedum roofs.” Like most successful planting plans, the selection of plants for living green roofs should include a matrix of plant genera and species that provide adequate horticultural diversity and are suitable to the artificially created roof environment desired.

The maintenance required for such plant mixes is limited and might include initial hand-watering during installation and the establishment period as well as occasional weeding, fertilizing, and spot repair.

The relatively thin profile of the components of a living green roof generally weighs 12 to 15 pounds per square foot. Although each application of a living green roof usually will have specific design requirements determined through a structural analysis, structural upgrading of standard roof decking is usually not required because the weight of the living green roof profile is about the same as the weight of the stone ballast applied to protect and preserve the waterproofing membrane of a conventional roofing system. A living green roof, therefore, can be employed in place of stone ballast when, structurally, limited or no additional weight can be added to the deck. Also, because generally there is little or no additional cost to provide increased structural support for new buildings, it can also be a cost-effective way to provide greater visual amenity and environmental quality. (Chapter 5 addresses structural considerations for both living green roofs and landscapes over structure.)

FIGURE 1-11a Utilization of roofs for stormwater management systems at a manufacturing plant. (Photo: renatur, 24601 Ruhwinkel, Germany)