1 Introduction to Green Infrastructure

Development and urbanization change the landscape from forests, to farms, to towns and cities. This development increases impervious surface by adding pavement and rooftops, while decreasing vegetated cover. Land disturbance from development also mobilizes sediment and releases nutrients to lakes, streams and wetlands - fundamentally changing aquatic habitats and their potential uses.

This change in the landscape decreases groundwater recharge and increases the pollutant load, frequency and volume of surface stormwater runoff.

A major focus of this guide is to define green infrastructure as a sustainable approach to stormwater management by employing strategies to maintain or restore natural hydrology. Such strategies include infiltration, evapotranspiration, capture and reuse of stormwater.

This guide is not intended to be a design manual. The purpose of this guide is to present green infrastructure as a strategic approach to land development that addresses ecological, economical and social needs, also known as the triple bottom line. It is intended to aid municipalities and their development communities in a general understanding of how to incorporate green infrastructure into the community.

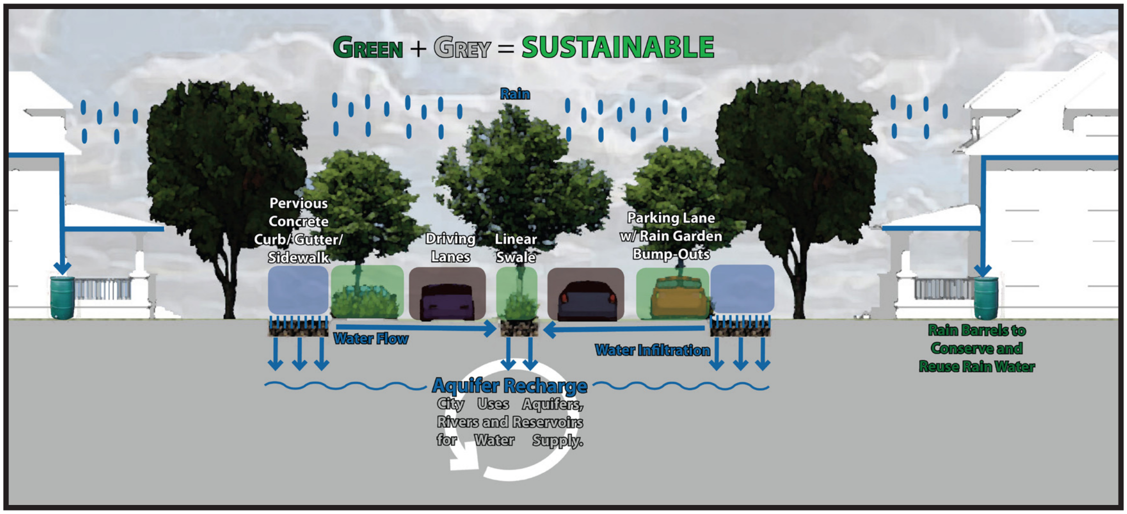


Figure 1.1 Integration of Green and Grey Infrastructure. Source: Williams Creek Consulting

"Most homebuyers today favor housing developments that include green space, biking and pedestrian paths, and natural areas." (McMahon, 2000).

This guide may also motivate a community to develop an integrative green infrastructure plan as a "greenprint" for conservation in the same way gray infrastructure plans are prepared for roads, sewers and utilities. A plan that integrates green and gray infrastructure can create a framework for future growth while preserving significant natural resources for future generations. It can also complement goals to reduce combined sewer overflows.

Green infrastructure plans and sustainable site development plans can help reduce opposition to new development by assuring civic groups and environmental organizations that growth will occur only within a framework of expanded conservation and open space lands. Communities and their partners can make green infrastructure an integral part of local, regional and state plans and policies (Benedict and McMahon, 2002).

Figure 1.2 shows some examples of on-site green infrastructure practices.

There are issues that need to be considered when locating and siting any stormwater management feature, and green infrastructure is no exception. Not all practices are appropriate or effective in a given situation. For example, porous pavement should not be used in highly contaminated areas unless engineered to avoid risks to groundwater. In another example, rain barrels can significantly contribute to volume reduction only if they are used in conjunction with other practices such as rain gardens that more effectively disconnect rooftop runoff from primary conveyance. (Rain barrels that are directly connected to the conveyance system are not very effective in addressing runoff volume reduction due to their limited storage capacity.)

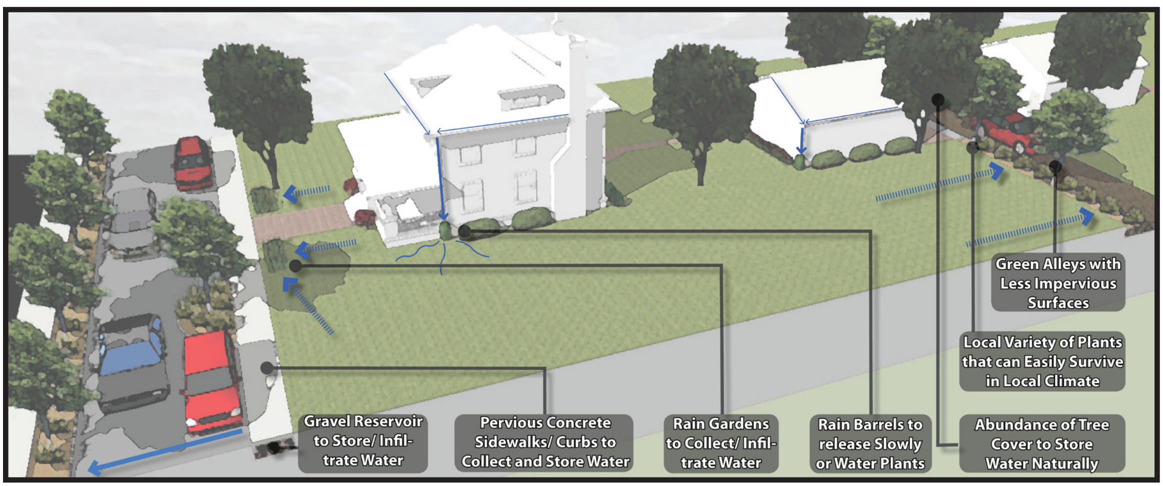


Figure 1.2 Examples of on-site green infrastructure practices. Source: Williams Creek Consulting.

Consideration also needs to be given to maintenance costs, retrofitting costs, groundwater contamination potential, poor performance of improperly designed systems, etc. Many of these precautions are discussed later in the document, and they are discussed in more detail in the numerous design manuals of reference.

Meeting the goal of today's water quality goals in stormwater runoff requires a change in runoff management strategies. This guide contains references to many of the resources available describing the methods that can be used to help maintain or restore pre-construction runoff conditions.

Figure 1.3 Triple Bottom Line. Source: Williams Creek Consulting

1.1 Concepts, Terminology and Trends

Historical Trends

Early on, communities focused stormwater management on flood control. Many communities are now required to implement stormwater management programs to address stormwater runoff pollution. Stormwater regulations require pollution prevention to the maximum extent practicable in new and redevelopment projects. On new development projects, state-of-the-practice stormwater management is now designed to mimic pre-construction runoff conditions as a way to better control pollutant runoff. The approach is to maximize infiltration, evapotranspiration, (a combination of water evaporation and plant transpiration) and reuse.

Because stormwater management has historically focused on flood control, many structural control measures familiar to the stormwater management community were not designed to meet water quality goals. Some of the best and most familiar stormwater control measures for flood control (pipe and pond systems, for example) provide limited water quality benefit relative to retention-based structural stormwater control measures and non-structural stormwater control measures that decrease the potential volume of runoff. Wet ponds do not necessarily retain clay particles, but they do retain some fine-grained particles and can offer robust performance when properly designed and used in conjunction with upland infiltration practices. Such combinations can result in some of the most robust and best performing systems available.

Historical trends in stormwater management have not been successful enough in meeting the goals of the Clean Water Act. The conventional approach to stormwater management has been to move stormwater off-site quickly through curb, gutter and basin systems, or more recently, within the past 20-30 years, to build large dry detention facilities to manage large but infrequent storm events. But, these conventional methods do not control the increase in runoff volume due to development.

Given abundant development and the resulting increases in volume and velocity of stormwater runoff, the consequences have been degraded streams, increased flash flooding and costly repairs at an accelerated rate. The more current concepts presented in this guide are based on more than 40 years of collective effort performed to help meet the goals of the Clean Water Act and other environmental goals, as well as social and economic interests. While green infrastructure alone is not likely to meet all the water quality goals, it should be the base of any program that works effectively to minimize pollutant loading to local and interconnected waterways. Certainly other factors such as those described throughout this guide need to be addressed, but green infrastructure offers a huge improvement over conventional stormwater management practices that have relied primarily on grey infrastructure alone. The integration of green and grey infrastructure requires a different approach in designing grey infrastructure; slowing runoff down in places, rather than moving it off site as fast as possible.

Terminology

The terms sustainability, green infrastructure, low impact development, conservation development, sustainable development and others are often used interchangeably in the stormwater industry. For the purpose of this publication, many terms are self-evident or are described as they appear in context. However, a brief explanation in the origin and evolution of these terms may be helpful.

Sustainability

Sustainable practices define effectiveness in terms of financial, social and environmental benefits or a "triple bottom line." This approach bases project decisions on an analysis of the cost and benefits where there is a balance between the effects on the environment, a project's financial commitments and the community where the project is located.

In addition to improved water quality, triple bottom line benefits may include neighborhood revitalization, expanded recreational opportunities, business attraction and retention, unique and aesthetically pleasing landscapes, lower cost development and increased property values.

Green Infrastructure

Green infrastructure uses vegetation, soils, and natural processes to manage water and create healthier urban environments. At the scale of a city or county, green infrastructure refers to the patchwork of natural areas that provides habitat, flood protection, cleaner air, and cleaner water. At the scale of a neighborhood or site, green infrastructure refers to stormwater management systems designed to mimic nature by soaking up and storing water.

The green infrastructure approach to urban stormwater management is the employment of sustainable site designs that apply smaller scale systems - dispersed more widely, located closer to the sources of runoff (buildings, parking lots, etc.), and integrated with other infrastructure systems and green networks. However, the concept of green infrastructure for stormwater management originates from a broader applicability. As defined by Mark Benedict and Ed McMahon, green infrastructure is an interconnected network of natural areas and other open spaces that conserves natural ecosystem values and functions, sustains clean air and water, and provides a wide array of benefits to people and wildlife (Benedict & McMahon, 2006).

EPA defines green infrastructure as "systems and practices that use or mimic natural processes to infiltrate, evapotranspire (the return of water to the atmosphere either through evaporation or by plants), or reuse of runoff on the site where it is generated."

Large blocks of contiguous natural vegetative cover provide organic matter and nutrients to aquatic ecosystems (e.g., headwaters). Riparian vegetative zones also provide nutrients and organic material to streams. Vegetative cover maintains natural hydrology and functions as a buffer, filtering pollutants. Vegetative hubs and corridors connect terrestrial animals to sources of water and food, maintaining the food web. The extent, composition, and pattern of green infrastructure are critical components in a landscape condition assessment.

As we build needed infrastructure, like roads, sewers and water lines, every community should strive to maintain or enhance the natural resources it may displace as part of this process. Prior to disturbance, the incorporation and enhancement of these systems provide a form of natural green infrastructure that help to minimize the cost by providing natural ways to manage the rate, volume and quality of stormwater runoff. Man-made green infrastructure restores or enhances these natural systems into the built urban environment to provide similar functions and values.

Low Impact Development

About the same time green infrastructure was introduced around 1994 to reflect upon the larger green network systems in Florida, Larry Coffman was developing an on-site approach to low impact development in Prince George's County, Maryland. With limited capacity for county planning and zoning, low impact development was applied as "rain garden" requirements for back yards. However, green infrastructure has grown to encompass small scale applications and low impact development has grown to include the broader community planning level. The terms are often used interchangeably, however low impact development, conservation development and similar practices fit well under the

Impacts from Changes in the Landscape with Development and Impervious Cover		
Changes in the Landscape	**Results**	**Impacts**
Increased impervious cover, hard surfaces.	Increased stormwater runoff; increased pollutants in runoff	Degraded water quality. Eroded streambanks/degraded streams.
Removal of riparian corridor.	Increased pollutants in streams.	Eroded streambanks/degraded streams. Impaired water quality, loss of habitat.
Building in floodplain	Loss of natural flood conveyance capacity. Increased runoff	Higher flooding potential. Increased stormwater quantity downstream, potential damage to downstream communities or property.
Exposed land surface	Increased runoff. Increased soil erosion.	Degraded water quality from sediment. Eroded streambanks/degraded streams from higher runoff quantity and sediment load.

Table 1.1 Degraded water quality from sediment. Source: Williams Creek Consulting.

umbrella of green infrastructure. These concepts all serve to support minimizing the increase in run off volume and velocity by emphasizing the use of non-structural stormwater control measures and on-site controls.

Distinguishing Between Construction and Post-Construction

For the purpose of this guide, best management practices are methods directed primarily at construction phase erosion control and runoff management. Stormwater control measures, post-construction best management practices, are methods directed primarily at permanent post-construction phase runoff management. Best management practices and stormwater control measures are required for new and redevelopment, however retrofitting existing development is briefly discussed in Chapter 5.

Missouri state stormwater regulations require both construction best management practices and post-construction stormwater control measures in projects that disturb an acre or more. Construction best management practices are those designed and installed specifically to minimize the impacts of sediment carried in runoff from active construction sites. Examples include inlet protection, sediment fences and temporary seeding.

Post-construction stormwater control measures are permanent and designed to capture and treat runoff on a long-term basis following completion of construction. A conventional example of this is a detention basin. However, today's examples may include rain gardens, bioretention cells and vegetated swales designed into the conceptual plan.

Figure 1.4 Porous asphalt alley, St. Louis, MO. Source: Metropolitan St. Louis Sewer District

Even though construction best management practices and post-construction stormwater control measures have distinct purposes, this does not preclude the use of a single practice for both purposes. For instance, a sediment basin used to capture sediment-laden runoff during construction can be converted to a detention pond to capture, partially treat and gradually release runoff. Careful planning, design, operation and maintenance and inspection are needed to ensure the basin is effective both during construction and in the long-term.

1.2 A Vision for Urban Sustainability

The green infrastructure approach to urban sustainability calls for replacing the choice of large-scale curb, gutter or basin systems with smaller scale urban systems, distributed more widely, located closer to the sources of runoff, integrated with elements of buildings, and integrated with other infrastructure systems. The placement of these systems will connect well with the broader green infrastructure of our highly valued natural resources and trails within.

Every new residential, commercial and industrial development can be seen as an opportunity to integrate sustainable stormwater management with green building, self-reliant energy management and waste control, service orientation (rather than building orientation) and multi-purpose, mixed-use development for community benefit.

These opportunities require creativity, attention to regulatory goals and incorporation of new funding and management mechanisms. However, the benefits of transition will ultimately add value to the environmental, social and economic interests of the community.

Figure 1.5 Rain garden in roundabout designed to capture/infiltrate stormwater, Milwaukee, WI. Source: Bob Newport, EPA Region 5

1.3 Principles of Green Infrastructure and Its Tools

Applied principles of green infrastructure stormwater management can improve water quality and reduce the volume and velocity of stormwater runoff, by reducing the overall generation of runoff through increased green space and on-site low-impact stormwater practices. According to the Low Impact Development Center, "If the full suite of low impact development controls and site design practices are creatively used, low impact development is capable of automatically controlling the 10 and 100-year storms through its primary strategy of restoring the built area's natural rainfall-runoff relationship."

Unlike conventional stage-discharge management of large storms in centralized basins, non-structural stormwater control measures can control up to 90 percent of all storms through minimizing or eliminating runoff to the collection system through a strategy of green infrastructure and low impact development techniques. Certainly this is true for individual controls, lots and even highly controlled larger areas. Monitoring efforts are just now beginning to measure benefits of green infrastructure on large scale projects of 100 acres or more, so data is still forthcoming.

These principles and corresponding practices can be applied to new development, redevelopment and retrofit scenarios.

A. Streams, undisturbed green spaces, wetlands and riparian areas are all efficient low-cost natural stormwater management features. They are the existing stormwater management system and should be preserved and utilized where practical. Replacing the free services provided by these natural systems with man-made systems requires significant capital

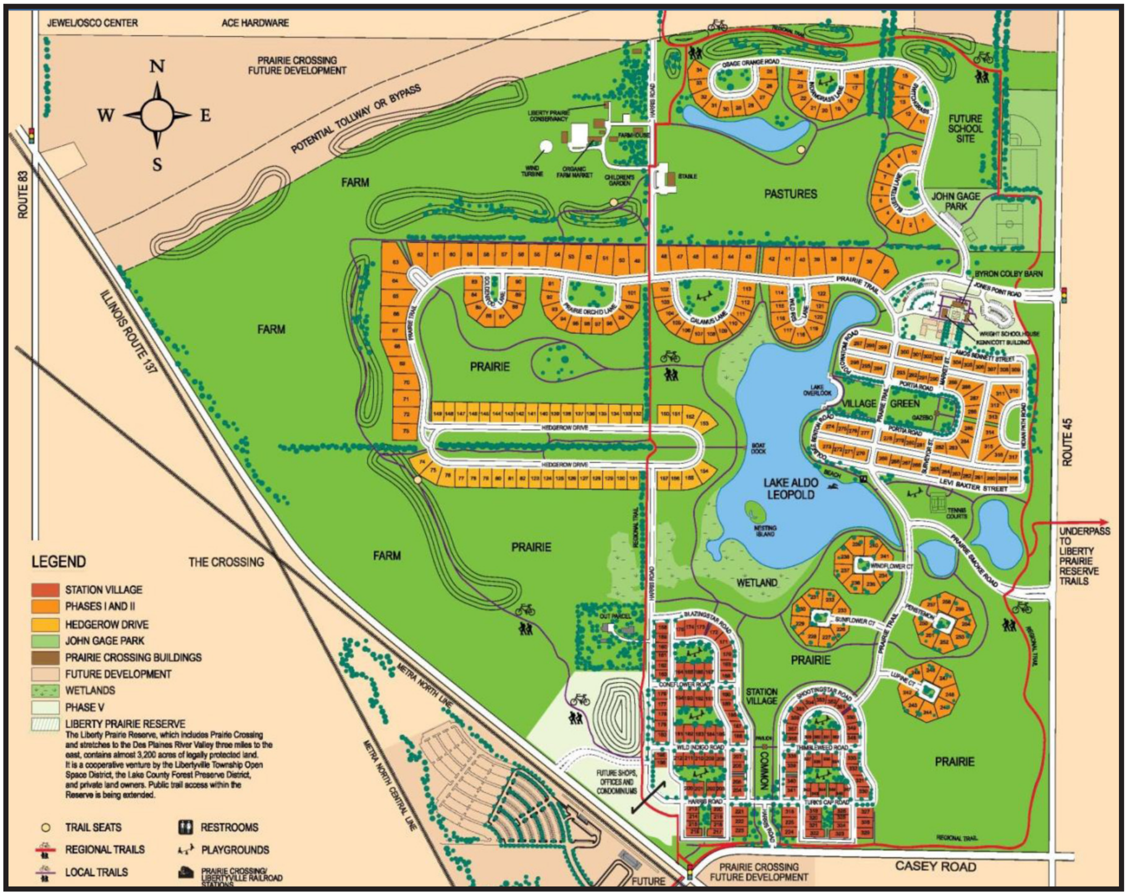


Figure 1.6 Prairie Crossing Development Site Plan. Source: Victoria Ranney, Co-Developer

Figure 1.7 Fields Neighborhood rain garden
Source: Peter Scherrer, ManShire Villages Development

investment and time, creates the need for ongoing operation and maintenance of these systems, and reduces the value of natural resources.

B. Capture rain where it falls. Prior to development, the rainfall-runoff process may be slow because precipitation falls on multiple vegetation layers and native soils whose horizons and structures have not been disturbed. Intact soil structures can allow a large portion of the precipitation to infiltrate, even in heavy clay soils. Runoff also tends to follow relatively long pathways across vegetated areas prior to entering streams.

Conventional stormwater practices tend to convey runoff away from where it falls and deliver it to centralized management areas such as ponds. The conventional pipe and pond style of runoff management concentrates runoff, increasing flow rates and reducing runoff travel times. It often consumes large areas of land otherwise available for buildings or parking, requires great amounts of earthwork to provide adequate slope for drainage and employs long runs of buried stormwater pipes.

Managing rain in close proximity to where it hits the ground can reduce the need for pipes, ponds, and earthwork, and can provide a more efficient means for infiltration and treatment of runoff. This system can be described as distributed storage.

In practice, the distributed storage areas may include rain gardens, bioretention, pervious pavement and pavers, rain barrels, and vegetated swales or linear dry detention systems. These systems can also help create a more aesthetically pleasing environment, provide improved pedestrian connectivity, maintain natural areas, reduce heat islands and even improve air quality.

C. Minimize impervious surfaces and direct connection. Impervious surfaces, such as roadways, parking lots and rooftops, eliminate infiltration and increase the rate and volume of runoff. Conventional curb and gutter systems compound the effects through direct connection throughout the conveyance system. Although many MS4 communities use rate control techniques such as detention basins, these are not necessarily effective at volume reduction.

Figure 1.8 Olivette, MO rain garden. Source: David A. Wilson, East-West Gateway Council of Governments.

By minimizing impervious surfaces and breaking direct connections of runoff, stormwater volume and flow rates can be decreased, thereby reducing likelihood of flash flooding, stream channel erosion and impaired water quality. There are many techniques to minimizing impervious surfaces, and they can include angled or directional parking, use of pervious pavements, maximum width streets, home clustering or conservation design. These, and other techniques, are outlined in Chapters 2 and 5 of this guide.

D. Optimize green space. Integrating stormwater management into green space helps minimize the need for separate, dedicated stormwater management areas. Green space can include parks, plazas, sidewalks and the urban forest. Dry detention basins can be designed to flood only during large storms, thus preserving their primary use. Shopping plazas can incorporate depressed planters to receive runoff, rather than using elevated or at-grade landscape areas. And existing, large diameter trees can be preserved to take advantage of their high rates of evapotranspiration and rainfall interception.

1.4 Benefits of Green Infrastructure: Environmental, Social and Economic

The following description touches on the general benefits of green infrastructure in stormwater management. These benefits are discussed in more detail and quantified in a report titled, *The Value of Green Infrastructure – A Guide to Recognizing Its Economic, Environmental and Social Benefits*. www.cnt.org. (Center for Neighborhood Technologies and American Rivers. 2010)

Figure 1.9 Pervious alley in St. Louis City.
Source: Metropolitan St. Louis Sewer District

1.4.1 Environmental Benefits

Missouri has an abundance of natural resources enjoyed by millions each year. As one of the most diverse geological states in the nation, Missouri touts beautiful streams, rivers, wetlands, caves, lakes, rock formations, fishery resources, conservation areas, state parks and historic sites. Katy Trail State Park is just one of many state parks enjoyed by millions of tourists and residents alike that demonstrate an appreciation of our natural resources. As the population grows and development expands, these resources and those in our neighborhoods are at risk of rapid degradation without responsible approaches to stormwater management in development. Green infrastructure in development not only helps to protect existing resources, it provides for greater enjoyment of those environmental resources within a community and it connects that community to the broader green infrastructure system enjoyed across the state.

Applying green infrastructure, low impact development and other sustainable design concepts, provides more than reductions to stormwater runoff rate and volume. These additional benefits add to the quality of life, carbon sequestration, traffic calming and economic development.

"Green infrastructure and its corresponding tools of low impact development are beneficial to a community's environmental, social and economic interests." (The Sheltair Group, 2001).

Annual Volume Reductions

Conventional or "grey" pipe and pond systems are designed to efficiently collect, store and release runoff. Green infrastructure focuses on decreasing the rate and volume of runoff to the collection system which better mimics pre-construction runoff conditions.

Improved Capacity to Piped Collection Systems

Green infrastructure can reduce the rate of runoff to existing collection systems, resulting in increased capacity for downstream inlets. It may also reduce peak rates used in sizing collection systems.

Integrating green infrastructure with grey may be the most effective approach in reducing peak flows and delaying discharges to combined sewers. Sending stormwater to treatment plants during periods of lower flows when overflows are not a threat, may be the best approach in an ultra-urban area where many green infrastructure controls are challenging to locate. Integrating the best features of both grey and green infrastructure provide an overall increased benefit compared to using one set of tools.

It is important to note that rehabilitation of existing systems is likely needed whether green infrastructure is incorporated or not; it is certainly not acceptable to retain leaking combined sewers because green infrastructure is being used. During one Missouri demonstration, Dr. Robert Pitt, PE noted that the flows in the combined sewers increased significantly after relining/repairing the sewers. They were leaking out more than infiltration in was occurring. The green infrastructure systems are very critical in this area to help offset the increased flows. Again, combinations of controls may be the most effective overall strategy.

Enhanced Groundwater Recharge

Green infrastructure can help to infiltrate runoff, which can improve the rate at which groundwater aquifers are recharged or replenished. Shallow groundwater provides about 40 percent of the water needed to maintain normal base flow rates in our rivers and streams. Enhanced groundwater recharge also boosts the supply of drinking water for private and public uses.

Improved Air Quality

Green infrastructure facilitates the incorporation of trees and vegetation in urban landscapes, which can contribute to improved air quality. Trees and vegetation absorb certain pollutants from the air

Figure 1.10 A mature tree can squester 250 pounds of carbon dioxide per year and can remove several thousand gallons of water from the ground annually. Source: Williams Creek Consulting

through leaf uptake and contact removal. If widely planted throughout a community, trees and plants can even cool the air and slow the temperature-dependent reaction that forms ground-level ozone pollution.

Increased Carbon Sequestration

The plants and soils that are part of the green infrastructure approach serve as sources of carbon sequestration, where carbon dioxide is captured and removed from the atmosphere via photosynthesis and other natural processes.

Additional Wildlife Habitat and Recreational Space

Greenways, parks, urban forests, wetlands and vegetated swales are all forms of green infrastructure that provide increased access to recreational space and wildlife habitat.

Improved Human Health

An increasing number of studies suggest that vegetation and green space - two key components of green infrastructure - can have a positive impact on human health. Recent research has linked the presence of trees, plants and green space to reduced levels of inner-city crime and violence, a stronger sense of community, improved academic performances, and even reductions in the symptoms associated with attention deficit and hyperactivity disorders.

Urban Heat Island and Energy Demand Reduction

Urban heat islands form as cities replace natural land cover with pavement, buildings, and other surfaces that retain heat. Tall buildings and narrow streets trap and concentrate waste heat from vehicles, factories, and air conditioners. Green infrastructure provides increased amounts of urban green space and vegetation, helping to mitigate the effects of urban heat islands and reduce air conditioning related energy demands.

Figure 1.11 Native parking lot bioswale. Anita B. Gorman Conservation Discovery Center - Kansas City, Missouri. Source: Copyright © Missouri Conservation Commission. All rights reserved - used with permission.

1.4.2 Social Benefits

Aesthetics and Sense of Community

The nature of green infrastructure provides for a more 'human-scale' environment versus the automobile centric environment, providing more walkability, "bikability" and functional and aesthetic gardens and landscapes. The vegetation and watercourses for the stormwater systems can be designed with landscape architectural prowess to present landmarks and community statements.

According to Dr. Robert Pitt, PE, "we have found these benefits (improved curb-side aesthetics for example) to be profound in retrofitted green infrastructure areas, especially in areas of prior poor infrastructure. Any expected increased costs associated with green infrastructure can likely be offset by these direct and indirect benefits."

Multi-Use Amenities
Communities can benefit from recreational amenities skillfully designed into utility services as multi-purpose capitol projects.

A Greater Choice of Lifestyles
Sustainable communities provide a greater choice for buyers who are increasingly aware of development impacts to the environment, to the tax base and to neighborhood amenities.

Flexibility
On-site infrastructure can allow communities more flexibility to effectively use their land base and can thereby minimize the challenges of locating gray infrastructure within right-of-ways and in a manner that requires long-term costly maintenance and repair.

Conflict Avoidance and Resolution
Integrating green infrastructure into development recommendations will more likely be amenable to community acceptance of development projects, thereby minimizing delays commonly associated with public protest.

1.4.3 Economic Benefits

Lower Costs and Delayed Capital Outlays
Depending on the type of development, green infrastructure can result in lower capital cost and lower operation and maintenance costs. While some costs may increase for project planning and site design, greater cost reductions come with reduced raised curbs, asphalt, storm sewer pipes and basin construction. Effective and efficient stormwater management reduces penalties for regulatory noncompliance. Cost savings are also associated with operation and maintenance of green buildings utilizing green infrastructure near and within the buildings (for example, lower energy bills associated with cooler buildings). Given the added federal and state regulatory emphasis on water quality protection, green infrastructure is more economical than adding treatment processes to conventional methods. (See case studies throughout this guide.)

User-pay
Integration of green infrastructure into the development project, on-site and within buildings, results in lower public expenditure due to demand side management. This user-pay principle encourages more efficiency and conservation within the marketplace, but also results in fewer stream bank restoration projects, basin dredging, and other repairs associated with stormwater damage from poorly designed systems.

Improved Investments by Stakeholders
Monthly management fees can be reduced for homeowners and their associations, as well as commercial and industrial owners. Such reductions increase marketability of development.

Figure 1.12 Prairie Crossing Home with native plant and rain garden. Source: Victoria Ranney, Co-Developer

Local Green Job Creation and Procurement

More efficiency means more dollars in the hands of local residents. Choosing green infrastructure requires green design services that can be procured locally, along with landscaping services and less money is spent on constructing and operating systems in remote locations.

Increased Land Values

A number of case studies suggest green infrastructure can increase surrounding property values. In Philadelphia, a green retrofit program that converted unsightly abandoned lots into clean and green landscapes resulted in economic impacts that exceeded expectations. Vacant land improvements led to an increase in surrounding housing values by as much as 30 percent. This translated to a $4 million gain in property values through tree planting and a $12 million gain through lot improvements.

Utility Savings

Installing rain water harvesting systems such as storage tanks or cisterns for watering residential landscaping, or for capture and reuse in industrial or commercial applications can lower a facility's water costs by 25 percent or more.

1.5 Rethinking Stormwater

Water Quality and Small Storm Management

Small storm events have typically been overlooked in conventional stormwater management. The focus has been on large storms that reduce flood risk. However, technical research and other studies have clearly demonstrated the significance of small storm events to water quality and stable in-stream channels. Many municipalities are now expected to minimize pollution through better management of small storms, because the federal and state National Pollutant Discharge Elimination System regulations now regulate stormwater runoff quality.

The concentration of pollutants in urban stormwater runoff is generally highest in the initial stages of the storm. "The initial runoff, or 'first flush', mobilizes pollutants that have built up on pervious and impervious surfaces. Thus, pollutants are more concentrated in this 'first flush' with concentrations gradually diminishing as rainfall continues" (Mid-America Regional Council and APWA, 2009).

"Significant first flushes occur in small areas having large amounts of impervious cover (commercial areas, for example); it is much less obvious in larger areas having substantial pervious areas or complex drainage systems where the flows from the separate source areas (that have first flushes) combine over a longer period of time, erasing this effect. Therefore, source controls, such as most green infrastructure components, can be effective in this regard, while outfall controls less so." (Dr. Robert Pitt, PE)

In addition to runoff pollutants in the first flush, smaller, more frequent storms have been found to contribute to increased volume and energy in the streams causing incising, down cutting, erosion and channel destabilization, which ultimately increases sediment pollutant levels in streams due to the channel erosion. In the past, design criteria for a two year storm for channel protection was commonly used, however, now the recommended channel protection criteria is for the one year storm event.

According to Dr. Robert Pitt, PE from the University of Alabama, "Rains between 0.5 and 1.5 in. (12 and 38 mm) are responsible for about 75 percent of the runoff pollutant discharges and are key rains when addressing mass pollutant discharges" (Pitt, 1999). Small storm management can address factors such as rainfall intensity, site conditions, pollutant mobility, and flood potential.

Agricultural lands are not typically regulated under NPDES requirements, although cropland can erode an estimated 2.7 tons per acre per year nationally (USDA - NRCS, 2010.) Comparatively, Wisconsin Department of Natural Resources estimates that up to 30 tons per acre per year of sediment can be discharged from active construction sites (University of Wisconsin et al, 1997), while post-construction developed areas discharge up to 0.5 tons per acre (Burton et al, 2002).

Many technical reference manuals are now focusing on design of stormwater quality practices for storm events that produce up to 90 percent of the annual runoff volume, i.e. 0.5-1.5 inch rain events. These frequent rainfall events are relatively small when compared to large storm events used for designing flood control facilities. However, managing these small storm events with a decentralized approach on site can reduce the volume and rate of runoff, thereby minimizing pollutants carried off site and providing protection against flooding.

Stormwater as a Resource, not a Hazard

In conjunction with changes in federal, state and local regulations, many communities are now rethinking how to better manage stormwater runoff as a resource, rather than a hazard. Green infrastructure principles including low impact development, can be applied to capture, infiltrate, evapotranspirate or reuse stormwater to better mimic the natural runoff conditions.

A wide variety of individual stormwater controls usually must be combined to form a comprehensive wet weather management strategy (Pitt et al, 2008). According to the Low Impact Development Center, "If the full suite of low impact development controls and site design practices is creatively used, low impact development is capable of automatically controlling the 10 and 100-year storms through its primary strategy of restoring the built area's natural rainfall-runoff relationship."

National organizations such as the Association of State Floodplain Managers (Association of State Floodplain Managers, 2008) support "no adverse impact" for managing floodplains. This means that new developments and significant redevelopment should not increase flood depths or velocities.

Environmental protection and economic development are often viewed as conflicting objectives, especially when formulating public policy. This common viewpoint is being challenged in communities that have successful stormwater management programs to protect natural resources and streams alongside vibrant new developments. One such development is the Winterset subdivision in Lee's Summit, Mo.

According to Winterset developer Dave Gale with Gale Communities, "Planning with the land to minimize costs of cut and fill for both developer and builder, saving native trees and designing stormwater detention into the usable green-space plan have been keys to our consistent home site absorption and momentum during our 20 year history, and the reason for our receiving several national awards."

The most successful programs integrate environmental and economic interests. They also establish clear goals, guidelines, and criteria from the very initial stages of conceptual development through long-term operations and maintenance of best stormwater control measures so that all understand the requirements.

Volume as a Pollutant

Historically, stormwater runoff across the nation has been viewed as a potential flood hazard or source of property damage. To help prevent flooding, policy makers required that runoff be moved quickly away from structures and roadways and then detained to control the rate of release to receiving streams. While this helped reduce the short term flood hazards posed by runoff, flood management policies did not address the long term natural resource degradation which resulted from increased runoff volumes, rates and pollutants associated with development. In an extreme example of rate control with no concern for total volume, some post-construction stormwater basins have been lined to prevent infiltration.

Reducing runoff volume and rate can:

- Protect downstream channels.
- Reduce impacts from flash flooding during short, but high intensity storms.
- Improve base flow in small streams.
- Help conserve overbank storage areas in floodplains along larger streams.

To address volume as a pollutant and help minimize continued stream degradation, land development techniques and stormwater management systems need to reasonably mimic pre-construction runoff conditions in new development projects. This includes conserving natural grades and vegetation to the extent practicable, minimizing new impervious surface area, providing infiltration post-construction stormwater control measures to control and infiltrate small, frequent storm events, and minimizing or eliminating land disturbance within the floodplain or meander belt of receiving streams.

In areas of karst topography, wellhead protection, or other special groundwater concern, infiltration may not be desirable. In these areas, techniques such as reducing impervious area, maintaining existing vegetation, and installing restorative vegetation to increase evapotranspiration can be used to help achieve similar goals.

Where groundwater is a resource, care should be taken to minimize groundwater contamination. An example contaminant source is snow melt water infiltration and contamination from treatment media and salt. Except for salt, many potential groundwater contaminants can be reduced by pre-treatment (filtering through surface soils or media.) Such steps should also help to minimize stormwater contamination via dry wells or through porous pavement.

Using Infiltration and On-Site Practices to Control Volume and Pollutants

Figure 1.2 shows St. Louis, MO rain and runoff distributions between 1984 and 1992. According to Dr. Robert Pitt, "for Missouri, it is likely this figure is reasonably accurate for most of the state. The actual values for any community are dependent on location (rain patterns, etc.) with the same general shape shifting left or right."

Given these rainfall distributions, infiltration (with on-site beneficial use, if possible) should be used to remove as much of the water quality volume runoff as possible. Additional water quality runoff volume not captured through infiltration, evapotranspiration or re-use, should be treated. Channel forming events occur at that upper limit (typically the one-inch storm event is used), so energy reducing controls in these larger events will likely need to be added. It may be less practical to treat runoff events larger than the water quality volume event.

Finally, drainage design must be used to handle the rare events to prevent loss of life and property

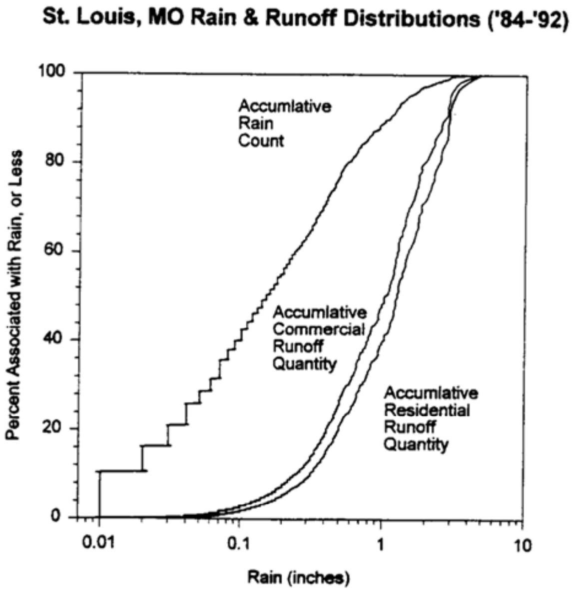
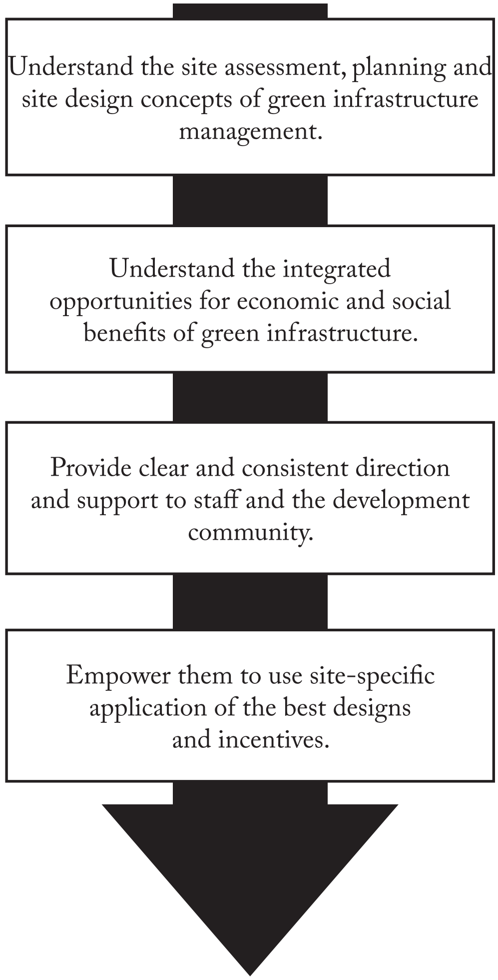


Figure 1.13 St. Louis, MO Rainfall and Runoff Distributions (1984-1992). Source: Dr. Robert Pitt, PE

damage. Extreme events occur, and secondary drainage systems are then needed to safely move or temporarily store the water. Therefore, it is obvious that many stormwater controls are needed for a comprehensive stormwater management program. Green infrastructure and other infiltration devices need to be applied first, and their use will reduce the "sizes" of the other components. Critical source area controls (and pollution prevention), construction erosion control, inappropriate discharge reductions are also all needed.

1.6 Leadership is Key

Strong leadership is critical to a stormwater management program that simultaneously improves quality of life, protects natural resources, and improves economic development. Without a local champion, many of these efforts fail due to lack of oversight and a return to business as usual. For leaders to be successful in planning and implementing a program, they need to team up with local champions to:



Understand the primary strategies and concepts of green infrastructure stormwater management. This document provides the vocabulary needed by leadership to better understand and describe the value of stormwater management and green infrastructure to the community of stakeholders including government personnel, developers and the general public.

Understand the ancillary economic and social benefits of green infrastructure. Communities educated on the value of their streams, lakes and wetlands may be more likely to place a higher priority on stormwater management. Further education on the financial and social benefits provided by green infrastructure can help provide the support needed for implementation of funding programs necessary to implement stormwater improvements including the creation of stormwater utilities and their associated fees.

Provide clear direction and guidance to staff and the development community. Planning efforts for improvements present an opportunity for local leaders to collaborate on setting goals, removing roadblocks, and establishing or revising relevant policies and ordinances. This collaboration can create land use policies and regulations that give staff the tools they need to work across internal and intragovernmental departments, and to better create public and private partnerships with the development community.

It is important to ensure equity through consistent application of criteria and the prevention of exemption abuse.

Empower to the development community to use the best planning and design tools available

Leadership is important in creating an atmosphere of cooperation between the government and land developers. Green infrastructure techniques may be in conflict with existing policies or ordinances governing land use, transportation or subdivision control. To resolve these potential conflicts, community leaders must clearly delegate decision making authority to relevant directors of planning, public works, street departments and economic development agencies who coordinate approval of development projects.

1.7 Use and Organization of this Guide

Effective stormwater management involves the full spectrum of local government elected officials, management, staff-level plan reviewers, developers, contractors and citizens. This guide was written to speak to each of these audiences. All must work in partnership to create and implement a stormwater program that results in multiple community benefits such as neighborhood revitalization, expanded recreational opportunities, attractive businesses, inviting landscapes, increased property values as well as improved water quality.

Elected Officials

Elected officials can use this guide as a tool for engaging the community in policy discussions and enabling department leaders and their staff to implement a quality stormwater program.

Information is also provided on:

- Typical regulatory requirements and recommendations for a post-construction runoff control program.
- The role of elected officials in developing goals, policies and local regulations that support a post-construction runoff control program.
- Why stormwater management is incorporated at the initial stages of the development process and that inter-departmental coordination is needed.

Planning Management, Economic Development Staff and Citizens

Leaders responsible for planning management and economic development staff will find Chapter 2 beneficial. They incorporate stormwater management into long range plans, the land development process and recommendations for water quality protection up front in site planning and design. Chapter 5 includes specific information about site design and on-site practices to be addressed in plan review and approval. Citizens will also be able to see in Chapters 2 and 5 where they have opportunities to influence the process and ensure their community values and goals are incorporated.

Public Works Directors

Public works directors have often been responsible for the implementation of the entire stormwater program. The guide describes each step of development and implementation of your post-construction runoff program. Current trends, key questions to consider, and references to examples and models are included to help with implementation. However, today's water quality requirements demand a close working relationship with planning departments as well.

Developers

Members of the development community can use this guide to help influence local policy toward more flexible yet functional stormwater practices. By understanding how the recommended practices meet state and federal requirements, they will also be able to influence a more streamlined approval process to remove local roadblocks and to provide more economical approaches to water quality requirements. Chapter 2 and Chapter 5 will be of most interest to developers. Chapter 2 provides information and suggestions on planning for stormwater management throughout the development submittal process. It identifies tools to use to protect natural resources and control stormwater runoff from pre-submittal stages through final submittals. Examples of opportunities for cost-savings will also be provided. Chapter 5 is focused on the details of site design and choosing best stormwater control measures. In addition, Chapter 3 and Chapter 4 discuss how to be involved in developing a community's stormwater management goals and stormwater program.

Designers, Engineers and Planners

Designers, engineers and planners may primarily be interested in Chapters 2 and 5, which discuss sustainable site design, and provide information on the impacts of precipitation patterns, soils and local geology. Also provided is an overview of on-site practices, existing design manuals and selected references from within the state and across the country; and, some detail on how the land development submittal process can be modified to allow or encourage green infrastructure. As communities implement these ideas, it will be useful to understand the background and drivers for making changes. A successful program requires keen leadership commitment to these changes until they become common practice. Designers and engineers may also be interested in Chapter 3, which describes the process for setting goals in a community, and Chapter 4, which summarizes the steps for developing the local ordinance or regulation to provide for stormwater quality management.

Plan Reviewers and Planning Commissioners

Staff members who typically review plans will primarily be interested in Chapter 5, which provides an overview of the latest site assessment and design approach for stormwater quality management. This group will also be interested in Chapter 2 which describes the updates needed to properly incorporate stormwater quality management into the land development review and approval process.

Chapters 3 and 4 may also be of interest to plan reviewers. The chapters describe steps and considerations for developing or updating a program and the regulatory mechanisms required to meet stormwater quality management goals.