

# INTRODUCTION

► Meg Calkins

**THE NATURAL ENVIRONMENT IS COMPRISED OF COMPLEX,** interrelated systems of water, soil, air, atmosphere, flora, and fauna that are constantly evolving, balancing, changing, and rebalancing. These ecosystems offer services such as air and water cleansing, water supply and regulation, and productive soil that sustain and enhance human systems—services that are critical to survival of all species. Designed sites can protect, sustain, and even provide these critical ecosystem services. Offering potential to serve multiple functions, sites can be productive, provide ecosystem services, *and* offer rich aesthetic experiences to the site occupants.

This idea of ecosystem services as a basis for design is a profound shift in the way that we think about the role of designed sites. If we are to design and manage sites that support and engage natural processes, we need to shift our focus from creating and maintaining static, isolated landscapes to that of designing and managing complex, interrelated living systems of the built environment. And as a model for designing site systems that can ensure sustainable development, we need look no further than the principles inherent in our planet's ecosystems, principles that include zero waste, adaptation, and resiliency.

If we are to protect the world's ecosystems for future generations, the human-made environment must foster the health of both ecological and human systems. Design of the built environment, including site design, plays a critical role in this. In 2000, the United Nations commissioned the Millennium Ecosystem Assessment, a global study by 1,360 scientists from an international consortium of governments, universities, nonprofits, and businesses. The 2005 concluding report stated that “human activity is having a significant and escalating impact on the biodiversity of world ecosystems, reducing both their resilience and bio-capacity” (MEA 2005). The report, referring to natural systems as humanity’s “life support system,” established that “ecosystems are critical to human well-being—to our health, our prosperity, our security, and to our social and cultural identity” and unless we change the way that we develop land, use resources, and produce food, these services will be seriously compromised for future generations. The report warns: “At the heart of this assessment is a

stark warning. Human activity is putting such a strain on the natural functions of Earth that the ability of the planet's ecosystems to sustain future generations can no longer be taken for granted" (MEA 2005).

In response to this imperative, the Sustainable Sites Initiative™ (SITES™), a partnership of the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center at the University of Texas at Austin, and the United States Botanic Garden, have released *Guidelines and Performance Benchmarks* to guide development of sustainable sites through a voluntary credit rating system. These guidelines and benchmarks encourage the protection, restoration, and provision of ecosystem services as a basis for sustainable site design. They address the design and management of systems of vegetation, soils, water, materials, energy, and culture.

This book has been created to offer comprehensive and detailed information on strategies, technologies, tools, and best practices for sustainable site design. This book, like the SITES *Guidelines and Performance Benchmarks*, is based on the premise that any site in any location can be designed and managed to foster healthy ecosystems, and promote ecosystem services and sustainable human systems. It is intended to assist practitioners with successful implementation of the SITES rating tool, and it will also stand as a resource guide for the design and management of sustainable sites. This publication, developed with the cooperation of the Sustainable Sites Initiative, will complement the *Guidelines and Performance Benchmarks*, the prerequisites and credits, and future SITES publications. It will be a companion resource that practitioners can turn to for deeper guidance on the topics of hydrology, vegetation, soils, materials, human health and well-being, and site selection.

## SUSTAINABLE SITE DESIGN DEFINED

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Sustainable design as defined by SITES is "design, construction, operations and maintenance practices that meet the needs of the present without compromising the ability of future generations to meet their own needs" (SITES 2009a). This is based on the definition of sustainable development from the United Nations World Commission on Environment and Development's Bruntland Report, *Our Common Future* (UNWCED, 1987). For site design, this translates to fostering both human and natural ecosystem health, closing material and resource loops, and designing with respect for nutrient and water cycles. Sustainable site design emphasizes design of whole, complex functioning systems; a widened scale of analysis and design consideration; highly site-specific (as opposed to universal) design responses; and continued monitoring, management, and adaption to ensure healthy, functioning systems for the life of the landscape.

Design of sustainable sites involves a fundamental shift in the way that we think about the Earth and its resources. We must shift from the extractive mind-set of viewing the Earth's resources as abundantly available for human consumption to the understanding that Earth's resources and ecosystems are the sustainers of life on this planet and must be protected. New development must work toward fostering the health of ecosystems and the services they provide through their protection and restoration. We must forge a new and respectful relationship with natural systems, acknowledging their critical role in our health and the health of the planet.

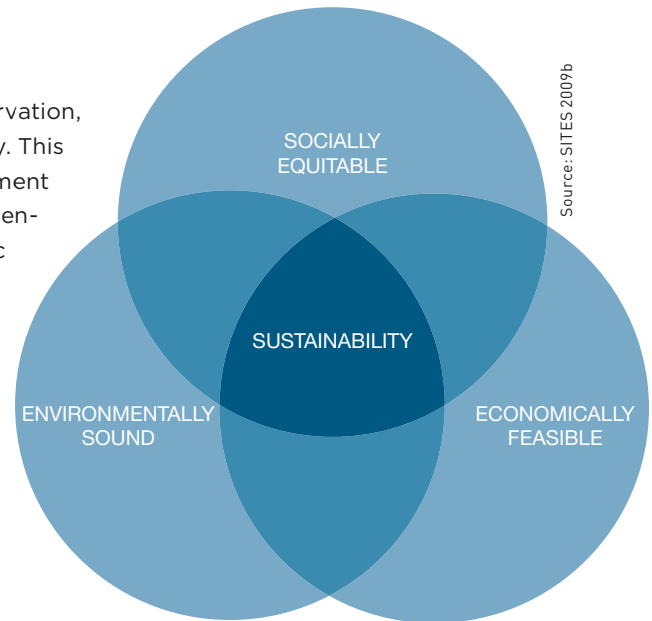
## Triple Bottom Line

Sustainability encompasses not only environmental conservation, but also the ideals of social equity and economic feasibility. This “triple bottom line” is the key to truly sustainable development (Figure 1-1). While this book primarily focuses on environmental sustainability, it addresses areas of social and economic sustainability as they relate to environmental issues and sustainable site design. Design of the built environment also has a direct impact on human and cultural systems. Therefore, a chapter is devoted to human health and well-being considerations of site development.

## Ecosystem Services

Ecosystem services are defined in the Millennium Ecosystem Assessment as “the benefits humans obtain from ecosystems” (MEA 2007). Living elements of ecosystems, such as vegetation and soil organisms, interact with the nonliving elements such as water, air, and bedrock in ecosystem processes to produce goods and services that offer direct or indirect benefits to humans. The MEA groups ecosystem services into four broad categories (MEA 2005):

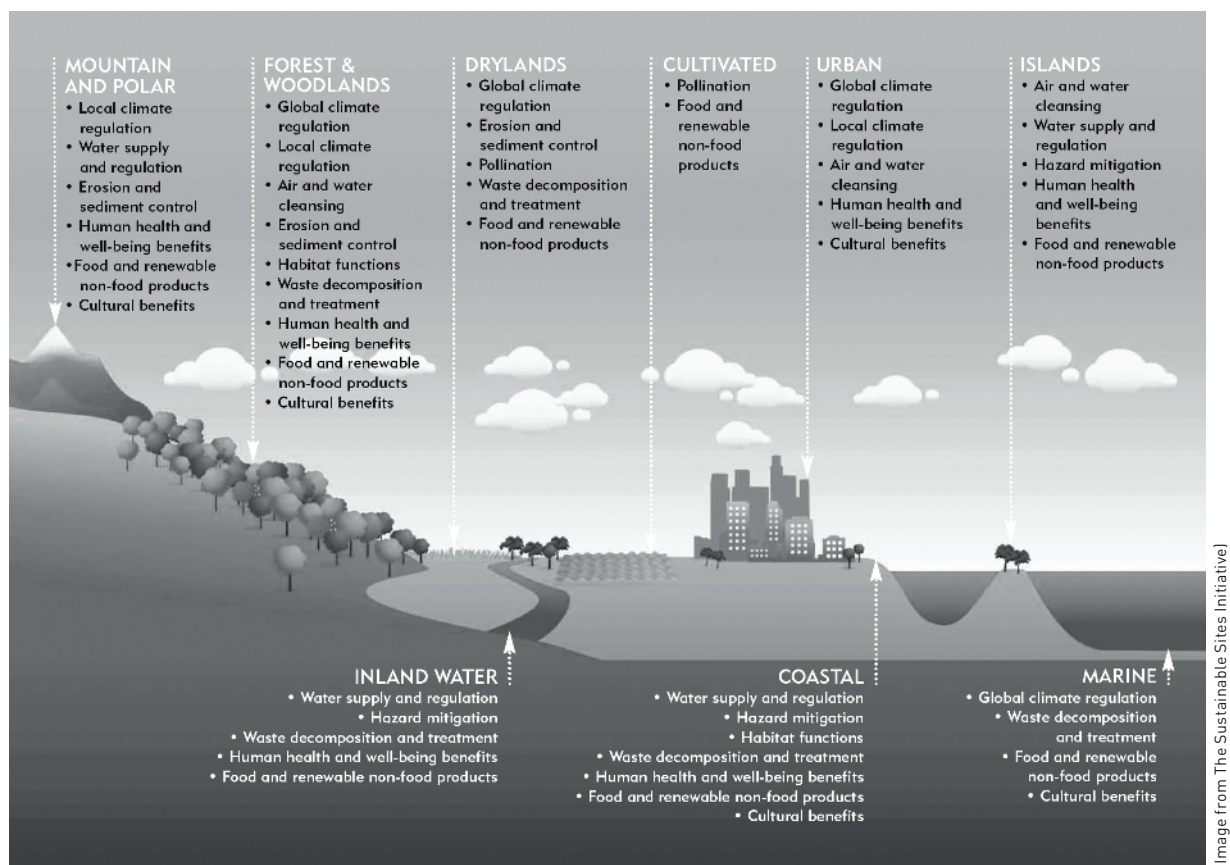
- ▶ *Provisioning*, such as the production of water, clean air, food, and medicines;
- ▶ *Supporting*, such as pollination, waste decomposition, and nutrient cycling;
- ▶ *Regulating*, such as global and local climate regulation, erosion control, disease control; and
- ▶ *Cultural*, such as health, spiritual, recreation, and relaxation benefits.



**FIGURE 1-1:** Sustainable design addresses overlapping aspects of environmentally sound, socially equitable, and economically feasible development.

There are many ecosystem services that can be provided by sites (Figure 1-2) (Table 1-1). Some examples are:

- ▶ Trees regulate local climate through evapotranspiration, shade, and wind control.
- ▶ Vegetation mitigates local air quality.
- ▶ Soils and vegetation infiltrate and purify stormwater protecting adjacent waterways and the water table.
- ▶ Vegetation and construction materials mitigate heat island impacts in urban areas.
- ▶ Vegetation, water, and materials are combined to make parks, gardens, and open spaces for human health and well-being and cultural benefits.
- ▶ Water and soil organisms break down waste and cycle nutrients.



**FIGURE 1-2:** Ecosystem services by landscape type.

It is important to note that site development decisions can impact ecosystem services far away from a site as well—and these impacts are not often easily seen or understood. Decisions about stormwater management and vegetation inputs (e.g., fertilizers and herbicides) can impact waterways hundreds of miles downstream. Resource extraction and material manufacturing can impact ecosystems halfway around the world. And air currents can carry airborne pollutants far away from the manufacturing plant that released them.

**TABLE 1-1: Ecosystem Services**

ECOSYSTEM SERVICE	FUNCTION
Global climate regulation	Maintaining balance of atmospheric gases at historic levels, creating breathable air, and sequestering greenhouse gases
Local climate regulation	Regulating local temperature, precipitation, and humidity through shading, evapotranspiration, and windbreaks
Air and water cleansing	Removing and reducing pollutants in air and water
Water supply and regulation	Storing and providing water within watersheds and aquifers
Erosion and sediment control	Retaining soil within an ecosystem, preventing damage from erosion and siltation
Hazard mitigation	Reducing vulnerability to damage from flooding, storm surge, wildfire, and drought
Pollination	Providing pollinator species for reproduction of crops or other plants
Habitat functions	Providing refuge and reproduction habitat to plants and animals, thereby contributing to conservation of biological and genetic diversity and evolutionary processes
Waste decomposition and treatment	Breaking down waste and cycling nutrients
Human health and well-being benefits	Enhancing physical, mental, and social well-being as a result of interaction with nature
Food and renewable nonfood products	Producing food, fuel, energy, medicine, or other products for human use
Cultural benefits	Enhancing cultural, educational, aesthetic, and spiritual experiences as a result of interaction with nature

Source: SITES 2009a

## THE ECONOMIC VALUE OF ECOSYSTEM SERVICES

The services that healthy ecosystems provide have economic value. And while these services are often viewed as “free” or “public” and are left off the balance sheets of manufacturing and development costs, the value of these services is substantial. One of the few comprehensive studies placed the value of ecosystem services at \$33 trillion per year in 1997—nearly twice the global gross national product at that time of \$18 trillion (Costanza, d’Arge, deGroot et al., 1997). The Millennium Ecosystem Assessment estimates the value of the services that wetlands alone provide to humanity at \$15 trillion annually, including the water supply on which an estimated 1.5 to 3 billion people depend. Yet human practices are destroying and degrading wetlands at a faster rate than any other type of ecosystem (Nature Conservancy 2005). The price of resources is often based on the cost of extraction and fails to reflect the true cost of environmental degradation and depletion for future generations. Such an economic system can undervalue these services and encourage wasteful use of resources.

While a 2002 study estimated the economic value of the approximately 3.8 billion urban trees in the United States at \$2.4 trillion (Nowak, Crane, and Dwyer 2002b), their actual value goes far beyond this in terms of the ecosystem services that urban trees provide. Benefits of urban forests include: sequestering carbon, moderating climate and energy use, cleaning the air, improving water quality and slowing stormwater runoff, reducing noise, providing habitat for urban wildlife, remediating contaminated soils, enhancing real estate values, and generally providing economic and social well-being to communities. Following are some results from studies identified in a report by Nowak et al. for the U.S. Department of Agriculture, Forest Service that have quantified values of some individual urban forest ecosystem services (Nowak et al. 2010). The studies found:

- ▶ Urban trees in the conterminous United States remove an estimated 784,000 tons of air pollution annually, with a value of \$3.8 billion (Nowak, Crane, and Stevens 2006).
- ▶ The establishment of 100 million mature trees around residences in the United States is estimated to save about \$2 billion per year in reduced energy costs (Akbari et al. 1992; Donovan and Butry 2009).
- ▶ Urban trees in the conterminous United States currently store 770 million tons of carbon, valued at \$14.3 billion (Nowak and Crane 2002).
- ▶ During an intense storm in Dayton, OH, the tree canopy was estimated to reduce potential runoff by 7 percent (Sanders 1986).
- ▶ A stronger sense of community and empowerment to improve neighborhood conditions in inner cities has been attributed to involvement in urban forestry efforts (Kuo and Sullivan 2001a, 2001b; Sommer et al. 1994a, 1994b; Westphal 1999, 2003).

In addition to global economic benefits of ecosystems services, economic returns can be realized from the provision of healthy ecosystems at both the site scale and regional scale. Therefore the key to widespread adoption of sustainable site design strategies may lie in the economic value of the ecosystem services they provide. The economic benefits of sustainable development strategies are being increasingly quantified, and this is having a direct impact on their adoption. For example, research has shown savings in infrastructure and development costs with sustainable stormwater management (Wise 2008); reduced air-conditioning costs with shading of buildings and cooling of adjacent pavements (Akbari, Pomerantz, and Taha 2001); increased worker productivity and patient healing with views to vegetation and natural elements (S. Kaplan 1995; R. Kaplan 2007; Ulrich 1984); and cost savings in reuse of onsite structures (U.S. EPA 2000). At the regional scale, savings from sustainable site development can include reduced loads on wastewater treatment plants as a result of sustainable stormwater strategies (Wise 2008); reduced healthcare costs related to poor air quality (Romley, Hackbarth, and Goldman 2010); and reduced material costs for roadway projects with use of recycled materials (PCA 2005). These cost savings are either directly or indirectly related to services that are provided by healthy ecosystems. And they hold the potential to be a strong selling point for use of sustainable development strategies, hastening their widespread adoption.

## ECOSYSTEM SERVICES AS A BASIS FOR DESIGN

Providing new ecosystem services, or protecting existing ones, creates a firm basis for sustainable site design project goals. This is a way to make environmental, economic, and even social goals clear and sometimes measureable (SITES 2009b). For example, construction of a green roof can reduce rainwater runoff through retention and evapotranspiration of plants. These same plants can offer other ecosystem services, such as heat-island reduction, air quality improvements, and contributions to human well-being through views of plants from adjacent buildings (Figure 1-3).

Measuring the contribution of a site strategy to one or more ecosystem services offers a way to assess the performance of the strategy and its contribution to the goals of a sustainable site. It also may provide some measure of the economic benefit of the strategy (Windhager et al. 2010). Using the green roof example, it is possible to quantify the reduced air-conditioning loads on the building with the green roof, yet it would be very challenging to measure the improved air quality from just one green roof. We know there will be some improvement, but we are not sure just how much, and it is difficult to assign a dollar value to the benefit.





(Design by: Phillips Farevaag Smallenberg, Vancouver BC; Photo by Lara Swimmer)

**FIGURE 1-3:** Office workers at the Washington Mutual roof garden lunch adjacent to meadow grasses and native trees in downtown Vancouver. The roof garden offers ecosystem services including human health and well-being benefits, wildlife habitat, stormwater management, and others.

The accurate assessment of the economic value of ecosystem services is at the heart of challenges to use of ecosystem services as a basis for design. Windhager and colleagues identify the following major challenges to use of ecosystem services as a basis for design (Windhager et al. 2010):

1. Not every ecosystem service can be evaluated economically with accuracy—and this often results in undervaluation of the services.
2. The economic value of an ecosystem service is a snapshot of a point in time and the value will change, sometimes significantly, as supply diminishes.
3. If a design objective focuses on a single ecosystem service, opportunities may be missed for use of a design strategy that supports multiple ecosystem services.
4. Direct measurement of services that sustainable design strategies provide can be challenging and likely outside the scope of most design projects. Strategy performance may be modeled during the design process for some strategies, such as stormwater infiltration, but minimal monitoring of strategies during the operation phase is performed due to associated costs, potential liabilities, and disconnections between the design phase of a project and the operations of the built project.



## Sustainable Sites and the Urban Realm

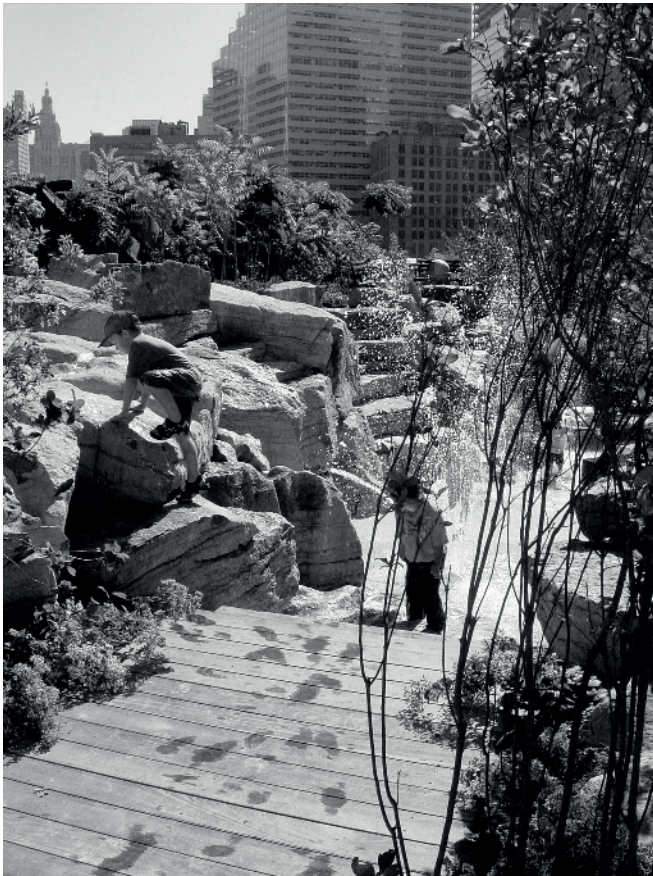
Nearly 83 percent of the U.S. population (250 million people) lives in urban areas (U.S. Census Bureau 2011). This statistic underscores the imperative for healthy urban ecosystems and the provision of natural settings in the urban environment. In addition, the resource needs and negative environmental impacts of urban areas are often greater than those of nonurban areas so it is practical to address these issues with design and planning for the provision of ecosystems services in urban areas to the extent possible.

The urban setting offers a vast opportunity to be a productive place, particularly in the public realm. Rather than an underutilized vastness of hardscape, pavement, and a car-dominated urban fabric, what if every square foot beyond roads, buildings, and sidewalks is used to produce food, provide wildlife habitat, produce and manage energy, infiltrate and cleanse stormwater, and offer places for human interaction with nature? The role of sustainable sites in cities is therefore threefold: to provide ecosystem services and habitat, to be productive places, and to sustain cultural connections to nature (Figure 1-4).



(Photo from Darrin Nordhal)

**FIGURE 1-4:** In Seattle, a forgotten strip of land that once attracted only those engaged in illicit behavior is now a source of fresh food and community pride. Residents of the Queen Anne neighborhood worked with the Department of Transportation to transform a neglected street median, rampant with invasive plants and pricked with hypodermic syringes, into a community garden and gathering space. They cleared the median of its debris and weeds and constructed raised vegetable beds and planted fruit trees.



**FIGURE 1-5:** Michael Van Valkenburgh Associates designed Tear-drop Park to offer natural environments in a highly urban setting, Battery Park City in New York. Natural stone, interactive water fountains, and native plantings are combined to offer “nature play” spaces for adventure and sanctuary to urban children.

Proximity to nature in urban settings can lead to long-term cultural and environmental sustainability by increasing human respect for and care of the environment. Contact with nature can improve conservation behavior by raising awareness and increasing knowledge of and respect for natural processes. The closer that people are to processes of rainwater cycles, vegetation growth, and food production, the more aware they will be of what happens to the rainwater, what kind of vegetables are in season and where they are grown, and what kind of wildlife depend on our urban forests. It is well documented that the people who care most about the natural environment are those who have had many experiences in it (Figure 1-5). In some locations, a native plant garden on an office building roof may be the only green space around, but if people can eat lunch next to flowering plants with birds and bees, they will be connected to natural processes in addition to receiving the benefits of relaxation, stress reduction, and healing that are well documented through exposure to vegetated places (S. Kaplan 1995, Kellert 2005).

When we recognize that ecosystems can and sometimes do function in cities, we recognize their enormous potential for providing ecosystem services and resources. Instead of a place of consumption and waste, sites can be a place of production. Instead of collecting stormwater and sending it as quickly as possible to receiving streams and then bringing in potable water for irrigation, sprinkler systems, and

toilet flushing, why not capture the rainwater and reuse it onsite or close to the place that the rain falls?

Cities do not have to be consumers. They can be producers of resources for their consumption, closing the loops of resource flows. Additionally, a city with food production, habitat, and wildlife in the public realm holds the potential to draw people outside to care for these systems, increasing a sense of community and common purpose—important components of cultural sustainability. It also makes them more desirable places to live and work, contributing to economic sustainability (Figure 1-6).





(Design by Hoerr Schaudt Landscape Architects; Photo by Scott Shigley)

**FIGURE 1-6:** The roof garden at the Gary Comer Youth Center in Chicago's Grand Crossing Neighborhood is an after-school learning space for youth and seniors in a neighborhood with little access to safe outdoor environments. The garden is used for horticultural learning, environmental awareness, and food production.

## Learning from Natural Systems

Natural systems can offer many lessons for sustainable site systems. The concept of biomimicry argues that the best and most efficient responses to environmental challenges are those that mimic natural processes that have maintained and self-regulated over millennia. Biomimicry draws lessons from nature and views “the conscious emulation of life’s genius as a survival strategy for the human race and a path to a sustainable future” (Benyus 2002). Construction ecology, an idea coined by Charles Kibert and co-editors of *Construction Ecology*, is “a view of the construction industry based on natural ecology and industrial ecology for the purpose of shifting the construction industry. . . onto a path closer to the ideals of sustainability” (Kibert, Sendzimir, and Guy 2002). They add: “Construction ecology embraces a wide range of symbiotic, synergistic, built environment-natural environment relationships to include large-scale, bioregional, ‘green infrastructure’ in which natural systems provide

energy and material flows for cities and towns and the human occupants provide nutrients for the supporting ecological systems.”

The shared concept of these ideologies is that nature has already solved many of the problems that humans are struggling with and that we can learn the solutions to our environmental problems from natural templates. This idea can offer direct applications of ecological concepts to sustainable site design. For example, bioretention strategies mimic the natural processes of stormwater infiltration and pollutant removal in natural landscapes. Onsite wastewater treatment components emulate natural processes with a trickling filter acting as a waterfall or river rapids, and a sand filter as a riparian edge. Constructed wetlands mimic the processes of natural wetlands, and a rain garden can reflect a depression found in a natural landscape.

## CHARACTERISTICS OF ECOSYSTEMS IN NATURE

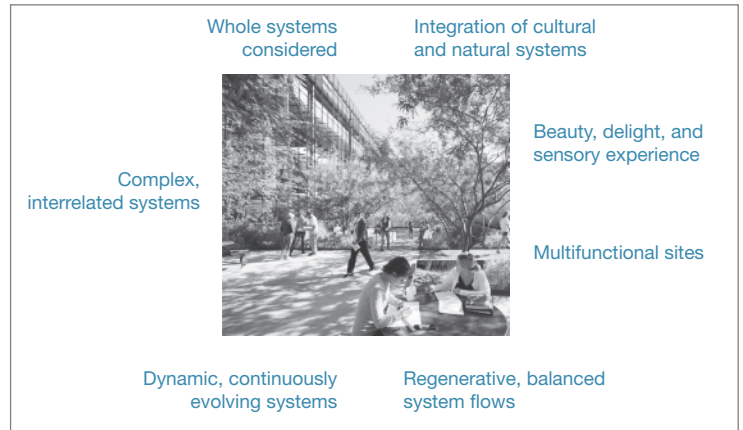
An ecosystem is defined as “a dynamic complex of plant, animal, and microorganism communities and the nonliving environment interacting as a functional unit” (MEA 2005). The complexity of relationships within an ecosystem makes them nearly impossible to replicate exactly, even in ecological restoration projects. Therefore, that should not be the aim of sustainable site design. Instead, ecosystem functions can offer a model for the complex, functional, adaptive systems of sustainable sites. We can learn from the way that ecosystems work to design living site systems that can interface in a positive way with ecosystems and provide ecosystems services.

Some characteristics of ecosystems that can offer lessons for sustainable site design are (Lowe 2002):

- ▶ Efficiency and productivity are in dynamic balance with resiliency.
- ▶ Ecosystems remain resilient in the face of change through a high biodiversity of species organized in a complex web of relationships.
- ▶ The web of relationships is maintained through self-organizing processes.
- ▶ Each individual in a species acts independently yet its activity patterns cooperatively mesh with the patterns of other species. Cooperation and competition are interlinked and held in balance.
- ▶ Waste from one process is food for another. There is no waste in nature.
- ▶ The sole source of power for ecosystems is solar energy.
- ▶ Feedback loops can move systems toward balance.

## Attributes of a Sustainable Site

Landscapes are the place where human and natural systems come together; thus they are uniquely positioned to foster both ecosystem and cultural health and well-being if they are designed and operated with sustainability aims in mind. Sustainable sites possess many unique qualities that can be quite different from conventionally designed sites. Sustainable sites are comprised of complex, interrelated, living dynamic systems that are often wholly unique to a particular place. Cultural and natural systems are well integrated, and closed-loop, balanced systems are constantly managed and adapted either by natural processes or by human intervention to ensure positive flows of resources. The following describes in more detail the unique attributes of sustainable sites and the processes that will create and sustain their function (Figure 1-7).



(Project design by Ten Eyck Landscape Architects; Photo by Bill Timmerman)

**FIGURE 1-7:** Sustainable sites are comprised of complex, interrelated, living dynamic systems that are often wholly unique to a particular place. Cultural and natural systems are well integrated, and closed-loop, balanced systems are constantly managed and adapted either by natural processes or by human intervention to ensure positive flows of resources.

### COMPLEX INTERRELATED SYSTEMS

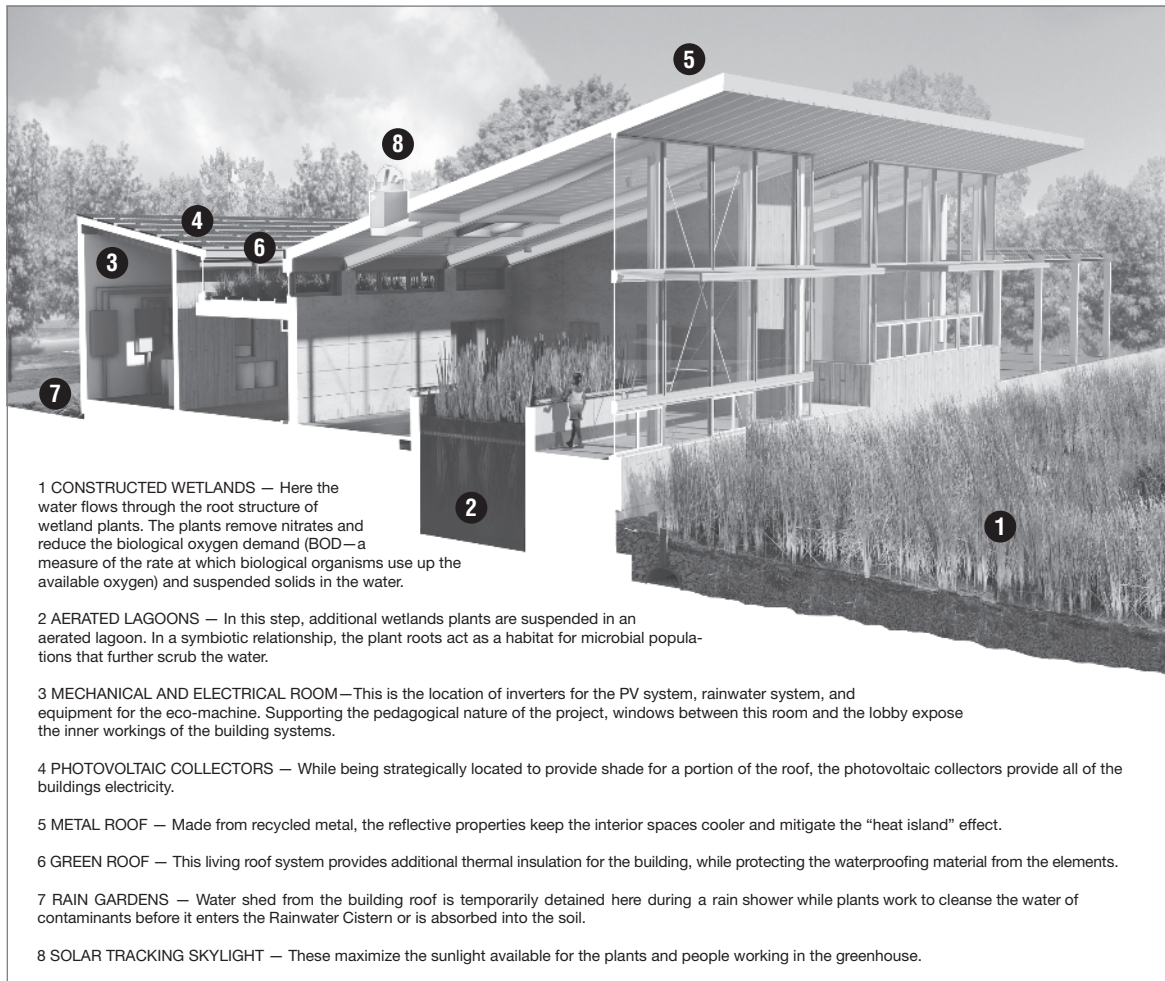
Sustainable sites are comprised of complex interrelated systems of water, vegetation, fauna, soil, materials, and culture. Healthy relationships among these systems are critical to achievement of a sustainable site as they are all tightly woven together, both impacting and supporting each other. For example, stormwater quality can be improved through pollutant removal by plants and soil, yet stormwater flow across sparsely vegetated soil can carry valuable topsoil into receiving waters, causing sedimentation and loss of soil fertility. Decisions about paving materials directly impact water quality, air quality, and soil and vegetation health both on and off the site. Planting design impacts habitat value, water use, and building energy use. Cultural systems are uniquely intertwined with these natural systems—both in negative and positive ways.

### WHOLE SYSTEMS DESIGN

Whole systems design engages complex systems across their entire spectrum—from building to site to region. Design of whole systems can maximize positive relationships both within a system and with other systems (Figure 1-8). For example, it's not enough to just infiltrate

stormwater on a site without considering its potential to contribute to the water supply for a project or its potential role for treatment of wastewater from the building onsite.

Consideration of whole, interrelated systems will likely give rise to design synergies. For instance, installation of a green roof can benefit water, faunal, energy, material, and atmospheric systems. And if a project is engaging in a voluntary rating system, like SITES or LEED (Leadership in Energy and Environmental Design), these synergies resulting from whole systems design can result in achievement of multiple credits.



**FIGURE 1-8:** The water systems of the Omega Center for Sustainable Living buildings and landscape were conceived holistically. All water is used and purified in a closed hydrological loop. The project draws water from deep wells that tap the aquifer below the campus for building uses. Wastewater is treated in the EcoMachine then released into the onsite subsurface flow wetland where it is allowed to infiltrate the ground, eventually replenishing the groundwater supply.



## INTEGRATION OF CULTURAL AND NATURAL SYSTEMS

The health of cultural and natural systems is inextricably linked (Wilson 1984). Cultural and natural systems can impact each other in both positive and negative ways. Development of the built environment has, more often than not, negatively impacted natural systems of a site, but it is possible for cultural and natural systems to coexist and even enrich each other. In addition to life-sustaining ecosystem services, the psychological benefits of interaction with natural systems are increasingly important as a growing percentage of the population resides in urban areas. Visual access to natural areas can increase worker productivity, student learning, and healing of hospital patients. Opportunities to occupy landscapes can reduce feelings of stress, anxiety, and aggression and restore calm in our increasingly fast-paced world; and recreational opportunities in built landscapes can contribute to physical fitness and improved human health.

## BEAUTY, DELIGHT, AND SENSORY EXPERIENCE

The aesthetic potential of sustainable landscapes is a crucial aspect of sustainable cultural systems. Beauty, delight, and the sensory qualities of a designed landscape are important for human health and human connection to natural systems and processes. Elizabeth Meyer, in “Sustaining Beauty: The Performance of Appearance,” contends that landscape architects and designers have the unique responsibility to make “places that are constructed performing ecosystems and constructed aesthetic experiences.” She emphasizes the “performance” of a landscape’s appearance and argues that “the experience of beauty should have as much currency in debates about what a sustainable landscape might, and should, be as the performance of its ecological systems” (Meyer 2008).

Meyer maintains that “it will take more than ecologically regenerative design for culture to be sustainable, that what is needed are designed landscapes that provoke those who experience them to become more aware of how their actions affect the environment, and to care enough to make changes.” Aesthetically engaging environmental experiences, including beauty, can “re-center human consciousness from an egocentric to a more bio-centric perspective” (Meyer 2008).

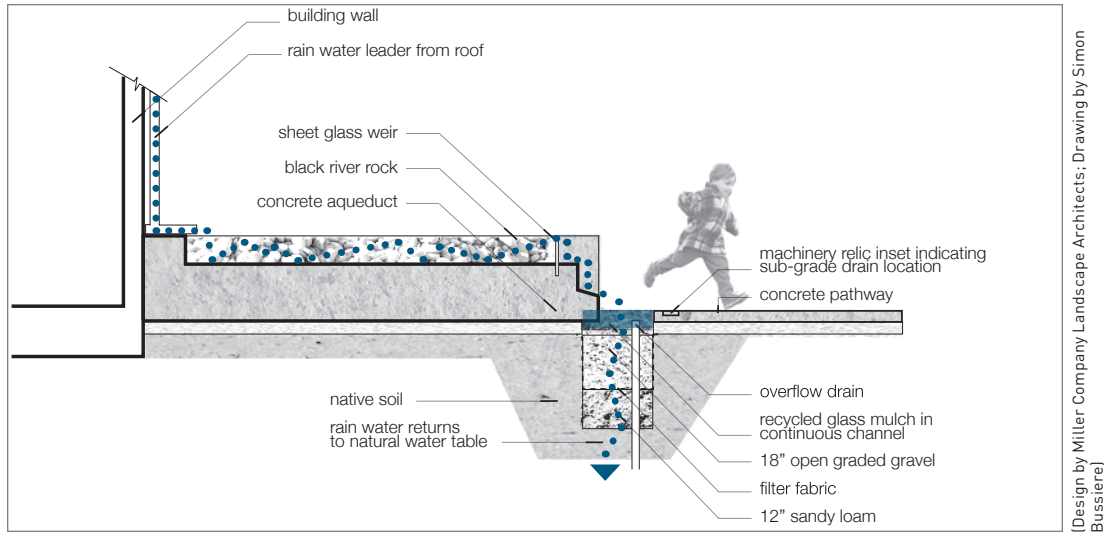
The eco-revelatory potential of sustainable site design, revealing natural processes to site occupants, holds potential to foster an enduring bond between humans and nature, increasing the likelihood of their healthy coexistence (Figures 1-9 and 1-10).



(Design by Miller Company Landscape Architects)

**FIGURE 1-9:** This stormwater feature at the Pacific Cannery lofts in Oakland, CA, brings roof rainwater down past a bench next to the front door of a unit, connecting residents to the natural processes of rainfall.





**FIGURE 1-10:** This section through the Pacific Cannery Lofts stormwater feature illustrates water flow through a concrete seatwall aqueduct into a recycled glass infiltration trench “river” where it infiltrates the garden soil.

## MULTIFUNCTIONAL SITES

Sustainable sites are designed for multiple functions and must simultaneously create environmental, economic, social, and aesthetic value. For example, tree planting in urban areas

must consider heat island issues, habitat provision, carbon sequestration, stormwater mitigation, and aesthetics. And site systems can be productive as well as decorative. A corporate landscape can produce food as well as offer places for worker relaxation. Water can be harvested, spilling into an open cistern water feature, and then be used for irrigation or toilet flushing. A bicycle trail right-of-way can be planted with berry bushes and other plants that produce food, offer a connectivity corridor for wildlife between patches of woodland and a recreational opportunity for exercise. An integrated approach to the design of sites will promote these values and demonstrate that functional sites can complement, not displace, aesthetic value (Figure 1-11).

**FIGURE 1-11:** A multifunctional space, this accessible, sunken outdoor classroom of permeable stabilized granite at the Underwood Family Sonoran Landscape Laboratory at the University of Arizona provides a place for student study, building projects, and gathering. It serves an alternative function of water detention during desert storm events.



## REGENERATIVE BALANCED SYSTEMS

An important aspect of the Bruntland definition of sustainability is provision for intergenerational equity—in other words, preserving the ability of future generations to meet their needs. This idea necessitates the design of regenerative systems as opposed to systems that consume and degrade resources, compromising the possibility of their use for future generations. A regenerative site system will balance or achieve positive resource flows and create closed-loop systems where “waste” from one process is “food” for another. For example, a regenerative water system might capture rainwater from an impermeable surface, use it to irrigate food crops, then allow the excess water in the soil to evaporate or feed the water table, returning it to the natural water cycle.

## DYNAMIC, CONTINUOUSLY EVOLVING SYSTEMS

Like natural ecosystems, sustainable sites are comprised of dynamic, living systems that will grow, change, and require adaptation over their life. Resilience is the ability of an ecosystem to withstand or recover from disturbance or stress (Walker and Salt 2006). Disturbances such as drought, floods, disease, and urbanization will all impact an ecosystem’s ability to perform specific functions and provide ecosystem services. Resilience science argues that complex ecological systems possess multiple protective mechanisms to help buffer these stresses and return to a stable state. And change, even drastic change, offers new opportunities for positive developments, change, and adaptation.

Sustainable site design can foster the natural processes of resilience by integrating with natural systems and planning for change, adaptation, and resilience over time. And like the concept of resilience in ecosystems science, which argues that change, even drastic change, offers new opportunities for positive developments, change and adaptation in sites, if guided well, can offer many positive opportunities. Additionally, if sites are designed with the possibility of eventual change and adaptation in mind, the life of the site will likely be longer than that of a more constrained site form. Recognition of this attribute is critical to the function of sustainable sites as postoccupancy management activities must support and guide the change that will occur both naturally and intentionally. The traditional idea of maintenance (“to maintain”) implies a static landscape where change is halted and brought back to the original design concept. These current maintenance practices do not support the living, changing, and evolving ecosystems and human systems of sustainable sites.

Uncertainty, change, and uniqueness must be the design approach as we design dynamic living systems. Natural conditions are not static, nor should our site design solutions be. Site systems must perform over the life of the landscape—and there should be room for change, and opportunities for adaption must be built into our places (Figure 1-12).



(Design by Hargreaves Associates; Photo by John Golings)

**FIGURE 1-12:** Louisville's Waterfront Park by Hargreaves Associates is in the 100-year flood zone and parts of the park flood regularly. The park spaces were designed to accommodate these flood events, and the riparian edges along part of the park edge are designed to change and adapt as a natural riparian edge would.

## Design and Management Processes for Sustainable Sites

The characteristics of sustainable sites discussed above previously can be supported by design and management processes, such as: interdisciplinary collaboration on complex systems, engagement of a wide variety of project stakeholders during both design and operation of the site, measurement and verification of site system performance, and post-occupancy management and monitoring (Figure 1-13). These processes are discussed in greater detail in Chapter 2.

### MEASUREMENT AND ECOLOGICAL ACCOUNTING FOR BALANCED SYSTEMS

In order to achieve a balance or positive flow of resources for truly regenerative design, one must quantify the inputs and outputs through ecological accounting and lifecycle analysis activities both during site design and on an ongoing basis during site operation. Results of ecological accounting and ecosystem services measurement can inform initial design decisions over many points in the design process, and can continue to inform management and adaptation decisions over the life of the landscape. Performance benchmarks of some

SITES credits, such as those related to stormwater management, water efficiency, and organic waste, require ecological accounting activities and strive for a zero or positive balance flow of resources and closed loops.

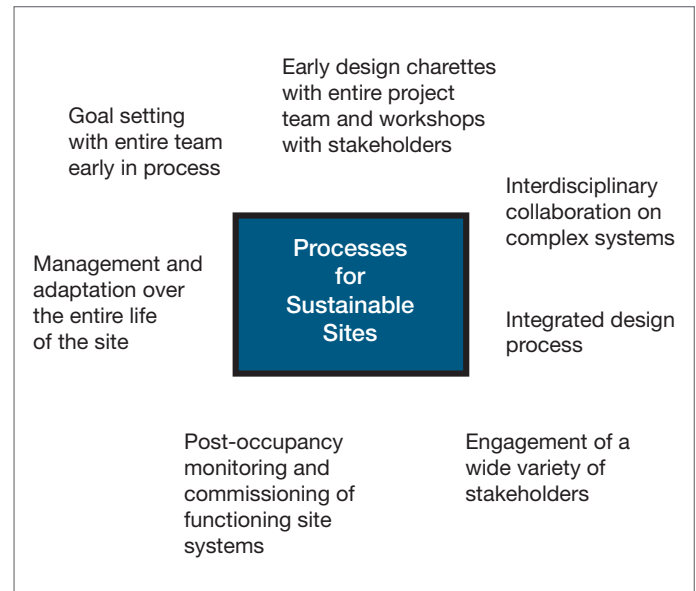
The activities of ecological accounting and life-cycle accounting can be complex and time consuming. And it is extremely complicated to quantify all input and output flows for multiple processes; however, if measurement begins in the design process, activities can proceed more easily into systems during site operation. For instance, if irrigation efficiency metrics are established during design, efficiency during operation will be easily measured against the established metrics.

Temporal fluctuations must be considered during accounting activities as well, adding an additional challenge to quantification. Human and natural systems will vary with changing seasons, variations in weather patterns, and unexpected human interventions. For example, a cistern for captured rainwater storage in California may stand empty from June to October just when one would like to have the irrigation water, then it may fill and overflow during the four-month rainy season when irrigation water is not needed. Or solar lights at an office complex might provide lighting in the evening after the sun goes down, but be “out of juice” at 7 a.m. when it is still dark as office workers arrive for work.

Given the challenging nature of ecological accounting activities, the results and methods of quantification should be shared with other professionals to assist in their activities. There are a growing number of databases and venues including and beyond peer-reviewed journals where this type of information can be shared.

## INTERDISCIPLINARY COLLABORATION ON COMPLEX SYSTEMS

Design of whole, sustainable systems necessitates a broader design approach with expertise and input from multiple disciplines. The environmental and social issues that must be addressed in sustainable design are too complex for just landscape architects or just civil engineers. By necessity, the sustainable site design process must include multiple disciplines that will collaborate on the complex, interrelated systems. For example, decisions about water systems



**FIGURE 1-13:** Sustainable sites require design and management processes that may vary from conventional practices, such as: integrated design, interdisciplinary collaboration on complex systems, engagement of a wide variety of project stakeholders during both design and operation of the site, measurement and verification of site systems performance, and postoccupancy management and monitoring.

for a project may be addressed by landscape architects, civil engineers, architects, mechanical engineers, and hydrologists in collaboration. They may even collaborate with city planners and code officials on innovative approaches to water capture, conservation, and reuse.

### **ENGAGE A WIDE RANGE OF STAKEHOLDERS IN BOTH DESIGN AND MANAGEMENT OF THE SITE**

A highly collaborative, multidisciplinary process can support the design and operation of complex and interrelated systems. An inclusive and integrated design team will vary by project, but is typically comprised of a variety of consultants, owners, contractors, and stakeholders (including users, citizens, regulators, and site managers). Early engagement of the entire team in visioning, goal-setting, and budgeting can ensure ethical and equitable decision making and socially sustainable sites. In addition, inclusion of a wide variety of stakeholders, such as future users and management personnel, during design phases will increase the chances of continuity of design intent and maximize the potential for good management decisions in the future.

Inclusion of a wide range of project stakeholders can necessitate intensive education, advocacy, and persuasion efforts by designers, other consultants, and/or proponents of sustainable site design. These efforts must often be tailored to the individual concerns of the stakeholders, and information provided can take the form of cost-benefit analysis, performance and maintenance information, and case study research. Some forums for stakeholder inclusion are charrettes, workshops, or public meetings. It is important to note that broad stakeholder involvement can increase the likelihood of some participants having a continued role in the operation of the site.

### **POSTOCCUPANCY MANAGEMENT AND MONITORING**

A crucial activity to ensure positive function for the dynamic systems of sustainable sites are feedback loops of postoccupancy monitoring, management, and adaptation. Continued involvement of the design team postconstruction can be a challenge, as many owners do not understand the importance of ongoing management with input from the professional consultants. Development of monitoring protocols and management plans can guide these activities over the life of the landscape and can connect design intentions with ongoing management activities. This book, like the Sustainable Sites Initiative, takes an unprecedented approach to the design and management of sustainable sites in that it thoroughly addresses postconstruction management activities.

## **Goals of Sustainable Sites**

Sustainable design holds the potential to heal unhealthy sites and regenerate many of the services of damaged ecosystems. Therefore, projects should avoid development of healthy

sites where an intervention might actually degrade the existing systems, and focus new development on damaged sites where design can heal degraded ecosystems. A major facet of this idea is to “do no harm” with design. The impacts, both onsite and away from the site, should be considered for every design decision. Sensitive sites should be avoided, and sensitive areas on the development site should be protected and untouched.

## USE CAUTION IN DEVELOPMENT, DON'T WAIT FOR PROOF OF HARM

Development intervention in complex systems, both cultural and ecological, can have unintended and unexpected consequences for both on- and offsite systems. The Precautionary Principle, as summarized in 1998 by the Wingspread Conference by the Science and Environment Health Network, states, “When an activity raises threats of harm to human health or the environment, precautionary measures should be taken even if some cause and effect relationships are not fully established scientifically.” In site development, the precautionary principle can be applied to decisions made about site interventions. Caution should be exercised, and where impacts of the decisions are unknown or unproven, the measure should likely be avoided.

## STRIVE FOR THE HIGHEST BENEFIT FIRST

The highest priority of any development should be to preserve healthy ecosystems, to conserve natural resources, and to regenerate damaged ecosystems. For various reasons, the best strategy or approach will not always be possible; therefore, the next best approach should be considered with every attempt made to maximize the most sustainable outcome. It is important to note that priorities will vary depending on region, owner goals, cultural needs, and local ecosystem issues. Establishment of priorities and goals early in the design process will assist the design team in evaluating various approaches to site development.

The depth to which a design strategy will meet the definition of sustainable design will vary. Many strategies may reduce harm by “conserving,” “reducing,” or “recycling” resources. They may not achieve the “balancing,” “producing,” or “regenerating” that is necessary to meet the true definition of sustainability—meeting the needs of the present without compromising the ability of future generations to meet their needs. Table 1-2 provides a few examples illustrating a range of approaches to water, vegetation, soils, materials, and energy systems.

Regenerative design, or truly sustainable design, is the ultimate goal; however, any progress toward this and away from wasteful, destructive site design is a positive thing. This book acknowledges that any effort toward sustainability is not too small, even though larger steps are preferable. The ultimate goal is a shift in the way we think about the Earth, our place in it, and its resources. But many small steps can add up to large impacts, and small steps taken



over and over can result in significant change to site development and management practices. Radical change, if it can be accomplished, is a great thing, but the reality is that incremental changes may be a much more realistic approach within the mainstream design and construction industry.

TABLE 1-2: Range of Approaches to Sustainable Site Design and Operation

WATER SYSTEMS			
<b>Conserve</b> Use efficient irrigation, specify low-water-use plants, employ low-impact development.	<b>Reuse</b> Harvest rainwater, capture graywater, reuse for irrigation, toilet flushing, sprinklers.  Infiltrate small storms' rainwater onsite.	<b>Balance</b> Net zero use. Capture rain and all wastewater (both black water and graywater); purify, store, reuse onsite for <i>all</i> water needs, and provide some to other sites.  Infiltrate and cleanse rainwater.	<b>Regenerate</b> Capture rain and all wastewater; purify, store, reuse onsite for <i>all</i> water needs, and provide some to other sites.  Match predevelopment hydrologic conditions.
VEGETATION			
<b>Preserve</b> Minimize removal of existing native vegetation.  Identify critical vegetation areas and protect during the development process.	<b>Protect</b> Do not introduce exotic species that could naturalize in the local environment. Do not use chemical treatments that pose a threat to the ecosystem.	<b>Restore</b> Remove invasive plant species.  Specify plants to create a native plant community. Restore appropriate plant biomass.	<b>Regenerate</b> Maximize ecosystem services of vegetation. Use vegetation to reduce heating and cooling loads on buildings, cleanse stormwater, minimize urban heat island effect, and provide habitat.
SOILS			
<b>Preserve</b> Protect healthy soils from damage due to construction and development. Prevent access to healthy soil areas during the construction process.	<b>Reuse</b> Reuse healthy soils that cannot be protected onsite. Take care to reduce damage during the removal and replacement process.	<b>Restore</b> Use appropriate techniques to remediate damaged soils that will restore desired physical, chemical, or biological properties lost during the development process or due to previous site activity.	<b>Regenerate</b> Use soil restoration and soil and vegetation management that will create opportunities for soil to regenerate over time, maintaining healthy soils and rebuilding damaged soils.



## MATERIALS AND RESOURCES

### Reduce and Recycle

Use recycled content products and reprocessed materials. Recycle construction and demolition debris.

### Reuse

Salvage and reuse construction and demolition materials. Design for disassembly and deconstruction.

### Balance

Do not rebuild. Reuse structures in place. Use durable materials and detail durable structures.

### Regenerate and Renew

Design sites and structures for adaptation and reuse.

Use living materials for structures.

Use renewable materials.

## ENERGY SYSTEMS

### Reduce

Design to reduce heating and cooling loads on buildings and maximize the benefits of solar and wind energy. Design to reduce heat island energy impacts.

### Offset

Purchase green energy credits and carbon offsets for building and site energy needs. Use solar-powered pumps, lighting, and site fixtures.

### Renew

Use passive and active energy production methods that rely on natural systems such as sun, wind, and water for all the energy needs of the site and building.

### Produce

Use passive and active energy production methods that rely on natural systems such as sun, wind, and water. Produce more energy than is needed for the site and building, and sell back to the local energy provider.

## CULTURAL SYSTEMS

### Preservation

Identify the social and economic needs of the community and engage the community and other stakeholders in the design process.

### Rehabilitation

Consider how the site will educate, build community, and create a sense of place. Create a program that will increase mental health, physical health, and social equity.

### Restoration

Use the project to encourage the development of job skills and create economic opportunities during and after development.

### Reconstruction

Design for human comfort and accessibility. Design for physical activity and mental restoration. Design for social interaction and community building.

## The Sustainable Sites Initiative

The Sustainable Sites Initiative (SITES) is an interdisciplinary endeavor by the American Society of Landscape Architects, the Lady Bird Johnson Wildflower Center at the University of Texas at Austin, the United States Botanical Garden, and allied stakeholder organizations to promote sustainable site planning and design, construction, and maintenance practices. The Initiative developed and administers voluntary national guidelines and performance

benchmarks to promote sustainable land development and management practices for the maintenance and regeneration of ecosystem services (Table 1-3).

The Initiative's central message is that any landscape has potential to contribute to ecosystem services and can address urgent environmental issues, such as global climate change, loss of biodiversity, and resource consumption, if properly designed and managed. The guidelines and performance benchmarks can be applied to a range of sites, with or without buildings; rural, suburban, and urban; large or small. Like this book, the guidelines are intended to be used by those who design, construct, operate, and maintain landscapes including landscape architects, engineers, developers, architects, planners, maintenance crews, restoration ecologists, horticulturalists, governments, and land stewards.

The *Guidelines and Performance Benchmarks* for soils, hydrology, vegetation, human health and well-being, and materials selection were developed by a multidisciplinary group of technical experts and a steering committee representing 11 stakeholder groups. Providing benchmarks based on sustainable outcomes, the guidelines are performance based rather than prescriptive instructions to encourage flexible use of technologies and strategies appropriate to each project, site condition, and region.

The *Guidelines and Performance Benchmarks* are organized as a series of prerequisites and credits for creating sustainable sites. The prerequisites are required and must be achieved for a site to participate in this voluntary program. Achievement of credits is optional, but a number of them must be attained in order for a project to be recognized as a sustainable site by SITES. Many credits offer a range of points depending on the level of achievement of the credit. For instance, a site may be awarded one credit for reducing irrigation use by 50 percent below the standard baseline and may receive an additional point for a 100 percent reduction. Some credits are worth more points than others based on carefully considered prioritization by the technical and steering committees.

SITES prerequisites and credits can be downloaded from the Sustainable Sites website. As they are periodically updated and revised, they are not listed in this book, although each chapter contains a summary of SITES credit content related to each chapter topic. SITES prerequisites and credits are organized into sections reflecting a typical site development project process. The sections are:

- ▶ Site Selection
- ▶ Predesign Assessment and Planning
- ▶ Site Design: Water
- ▶ Site Design: Soil and Vegetation
- ▶ Site Design: Materials Selection
- ▶ Site Design: Human Health and Well-Being
- ▶ Construction
- ▶ Operations and Maintenance
- ▶ Monitoring and Innovation

**TABLE 1-3: SITES Guiding Principles of a Sustainable Site****Do no harm.**

Make no changes to the site that will degrade the surrounding environment. Promote projects on sites where previous disturbance or development presents an opportunity to regenerate ecosystem services through sustainable design.

**Precautionary principle**

Be cautious in making decisions that could create risk to human and environmental health. Some actions can cause irreversible damage. Examine a full range of alternatives—including no action—and be open to contributions from all affected parties.

**Design with nature and culture**

Create and implement designs that are responsive to economic, environmental, and cultural conditions with respect to the local, regional, and global context.

**Use a decision-making hierarchy of preservation, conservation, and regeneration.**

Maximize and mimic the benefits of ecosystem services by preserving existing environmental features, conserving resources in a sustainable manner, and regenerating lost or damaged ecosystem services.

**Provide regenerative systems as intergenerational equity.**

Provide future generations with a sustainable environment supported by regenerative systems and endowed with regenerative resources.

**Support a living process.**

Continuously reevaluate assumptions and values and adapt to demographic and environmental change.

**Use a systems thinking approach.**

Understand and value the relationships in an ecosystem and use an approach that reflects and sustains ecosystem services; reestablish the integral and essential relationship between natural processes and human activity.

**Use a collaborative and ethical approach.**

Encourage direct and open communication among colleagues, clients, manufacturers, and users to link long-term sustainability with ethical responsibility.

**Maintain integrity in leadership and research.**

Implement transparent and participatory leadership, develop research with technical rigor, and communicate new findings in a clear, consistent, and timely manner.

**Foster environmental stewardship.**

In all aspects of land development and management, foster an ethic of environmental stewardship—an understanding that responsible management of healthy ecosystems improves the quality of life for present and future generations.

## Leadership in Energy and Environmental Design (LEED)

The LEED Green Building Rating Systems™ are voluntary national standards for developing sustainable and high-performance buildings and sites. LEED provides third-party verification that a building or community was designed and built using strategies aimed at improving performance across metrics such as: energy savings, water efficiency, Carbon dioxide emissions reduction, improved indoor environmental quality, and stewardship of resources and sensitivity to their impacts (USGBC 2009).

LEED is a product of the U.S. Green Building Council (USGBC), a national coalition of building industry professionals, contractors, policy makers, owners, and manufacturers. Their stated mission is “to transform the way buildings and communities are designed, built, and operated, enabling an environmentally and socially responsible, healthy, and prosperous environment that improves the quality of life.” Council members work in a committee-based, consensus-focused way to develop LEED products and resources, policy guidance, and educational and marketing tools to facilitate the adoption of green building. The council develops alliances with industry and research organizations and with federal, state, and local governments.

The USGBC states that “LEED™ was created to provide the people who design, build, and operate buildings with an organized consensus benchmark for defining and evaluating green buildings.” USGBC members developed and continue to refine the system through a membership consensus process.

Registered projects can choose from a variety of sustainable strategies and earn points toward a certified project in the following key areas:

- ▶ Sustainable Sites
- ▶ Water Efficiency
- ▶ Energy & Atmosphere
- ▶ Materials & Resources
- ▶ Indoor Environmental Quality
- ▶ Locations & Linkages
- ▶ Awareness & Education
- ▶ Innovation in Design
- ▶ Regional Priority

The USGBC offers a wide range of LEED Rating Systems that differ by project type. By meeting enough credits, a project can gain certification under one of the following:

- ▶ LEED for New Construction and Major Renovations
- ▶ LEED for Existing Buildings: Operations & Maintenance
- ▶ LEED for Commercial Interiors
- ▶ LEED for Core & Shell
- ▶ LEED for Schools
- ▶ LEED for Retail
- ▶ LEED for Healthcare
- ▶ LEED for Homes
- ▶ LEED for Neighborhood Development

## THE RELATIONSHIP BETWEEN LEED AND SITES

SITES was designed to complement LEED® (Leadership in Energy and Environmental Design) Green Building Rating System™ and other rating systems that focus on sustainability in buildings. While LEED does contain credits for sites, it addresses sustainable site issues in a limited way. The US Green Building Council and the Sustainable Sites ® Initiative are partnering to align and integrate credits in future editions of the rating systems.

## THE CONTENTS AND STRUCTURE OF THIS BOOK

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The *Sustainable Sites Handbook* is offered as a comprehensive resource for design professionals engaging in sustainable site planning, design, construction, maintenance, and monitoring activities. It offers current and detailed information on principles, strategies, technologies, tools, and references for sustainable sites. Diagrams, charts and tables, construction details, photos, calculations, and specification considerations are provided for a broad range of technologies and strategies.

While this book is intended to be a resource for designers who are either formally or informally using the SITES guidelines and performance benchmarks, it will not discuss specific SITES prerequisites and credits as they are continually being altered and refined. In addition, SITES credits are performance based, not prescriptive. There are a wide variety of strategies and technologies that can be employed to achieve a given credit, and this book offers technical information on these strategies and technologies. It is important to note also that use of one technology can achieve multiple credits or sustainable goals. For

example, a green roof can reduce stormwater quantities, provide habitat, reduce energy use for building air-conditioning, and contribute to reductions in the heat island effect.

Chapter authors are some of the same experts who carefully shaped the SITES rating tool, ensuring thorough coverage of the broad range of topics related to sustainable site systems.

This book is structured along the environmental and human systems of sustainable sites and is organized into the following chapters:

- ▶ Chapter 1, Introduction
- ▶ Chapter 2, Predesign: Assessment, Planning, and Site Selection
- ▶ Chapter 3, Site Design: Water Systems
- ▶ Chapter 4, Site Design: Vegetation Systems
- ▶ Chapter 5, Site Design: Soil Systems
- ▶ Chapter 6, Site Design: Materials and Resources
- ▶ Chapter 7, Site Design: Human Health and Well-Being Strategies
- ▶ Chapter 8, Site Occupancy: Operations, Maintenance, and Monitoring

**Chapter 1, Introduction**, lays out the ideological basis on which the book rests and introduced the Sustainable Sites Initiative. Following are summaries for the additional seven book chapters.

**Chapter 2, Predesign: Assessment, Planning and Site Selection**, discusses activities that should happen prior to the design phase of a sustainable site project. Discussion of site selection focuses on avoidance of inappropriate sites, such as those on prime farmland, adjacent to wetlands, floodplains and sensitive ecosystems, habitat of endangered species, and fireprone areas. Site types (e.g., greenfield, brownfield, grayfield, etc.) are defined and opportunities and design considerations for each are identified. Site assessment, inventory, and analysis techniques to better understand the regional context, climate, and energy issues, microclimates, hydrology, soils, vegetation, materials and resources, and cultural contexts are summarized. Techniques of integrated design, project design team formation, and engagement of stakeholders in design are discussed relative to goal-setting, performance target establishment, and programming.

**Chapter 3, Site Design: Water Systems**, leads the site design chapters with detailed information on the integrated strategies of sustainable water systems for stormwater, wastewater, and conservation of water. Discussion of stormwater technologies and strategies is guided by the following objectives: to control downstream flow rates, to reduce nonpoint source pollution, to infiltrate water at predevelopment levels, and to protect groundwater. Practices discussed are those that: reduce runoff, mitigate runoff by emulating

evapotranspiration and infiltration, convey runoff from larger events, protect or restore receiving water bodies, and maintain sediment and control erosion. Water conservation strategies are offered for rainwater and graywater capture, efficient irrigation, and water features using captured rainwater as the makeup water supply.

Chapter 3 also discusses onsite wastewater treatment techniques for primary, secondary, and tertiary treatment and disinfection. And systems such as solar aquatic systems and surface and subsurface constructed wetlands are explained. Last, options for reuse of treated water are offered.

**Chapter 4, Site Design: Vegetation Systems**, emphasizes the wide variety of ecosystem services provided by vegetation and provides information on fostering healthy plant communities in a variety of settings. It discusses criteria for appropriate plant and plant community selection, use of salvaged plants, and sustainable nursery and plant production practices. Use of plants in urban settings is addressed along with considerations for use of vegetation in stormwater structures, green roofs, and living walls. Vegetation protection techniques, ecological restoration, and firewise landscape principles are also discussed.

**Chapter 5, Site Design: Soil Systems**, emphasizes healthy soil as the foundation of a sustainable site. It presents detailed techniques for soil assessment, preservation, and management based on soil texture, organic matter, structure, compaction, volume, drainage, chemical status and nutrient availability, soil pH, biological activity, cation exchange capacity, soluble salts, and contamination. Soil replacement strategies, specialized soils, and soil management plans are also discussed.

**Chapter 6, Site Design: Materials and Resources**, addresses techniques to minimize environmental and human health impacts of construction materials across their entire lifecycle. It provides methods to evaluate impacts of materials and techniques of site and regional assessment for materials and resources. The chapter offers strategies for resource efficiency of materials such as deconstruction, material reuse, design for durability, and use of recycled content and reprocessed materials. Strategies to reduce the environmental and human health impacts are provided for the following basic site construction materials: concrete, stone and aggregates, brick, earthen materials, asphalt pavement, plastics, metals, biobased materials, and wood.

**Chapter 7, Site Design: Human Health and Well-Being**, offers techniques for the design of culturally sustainable sites beginning with techniques for assessing a site's social setting. It offers design strategies for sustainability awareness and education, equity in site development, construction and use, site accessibility, wayfinding, and safety. Design considerations for physical activity, restorative settings, and social interaction and community building are provided; and techniques for preserving historic and cultural features and patterns are offered.



**Chapter 8, Site Occupancy: Operations, Maintenance, and Monitoring**, offers detailed information for ongoing function of sustainable site systems during the site operations phase. Techniques for incorporating operations, maintenance, and monitoring considerations into site design are offered as well as a detailed discussion of the development of maintenance and management plans. Operations and maintenance strategies are provided for: recycling site waste from operations and maintenance, nourishing soil with sustainable soil amendments, integrated pest management, controlling and managing invasive plants, maintaining landscapes to reduce risk of catastrophic wildfire, reducing environmental and human health impacts from maintenance equipment, maintaining bioretention features, green roofs, and green walls, conserving potable water and treating makeup water in created water features, and maintaining pavements. The chapter discusses techniques of monitoring sites to inform active and adaptive stewardship.

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