LID

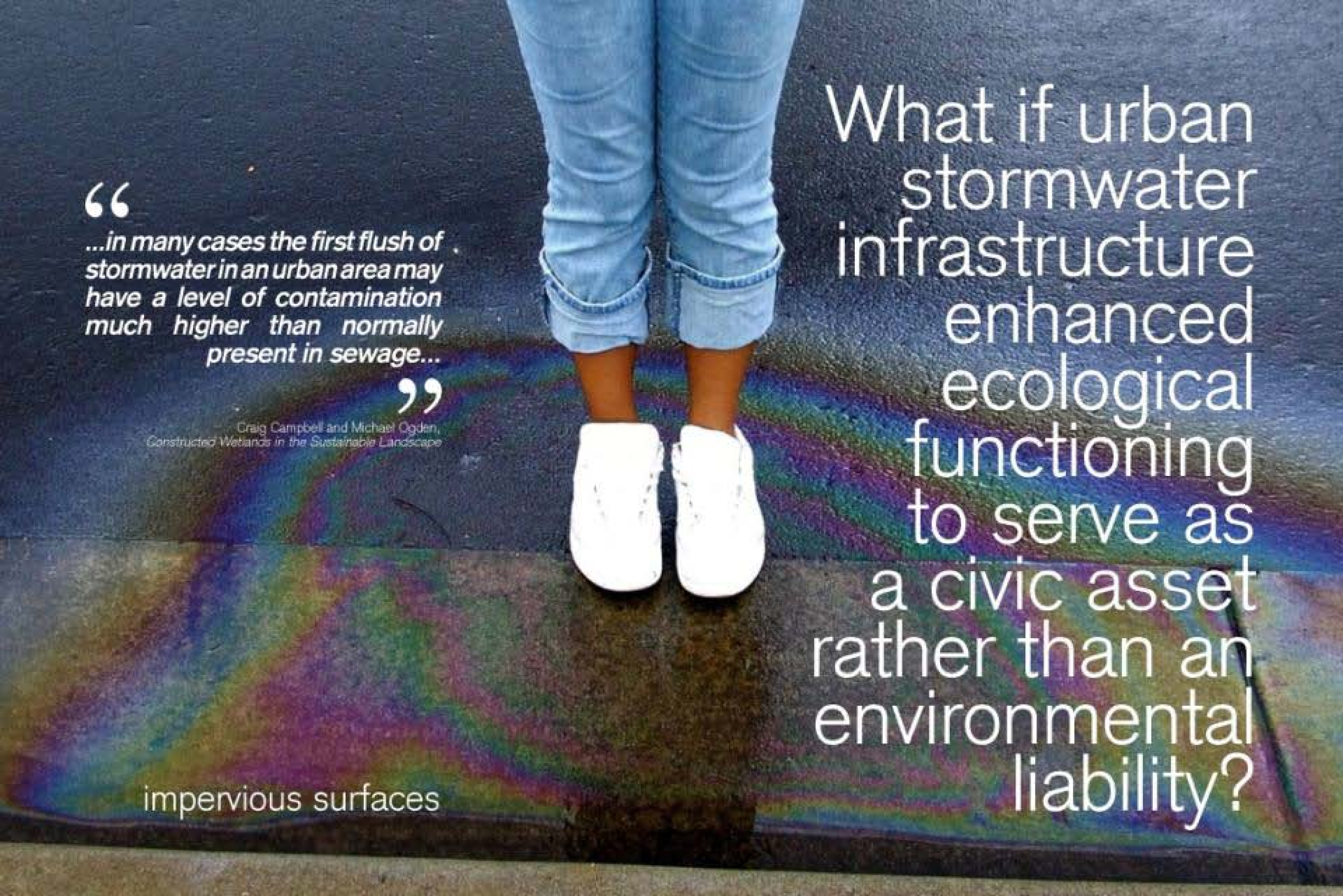
Low Impact Development

a design manual for urban areas

Jeff Huber, AIA, LEED AP

Project Designer and Adjunct Faculty

University of Arkansas Community Design Center


"...in many cases the first flush of stormwater in an urban area may have a level of contamination much higher than normally present in sewage..."
Craig Campbell and Michael Ogden, *Constructed Wetlands in the Sustainable Landscape*
What if urban stormwater infrastructure enhanced ecological functioning to serve as a civic asset rather than an environmental liability?
impervious surfaces

> *Lawns use more equipment, labor, fuel, and agricultural toxins than industrial farming, making lawns the largest agricultural sector in the United States.*

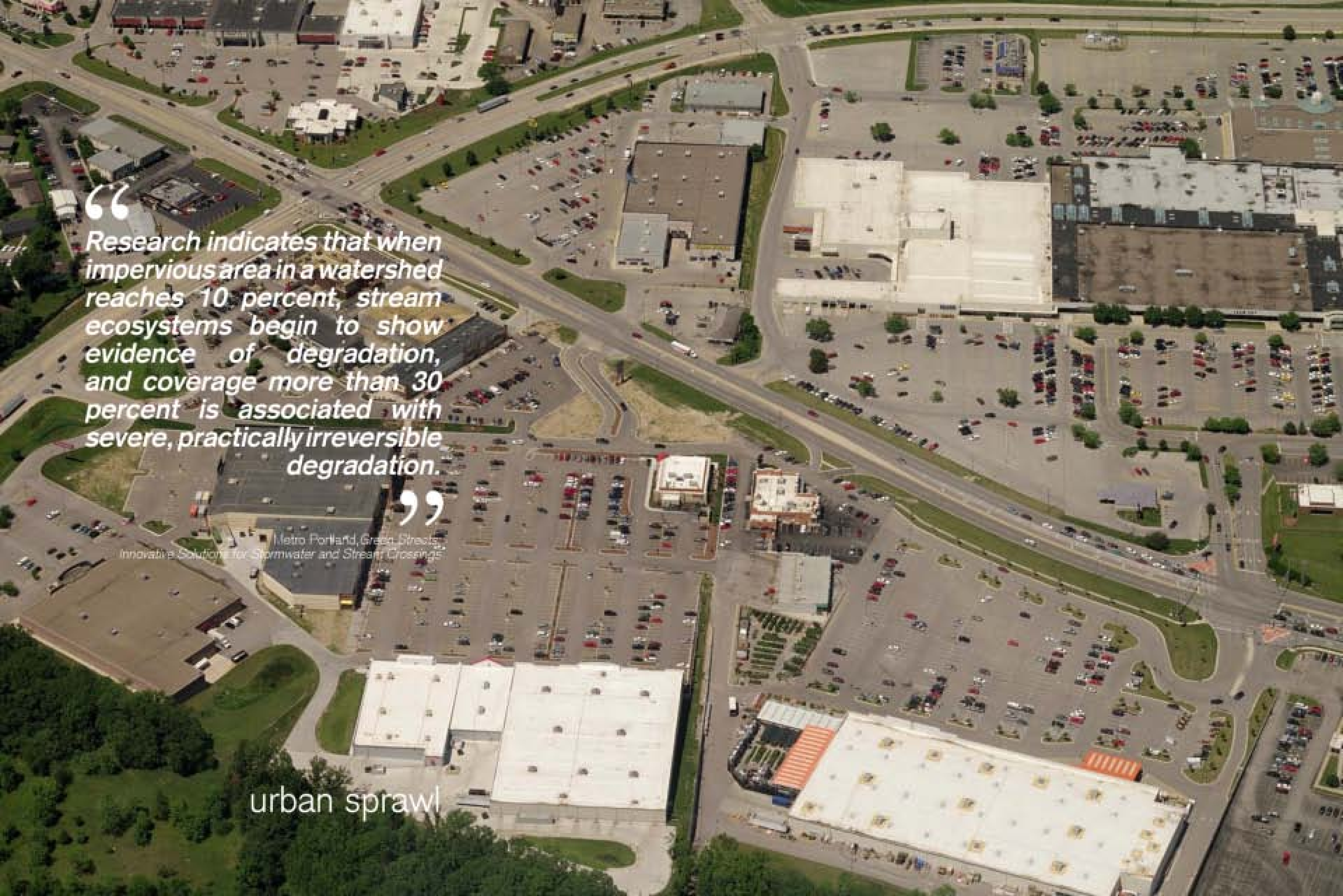
Richard Burdick, "The Biology of Lawns", *Discover*, July 2003

industrial landscapes

“By replacing the stream that was once here, the bare and sterile concrete replaces the fecundity of soil and plants. The concrete has just one purpose, ignoring the multiplicity of other purposes served by the landscape it replaced...”

John Tillman Lyle, “Landscape: Source of Life or Liability”, *Reshaping the Built Environment*

urban stream syndrome



"Research indicates that when impervious area in a watershed reaches 10 percent, stream ecosystems begin to show evidence of degradation, and coverage more than 30 percent is associated with severe, practically irreversible degradation."

Metro Portland, Green Streets:
Innovative Solutions for Stormwater and Stream Crossings

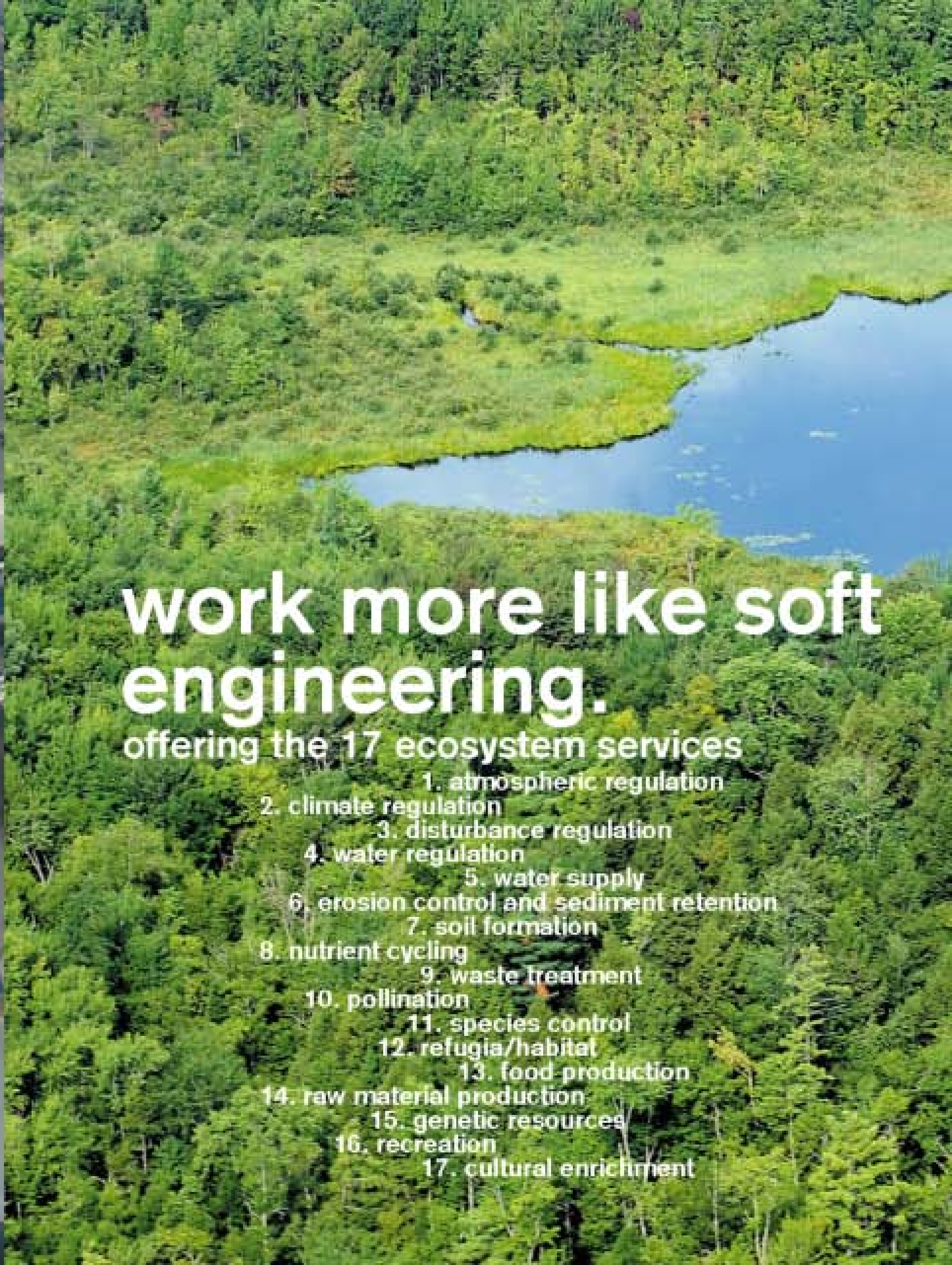
urban sprawl


“death by a thousand cuts”
flash flooding


water contamination

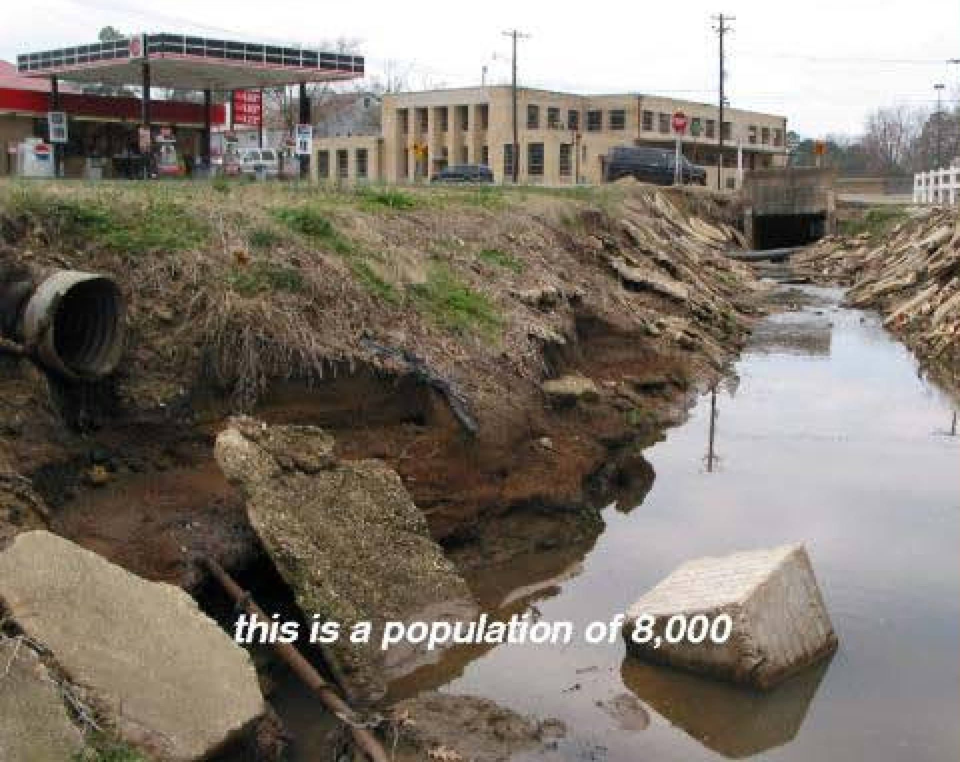

stream scouring


What Low Impact
Development (LID)
does is make hard
engineering...

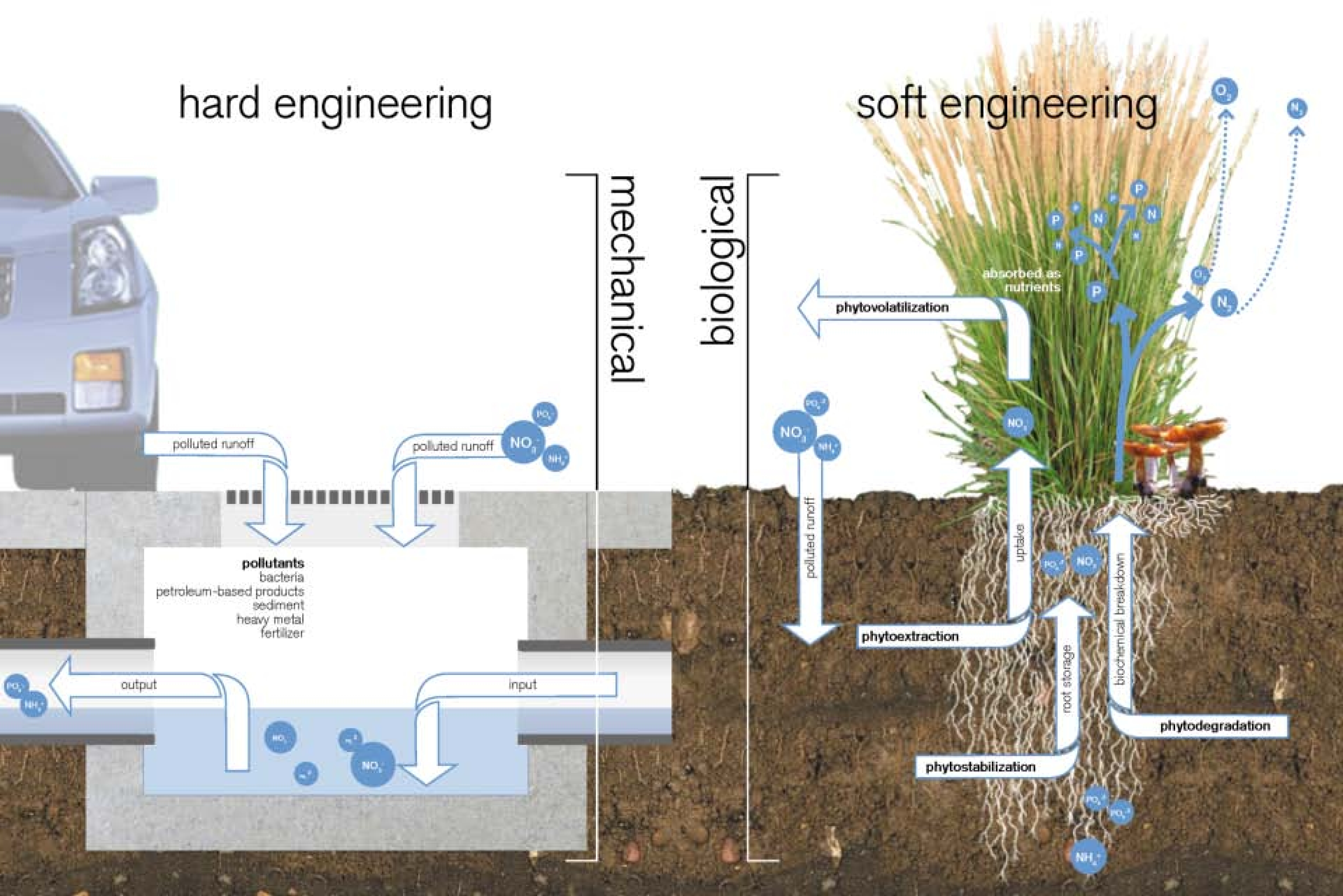

work more like soft
engineering.
offering the 17 ecosystem services
1. atmospheric regulation
2. climate regulation
3. disturbance regulation
4. water regulation
5. water supply
6. erosion control and sediment retention
7. soil formation
8. nutrient cycling
9. waste treatment
10. pollination
11. species control
12. refugia/habitat
13. food production
14. raw material production
15. genetic resources
16. recreation
17. cultural enrichment

hard engineering

Some believe that ecologically-based stormwater management is unattainable in dense urban areas, but consider the following...

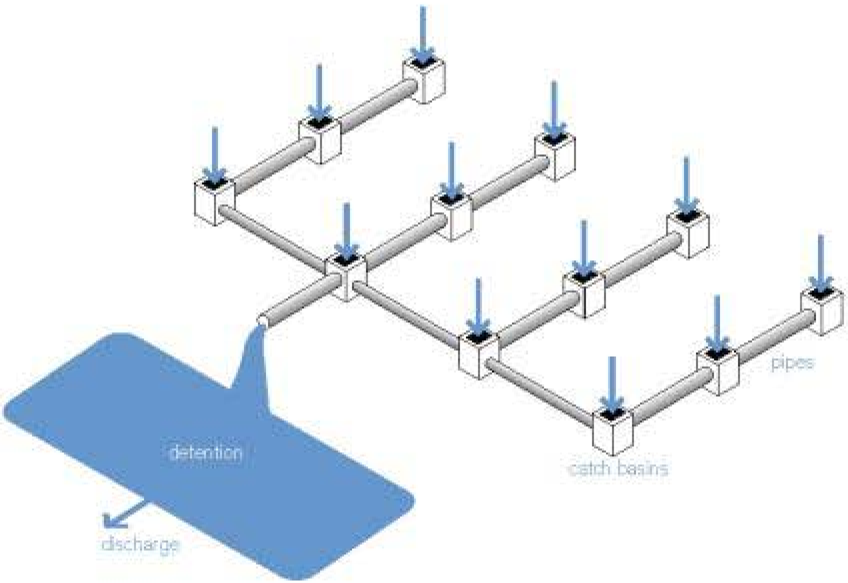


soft engineering

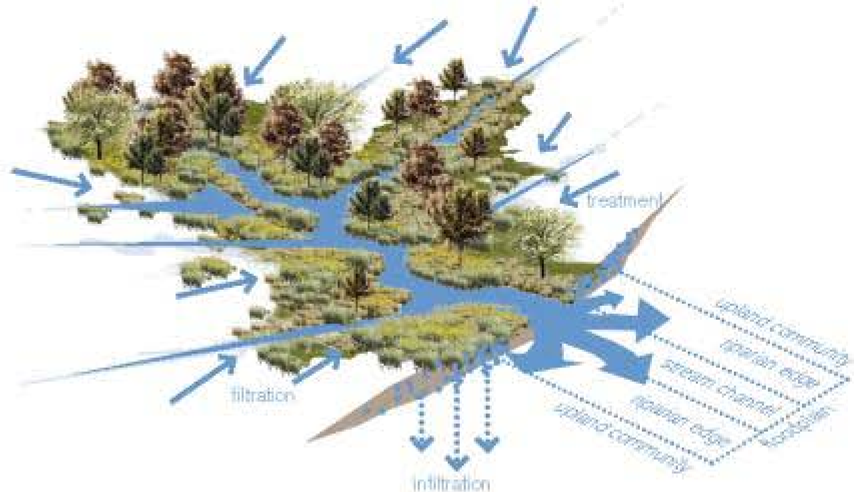

hard engineering
soft engineering
mechanical
biological
polluted runoff
polluted runoff
pollutants
bacteria
petroleum-based products
sediment
heavy metal
fertilizer
output
input
phytovolatilization
absorbed as nutrients
polluted runoff
uptake
phytoextraction
root storage
biochemical breakdown
phytodegradation
phytostabilization

hard engineering
...just transfers pollution
to another site

soft engineering
...metabolizes pollutants
on site—parks, not pipes!

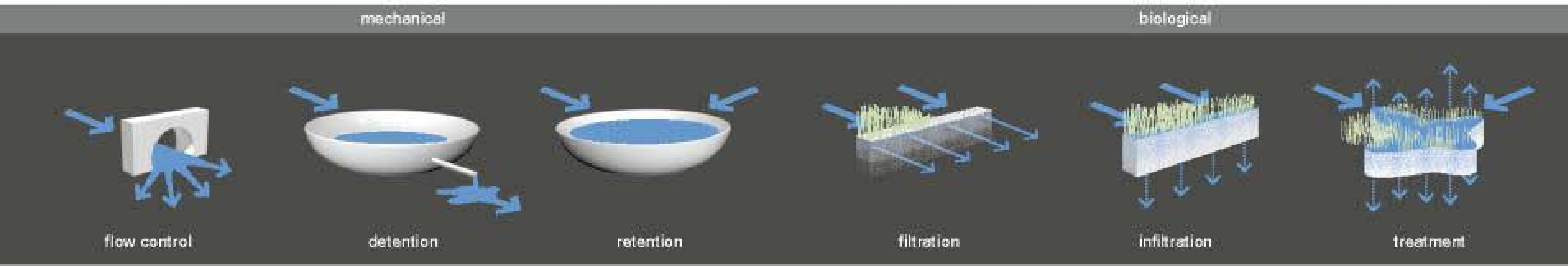


conventional management: "pipe-and-pond" infrastructure
drain, direct, dispatch



low impact management: watershed approach
slow, spread, soak

integrating hard engineering ...and soft engineering toward a LID approach



slow → spread → soak

flow control: The regulation of stormwater runoff flow rates.

detention: The temporary storage of stormwater runoff in underground vaults, ponds, or depressed areas to allow for metered discharge that reduce peak flow rates.

retention: The storage of stormwater runoff on site to allow for sedimentation of suspended solids.

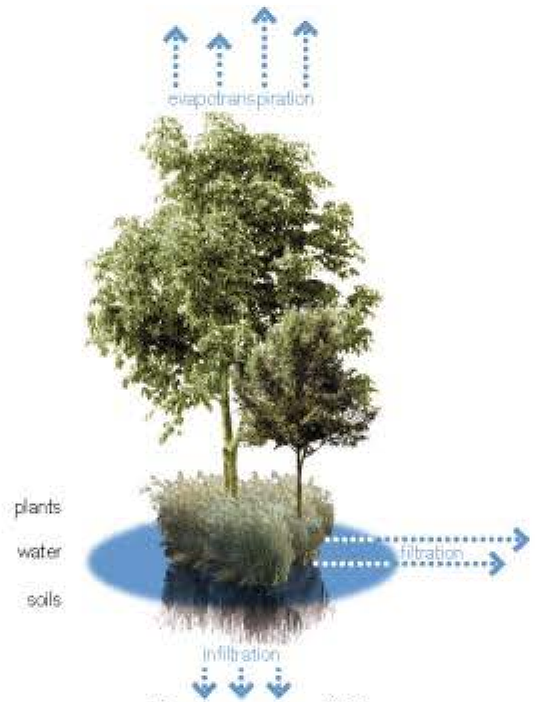
filtration: The sequestration of sediment from stormwater runoff through a porous media such as sand, a fibrous root system, or a man-made filter.

infiltration: The vertical movement of stormwater runoff through soil, recharging groundwater.

treatment: Processes that utilize phytoremediation or bacterial colonies to metabolize contaminants in stormwater runoff.

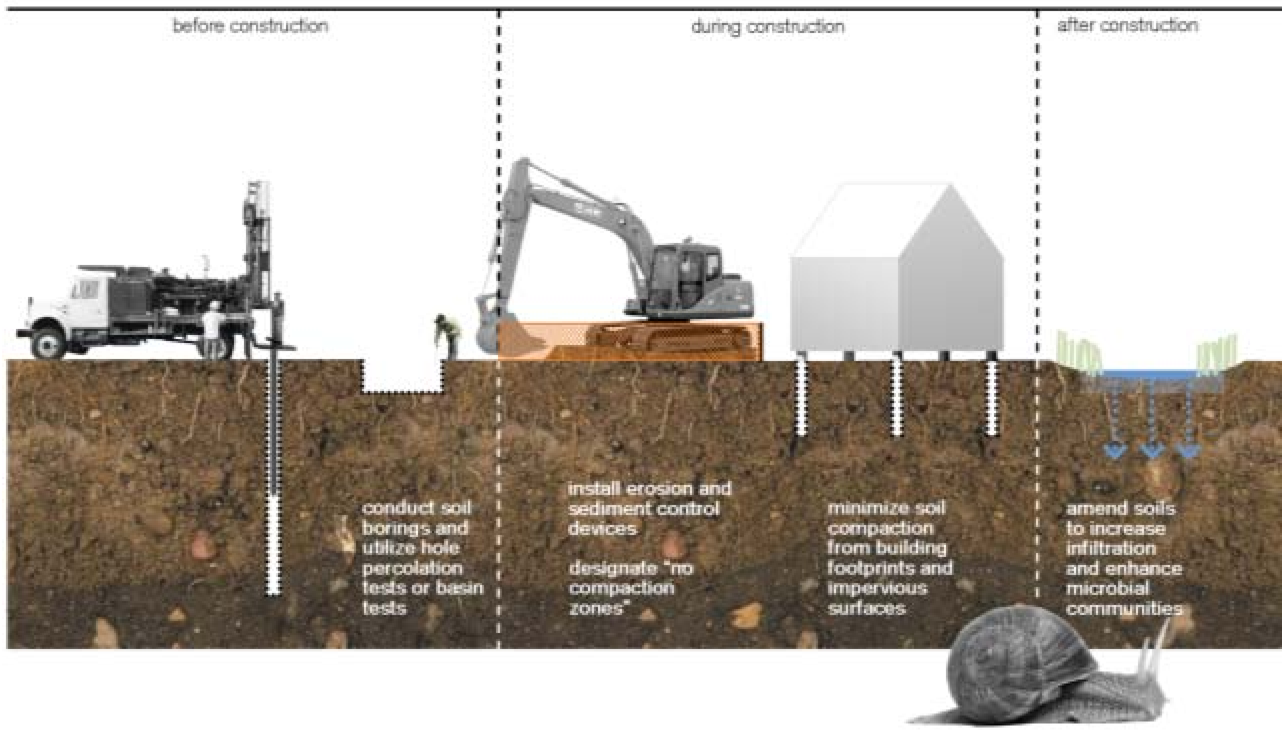
What is LID?

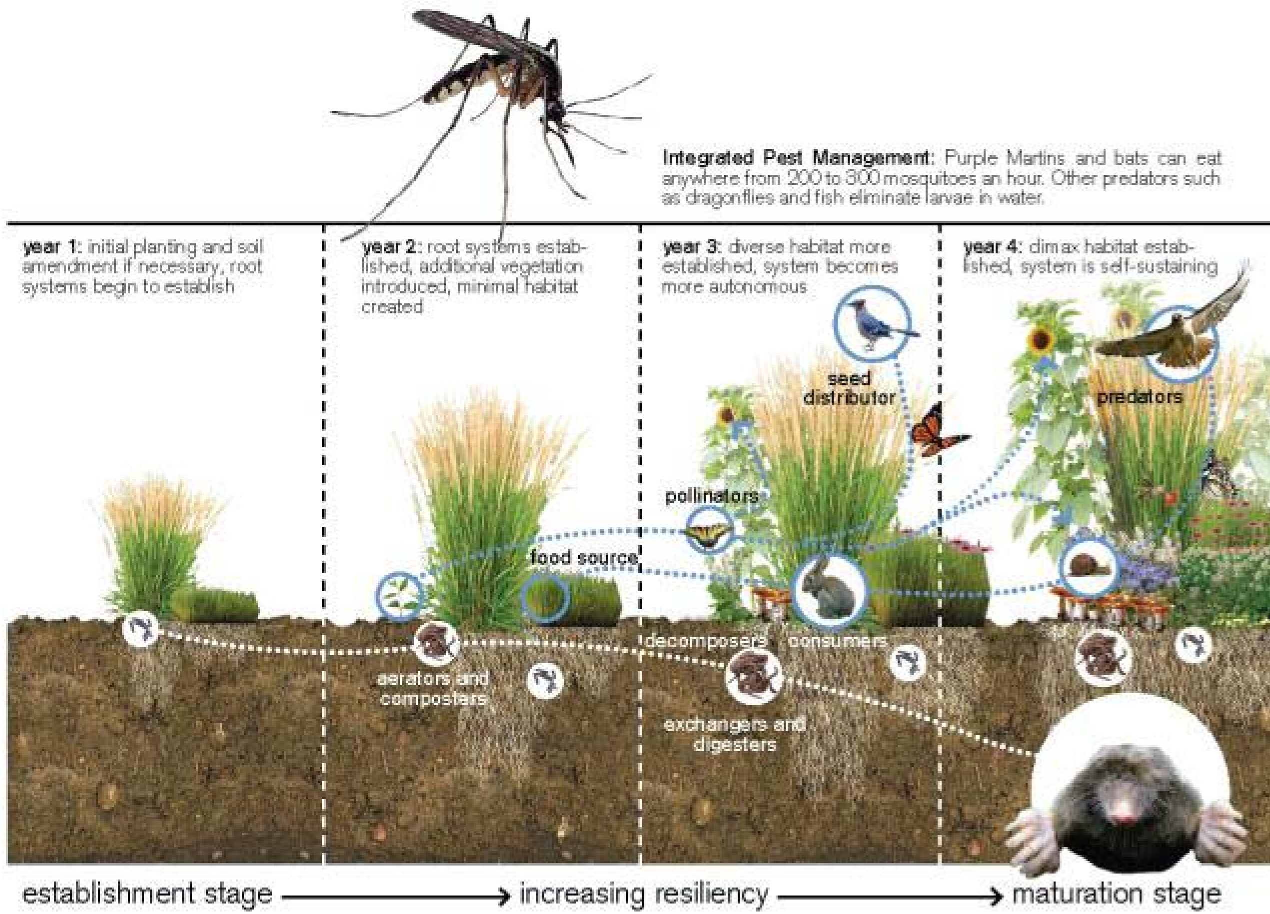
Low Impact Development (LID) is an ecologically-based stormwater management approach favoring soft engineering to manage rainfall on site through a vegetated treatment network. The goal of LID is to sustain a site's pre-development hydrologic regime by using techniques that infiltrate, filter, store, and evaporate stormwater runoff close to its source. Contrary to conventional "pipe-and-pond" conveyance infrastructure that channels runoff elsewhere through pipes, catchment basins, and curbs and gutters, LID remediates polluted runoff through a network of distributed treatment landscapes.



media and processes of LID

Stormwater infrastructure can be planned to deliver valuable ecological benefits to botanize the city...


before construction
during construction
after construction
conduct soil borings and utilize hole percolation tests or basin tests
install erosion and sediment control devices
designate "no compaction zones"
minimize soil compaction from building footprints and impervious surfaces
amend soils to increase infiltration and enhance microbial communities


Integrated Pest Management: Purple Martins and bats can eat anywhere from 200 to 300 mosquitoes an hour. Other predators such as dragonflies and fish eliminate larvae in water.
year 1: initial planting and soil amendment if necessary, root systems begin to establish
year 2: root systems established, additional vegetation introduced, minimal habitat created
year 3: diverse habitat more established, system becomes more autonomous
year 4: climax habitat established, system is self-sustaining
seed distributor
predators
pollinators
food source
decomposers
consumers
aerators and composters
exchangers and digesters
establishment stage → increasing resiliency → maturation stage

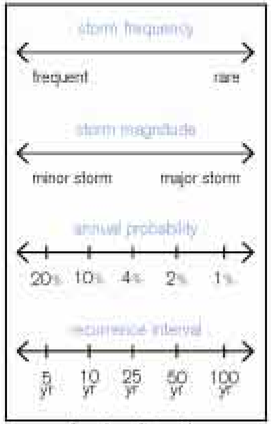
Applying LID: Water and Site

Designing for LID requires an understanding of hydrology, the science of water occurrence, distribution and movement on a given site or area. The initial phase of LID design must characterize the site's natural hydrology, connectivity up and down stream, location within the catchment area, and on-site flow paths.

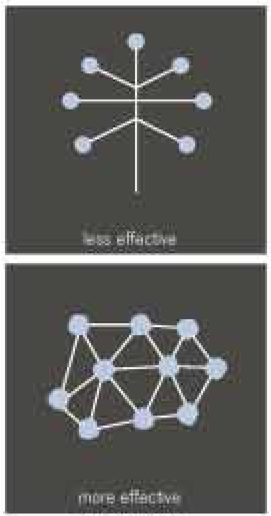
Understanding the amount of precipitation that typically occurs in an area is important for site planning and stormwater design. Precipitation occurs in different durations, amounts, and intensities, classified as storm events. A storm event is referred to in terms of a year, such as 10-year storm event. This terminology can be misleading, as a 10-year event does not indicate that it will occur once every 10 years, but rather that there is a 1 in 10, or 10 percent chance of that storm occurring in any given year. In other words, while there is only a one percent chance of a 100-year storm event happening every year, it does not mean that a 100-year storm event can't happen twice in the same year.

LID Design: Redundancy, Resiliency, Distribution

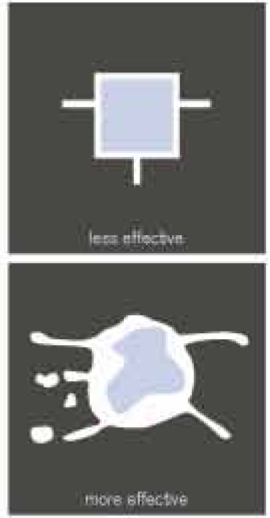
Ill-planned urban development results in the loss and fragmentation of ecological habitats, as well as the related loss of ecological biodiversity. Design principles can be introduced to increase the level of ecological services in urban infrastructure. These principles of redundancy, diversity and distribution replicate ecological processes optimizing the landscape's carrying capacity and resiliency in urban infrastructure. Utilizing ecological engineering, these principles treat stormwater through a network of landscapes that slow, spread, and soak runoff.



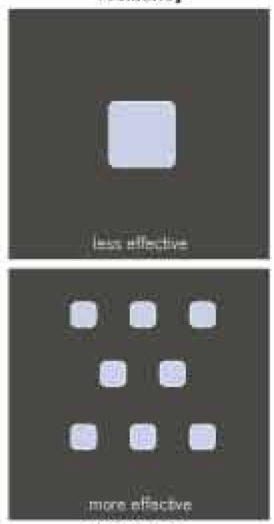
understanding storm event classifications



redundancy



resiliency



distribution

Redundancy

To avoid systemic failure (i.e., flooding) facility redundancy is important in LID design. While some facilities may work well in isolation for first flush and small storm events, a distributed circuit of facilities creates redundancy by connecting facilities in multiple routes. The alternate routes in a network reduce the effects of gaps, increasing performance and levels of service. For larger storm events (up to 100-year) and sites with poor soils, conventional (hard) and ecological (soft) engineering may be combined to create a hybrid system connected through surface facilities and underground conveyance.

Resiliency

To maximize ecological benefits, LID design should incorporate multiple LID facilities (see "What are the LID Facilities" pp. 142-187) with different levels of service. Using a diverse array of LID facilities that slow, spread, and soak stormwater assures full treatment capacity and resiliency in the system. Facilities that simply control flow and store stormwater should accompany more robust facilities that filter, infiltrate, and treat stormwater.

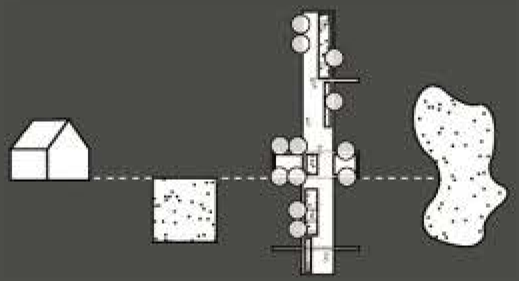
To optimize resiliency, ecosystems must be able to adapt to metabolic alterations in their environment induced by external or internal mechanisms. Biological diversity increases resiliency, enabling LID facilities to withstand shocks and rebuild itself when necessary. To obtain optimal resilience it is preferable to mimic natural systems that include fuzzy edges that enrich the system and avoid hard engineered designs characterized by rectangular basins and rigid channels.

Distribution

Distribution, or a dispersed spatial arrangement of LID facilities, optimizes the full carrying capacity of a site and avoids pitfalls associated with concentration. Water quality and quantity functioning are cumulative so that even very small facilities will provide benefits to the overall system. Usually, several small facilities will provide greater treatment, habitat, and avoidance of sensitive areas than one large facility.

How can we implement LID?

LID concepts are scalable to various sized projects and land-use types. Dividing urban development into its constituent components—building, property, street and open space—illustrates stakeholder action opportunities within each component. The goal is not just to minimize impact, but to develop regenerative and productive urban landscapes that continually renew ecosystem functioning.



building

design the building as a net energy producer that recharges groundwater and harvests rainwater

property

substitute an ecologically-based stormwater treatment system for an otherwise decorative landscape

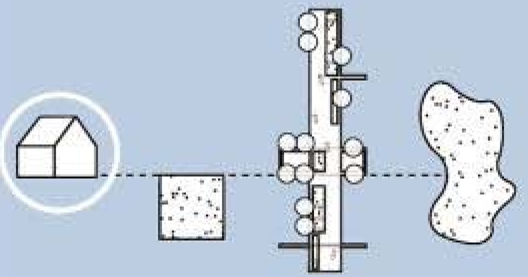
street

design the street as a garden to achieve traffic calming and stormwater management

open space

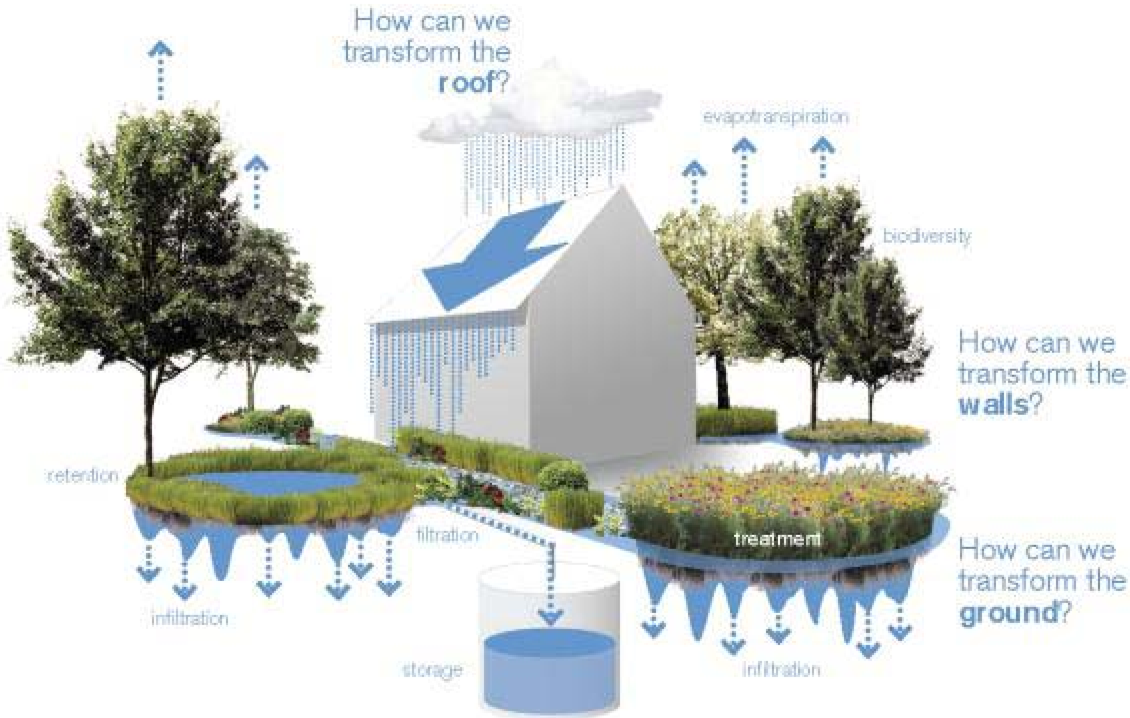
comprehensively plan open space as a green network that delivers vital ecological services at the scale of a watershed

building



conventional
drain, direct, dispatch

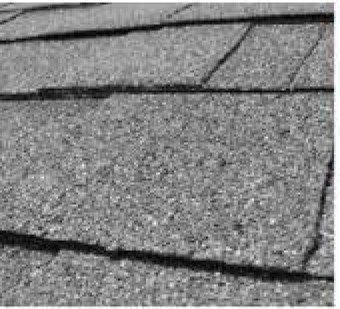
low impact
slow, spread, soak


How can we transform the **roof**?
evapotranspiration
biodiversity
How can we transform the **walls**?
retention
filtration
treatment
How can we transform the **ground**?
infiltration
storage
infiltration

Roof Materials

building

...one inch of rainfall on a 1,000 square-foot roof yields about 623 gallons of water.






asphalt/fiberglass shingle
Stormwater runoff from these roofs have high levels of pollution; treatment is needed at the wall and/or ground. If harvesting is desired do not use to irrigate edible landscapes or for potable needs.
- Harvesting Potential: Low
- Heat Island Mitigation: Low
- Initial Cost: Low
- Durability: 15-20 years

membrane roof system
Membrane roofs, like EPDM, modified bitumen, and tar and gravel, are petroleum-based and have high levels of pollutants; treatment is needed at the wall and/or ground. If harvesting is desired do not use to irrigate edible landscapes or for potable needs.
- Harvesting Potential: Low
- Heat Island Mitigation: Low
- Initial Cost: Low-Medium
- Durability: 10-30 years

wood shingle
Leaching from treated wood products may contain toxins and carcinogens. Make every effort to use products made from cedar since it is typically untreated and thus a safe harvesting alternative.
- Harvesting Potential: Moderate
- Heat Island Mitigation: Moderate
- Initial Cost: Medium
- Durability: 10-20 years

clay tile roof
Stormwater runoff from a clay tile roof may produce minor sediment. Clay tiles can offer high albedo surfaces for heat island mitigation. Clay roof tiles have excellent harvesting potential.
- Harvesting Potential: High
- Heat Island Mitigation: Moderate
- Initial Cost: Medium
- Durability: 50-75 years

metal roof
Stormwater runoff from a metal roof has very low pollutant levels. Metal roofs have excellent harvesting potential.
- Harvesting Potential: High
- Heat Island Mitigation: High
- Initial Cost: Medium to High
- Durability: 40-60+ years

vegetated roof
Also known as a "green roof," they can treat and retain 60-100% of the stormwater they receive. Other benefits include improved air quality, heat island mitigation, and urban biodiversity. (see "Vegetated Roof" pp. 170-171)
- Harvesting Potential: High
- Heat Island Mitigation: High
- Initial Cost: High
- Durability: 40+ years

alert on harvesting rainwater → safe harvesting potential

When considering rainwater harvesting, keep in mind that petroleum-based roofing and treated wood products leach toxins. Studies have shown that these products are known to cause cancer and mental defects. Harvested rainwater from these surfaces should only be used for ornamental landscape irrigation.

Harvesting rainwater from these surfaces is safe for use on edible landscapes because they do not pose contamination risks, but will require filtration and disinfection for potable (drinking) water uses.

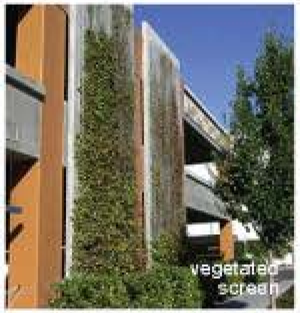
Wall Facilities

building

Cistern water quality in some cases is better or equal to well water quality.

rainwater harvesting

Connecting a cistern or tank to an existing gutter system is the easiest solution for harvesting stormwater. However, cisterns must be protected from sunlight to prevent algae growth and screened openings are needed to prevent mosquito larvae propagation. Residential cisterns typically store anywhere from 100 to 2,500 gallons (see "How to Harvest Rainwater" pp. 56-57). Metal or green roofs are best suited for rainwater harvesting. Any overflow should be diverted to an on-site LID facility. *Rainwater Harvesting* pp. 158-159



disconnecting/replacing/eliminating gutters

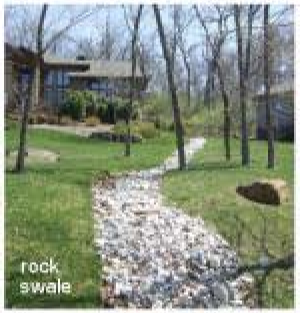
If you have a gutter system and it's connected with pipes to the street storm drain, disconnect it and keep stormwater on site. If gutters are removed, be sure that the drip edge directs runoff to LID facilities that slow and spread stormwater runoff. Compared to rain leaders, rain chains have better attenuation capacity for **one to two-year storm events**, however, during **10 to 100-year storm events** ground based facilities will be needed to attenuate beyond the capacity of rain chains. This illustrates the importance of redundancy where each facility works in tandem to support the other. No facility is left isolated.

vegetated screens and walls

Vegetated walls and screens are expensive LID facilities. However, they offer collateral benefits such as higher air quality, reduced heat island effect, building insulation and energy efficiency, aesthetic appeal, and filtration of roof stormwater runoff that can be conveyed or harvested. *Vegetated Wall* pp. 168-169

Ground Facilities

building

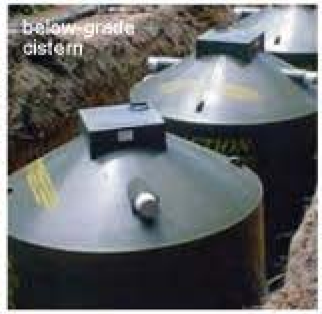


softscapes

For conventional roofs, splash blocks and rock swales can transition vertical stormwater flow in tandem with LID facilities to aid in horizontal network distribution. Rock swales slow and convey stormwater runoff, acting like a dry creek bed that receives and distributes concentrated runoff. Where steep grades are a concern, the rock swale may need to be lined with geotextile to prevent undercutting. For larger roof areas, wide rock swales and flow control devices, like level spreaders, will be needed. *Flow Control Devices* pp.148-149

below-grade storage

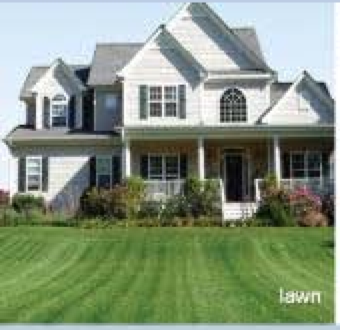
Connecting below-grade storage devices to an existing gutter system facilitates out of sight rainwater harvesting. Like on-grade rainwater harvesting systems, stormwater must be protected from sunlight to prevent algae growth and screened openings are needed to prevent mosquito larvae propagation (see "How to Harvest Rainwater" pp. 56-57). Metal or green roofs are best suited for rainwater harvesting. Any overflow should be diverted to an on-site LID facility. *Rainwater Harvesting* pp. 158-159



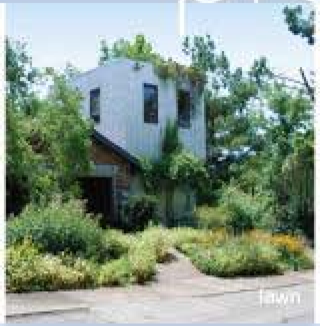
enhanced urban ecologies

By implementing a biodiverse treatment train across the property, stormwater can be filtered, infiltrated, and treated to improve water quality. These facilities can be designed as habitat for local pollinators and seed distributors, such as bees, butterflies, and migratory birds. LID landscapes are highly productive and self-organizing, and provide greater aesthetic value than turf lawns at a fraction of the required maintenance (see "What are the LID Facilities" pp. 142-143).

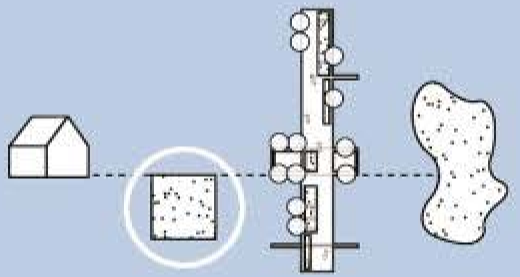
property



conventional
drain, direct, dispatch



low impact
slow, spread, soak




property
evapotranspiration
evapotranspiration
runoff
filtration
How can we introduce **productive landscapes**?
How can we increase **biodiversity**?
runoff
filtration
runoff
infiltration
How can we increase **on-site infiltration**?
How can we minimize **impervious surfaces**?

From Industrial to Low Impact Lawns

property

"...the lawn is one of America's leading crops."

*All information on these two pages from Ted Steinberg's *American Green: The Obsessive Quest for the Perfect Lawn*

the industrial lawn
a linear train of inputs and wastestreams

the low impact lawn
a regenerative, closed loop system

the problem of over-fertilization
Suburban lawn care consumes more herbicides per acre than most farmers broadcast to grow crops.

maintenance
The average lawn consumes more than 10,000 gallons of water per summer, causing water shortages in not just arid parts of the country.

clippings
"One recent university study found that nitrogen fertilization could be replaced by a whopping 50% without the least effect in the quality of the turf so long as the clippings stayed put."

lawn care
Lawn care is a $40 billion a year industry— more than the GDP of Vietnam in 2003.

productive lawn
An average sized lawn of around a third of an acre could produce enough vegetables to feed a family of six.

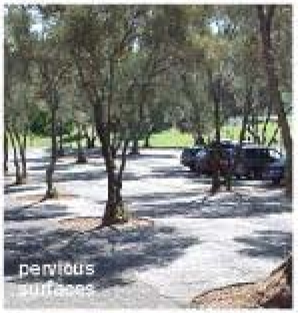
nutrient cycling
The bacteria necessary for nitrogenation of soil thrives in the polyculture of a low impact lawn; in the monoculture of industrial lawns the bacteria cannot survive.

compost
12.5% of refuse in landfills comes from food scraps while 12.8% comes from yard trimmings—this costly waste stream can be diverted and used for composting.

Botanizing Lot and Lawn

property

"The average urban lawn could produce several hundred pounds of food a year."



enhance lawns and lots with LID treatment facilities

Rain gardens are an excellent way to increase on-site infiltration within existing lawns. They take advantage of low lying areas as natural collection points for runoff and tolerate periods of extreme wetness and drought. In addition to aesthetic benefits, rain gardens facilitate bioremediation—the removal and breakdown of pollutants through plant processes. For parking lots, tree islands can be transformed into stormwater treatment facilities by cutting or removing curbs and sinking islands to receive stormwater runoff from impervious surfaces.

reduce impervious surfaces

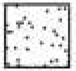
Since impervious surfaces do not allow for infiltration of stormwater, polluting substances that come into contact with hard surfaces are concentrated and channelized during a storm event, thus compounding polluted runoff dysfunctions. Pervious surfaces increase on-site runoff infiltration and prevent the transfer of pollution problems to another site. Pervious surfaces should be used at the beginning of the treatment network to slow and filter sediment before stormwater runoff reaches secondary LID facilities for treatment. Pervious paving is appropriate for parking zones and occasionally used drives, but should be avoided in high traffic areas.

remove high maintenance vegetation in favor of xeriscape

The industrialized lawn's life cycle costs for irrigation, turf seed, chemical fertilizer, herbicides, fuel and equipment, and waste management of lawn clippings, are substantial, while their shallow root systems provide little infiltration or ecological services. On the other hand, xeriscape lawns have significant economic and environmental benefits, such as increased biodiversity, food production, on-site infiltration, and low maintenance. A multi-species mix of native grasses is already adapted to an area's climate and able to exist as a stable plant community. Native grass lawns provide the same appearance as non-native monocultures, and only require mowing every three to five weeks.

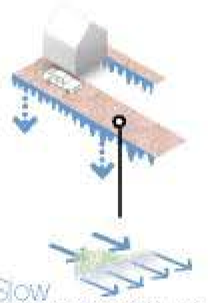
Lot Design

Property owners can implement varying degrees of LID on their lots.



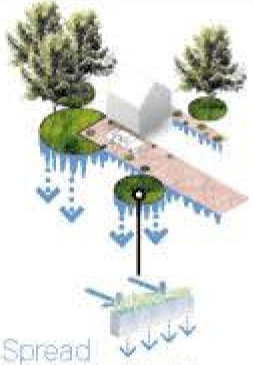
One-third of all residential water use in the US is currently used for landscaping.

filtration	infiltration	treatment



Slow

Use pervious paving for walks and drives. *Pervious Paving* pp. 172-173



Spread

Use rain gardens to treat the first flush of any storm event and infiltrate runoff from **one to ten-year storm events**. *Rain Garden* pp. 178-179

Soak

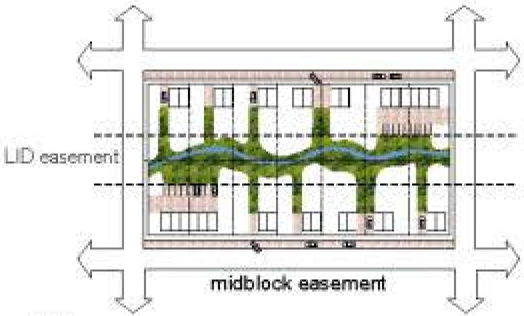
Replace industrial lawn with xeriscape lawn to treat and infiltrate runoff from **one to twenty-five-year storm events**. Consult local nurseries or a landscape design professional for optimal seed mix and plants.

footprints, and protecting existing vegetation.

Block Design

property

Incorporate shared conservation areas into LID neighborhood fabrics by connecting property to easements.

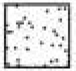


Slow
Filter stormwater through the use of pervious paving on driveways. *Pervious Paving* pp. 172-173

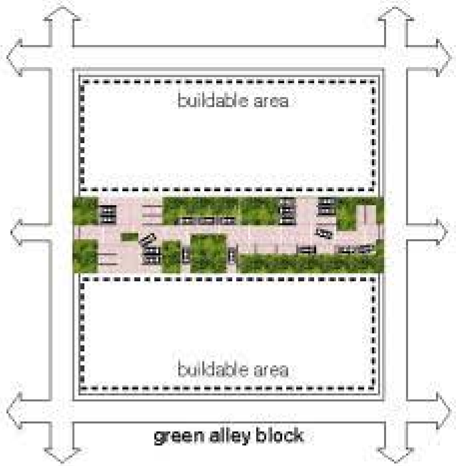
Spread
Locate buildings away from critical areas and create a series of rain gardens for attenuation and filtration of stormwater runoff from **one to ten-year storm events**. *Rain Garden* pp. 178-179

Soak
Plant and maintain vegetation in the riparian corridor. This is especially important in upstream developments. *Riparian Buffer* pp. 180-181

Block Design



Utilize a green alley in lieu of conventional alleys to combine the functions of access, parking, and stormwater management.



green alley block

Slow

Use flush curbs to allow water to be distributed evenly over treatment facilities. *Flow Control Devices* pp. 148-149

Spread

Reduce impervious surfaces to filter and attenuate stormwater from the street. *Pervious Paving* pp. 172-173

Soak

Apply rain gardens and bioswales in the easement for treatment during **one to ten-year storm events**. These facilities must be connected to secondary facilities to handle 10 to 50-year storm events. *Bioswale* pp. 182-183

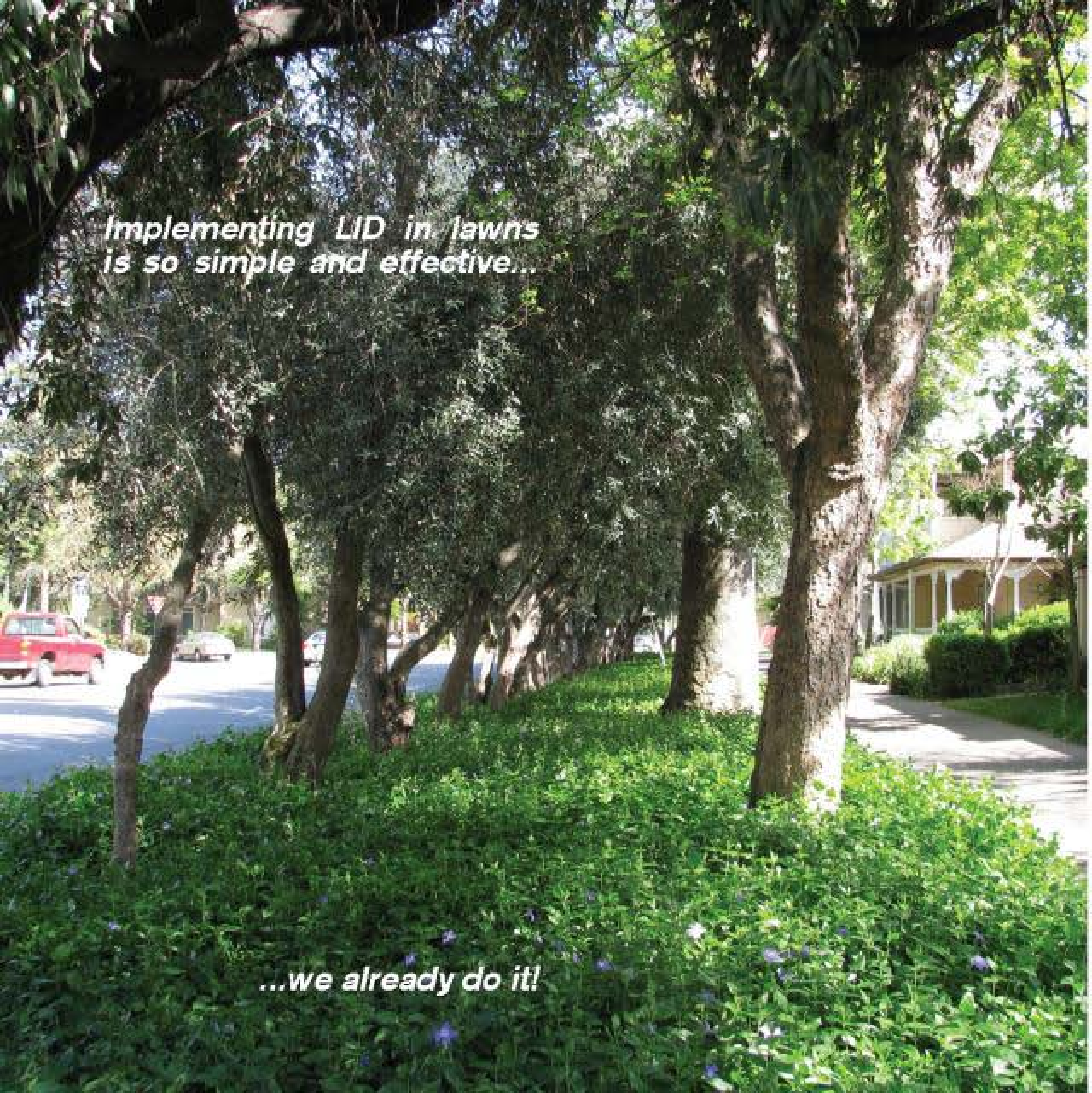
Block Design

Employ LID easements along the street to create a connective fabric for stormwater management.

Slow
Reduce impervious surfaces to attenuate stormwater from the street. *Pervious Paving* pp. 172-173

Spread
Use curb cuts to allow water to distribute evenly into the swale. *Flow Control Devices* pp. 148-149

Soak
Create LID easements with bioswales to treat and convey water to larger LID facilities. *Bioswale* pp. 182-183


Implementing LID in lawns
is so simple and effective...
...we already do it!

Surface Materials

property

An impervious surface will generate two to six times more runoff than a natural surface.






porous asphalt
These pavements, used mostly for parking lots, allow water to drain through the pavement surface into a stone recharge bed and infiltrate into soils below the pavement.
- Heat Island Mitigation: Low
- Initial Cost: +10% above conventional
- Maintenance: Vacuum
- Durability: 10-30 years

pervious concrete
This pavement technology eliminates the need for retention ponds and other stormwater BMPs, lowering overall project costs.
- Heat Island Mitigation: Low to Moderate (depending on color)
- Initial Cost: +10% above conventional
- Maintenance: Vacuum
- Durability: 10-30 years

interlocking paver systems
Pre-cast concrete, natural stone, or brick units allow water to permeate around or through their surfaces.
- Heat Island Mitigation: Low to Moderate (depending on color)
- Initial Cost: High
- Maintenance: Vacuum
- Durability: 10-50 years

alternative paving systems
One sustainable alternative material type is recycled rubber paving, which can be modular pavers or poured in place.
- Heat Island Mitigation: Moderate
- Initial Cost: Medium
- Maintenance: Vacuum
- Durability: 10-50 years

gravel systems
These systems consist of an injection molded ring and grid structure, underlain by geotextile fabric and a sandy gravel base course.
- Heat Island Mitigation: Moderate to High (depending on color)
- Initial Cost: Medium to High
- Maintenance: Add gravel
- Durability: 10-20 years

grass concrete and turf pavers
These systems provide significant load bearing strength while protecting vegetation root systems from compaction. Void spaces within the system allow excellent root development and water storage capacity.
- Heat Island Mitigation: High
- Initial Cost: High
- Maintenance: Watering
- Durability: 20-40 years

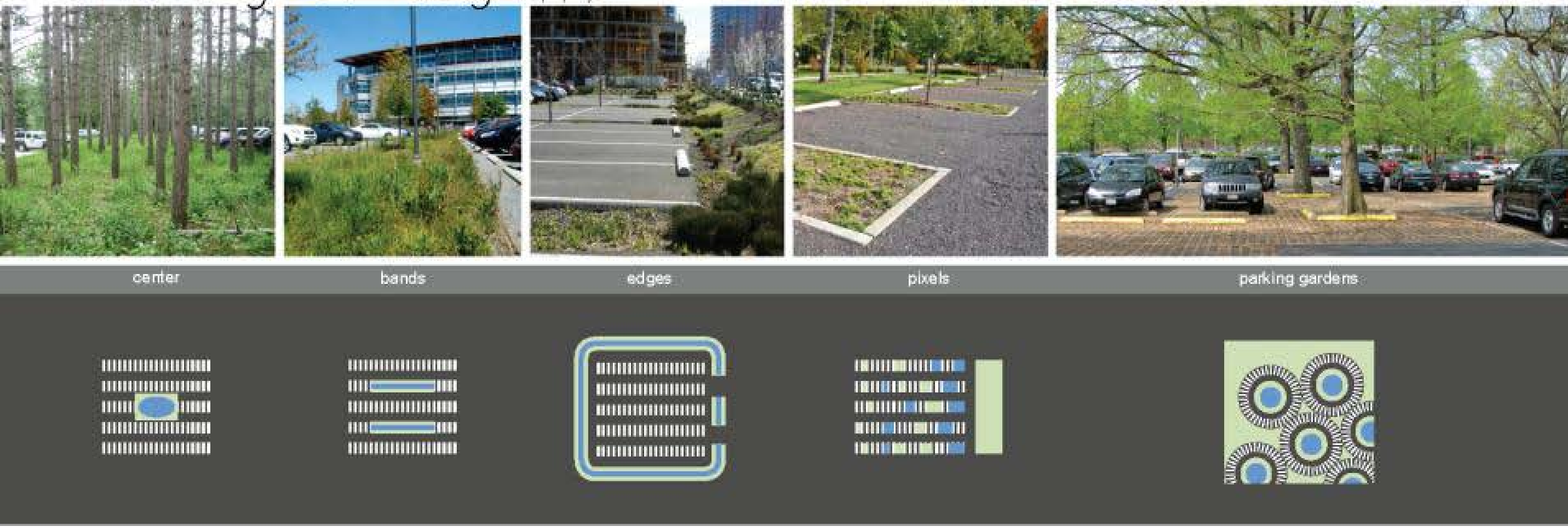
15 percent void space → 90 percent void space

When considering pervious paving, keep in mind that the voids of some systems require frequent vacuuming.

Gravel and vegetated systems have larger void spaces, thus allowing for greater infiltration capacity. However, these systems will require occasional mowing and sediment removal.

Parking Lot Design

property



minimum level of ecological service → maximum level of ecological service

Pixelated Parking

property

Reduce impervious surfaces by pixelating the parking surface with LID paving and landscapes.

Slow

Remove curbs and sink tree islands in parking stalls to receive and filter stormwater from **one to ten-year storm events** as it enters treatment landscapes. *Bioswale* pp. 182-183

Spread

For **10 to 25-year storm events**, use underground storage if soils are poorly drained or land area is limited. *Underground Detention* pp. 152-153 and *Wet Vault* pp. 156-157

Soak

Use oversized pipes to connect bioswales to an infiltration basin or a retention pond, which retain and infiltrate runoff during **25 to 50-year storm events**. *Retention Pond* pp. 160-161


atmospheric regulation
flow attenuation
soil formation
infiltration
erosion control
climate regulation
filtration
sediment retention
flow attenuation
Heifer International
Little Rock, Arkansas

Parking Gardens

property

Reconfigure conventional parking lot models to serve the hydrology of the site, where cars sit in their own treatment basins.

Slow

Construct rain gardens in center of parking modules to treat first flush and infiltrate most contaminated runoff during **one to ten-year storm events**. *Rain Garden* pp. 178-179

Spread

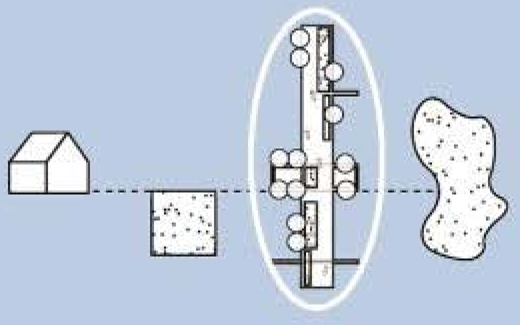
Convey water through oversized perforated pipes from rain gardens to treatment facilities during **10 to 50-year storm events**. *Oversized Pipes* pp.146-147

Soak

Use residual spaces as large treatment meadows that eliminate runoff contaminants as infiltration occurs. *Infiltration Basin* pp. 184-185

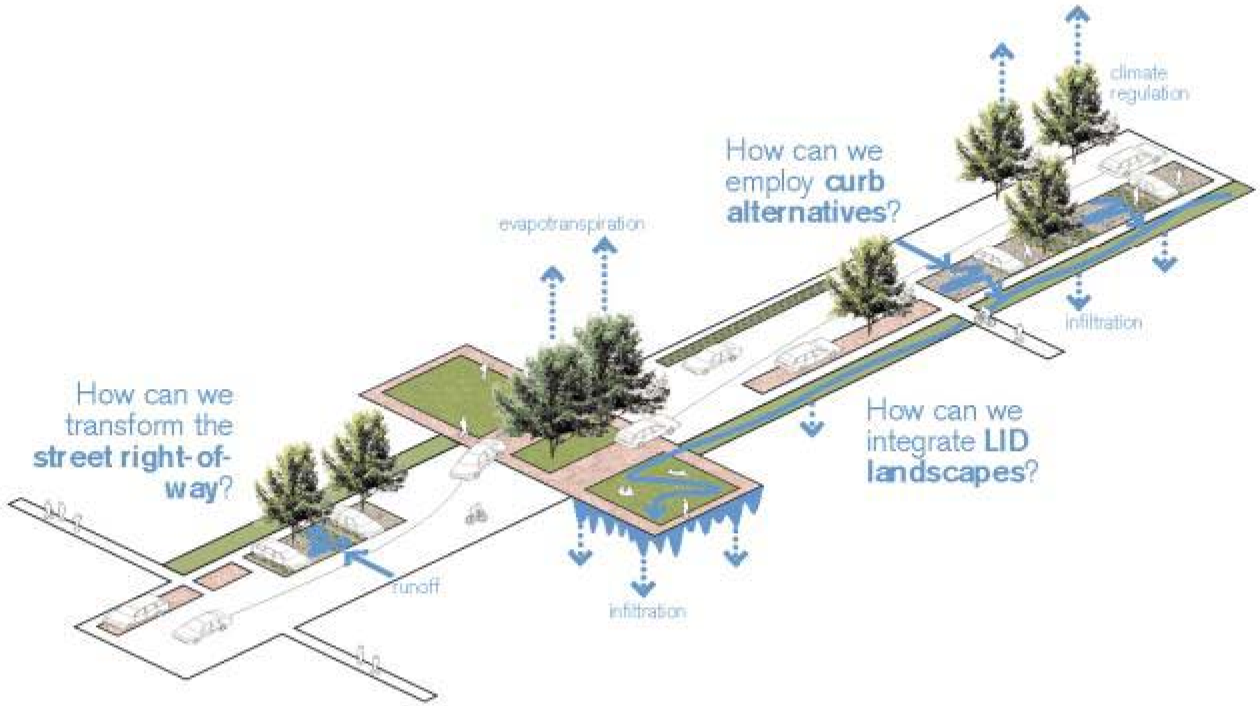

carbon regulation
evapotranspiration
atmospheric regulation
heat island mitigation
sediment retention
shaded parking
infiltration
erosion control
filtration
flow attenuation
Missouri Botanical Gardens
St. Louis, Missouri

street



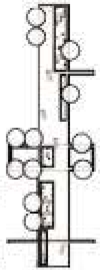
conventional
drain, direct, dispatch

low impact
slow, spread, soak

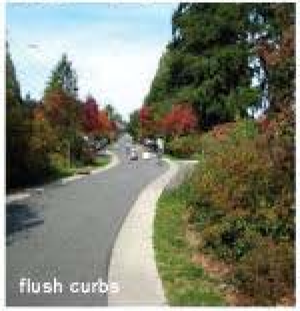


How can we transform the **street right-of-way**?
runoff
evapotranspiration
infiltration
How can we employ **curb alternatives**?
climate regulation
infiltration
How can we integrate **LID landscapes**?

Components of Low Impact Streets

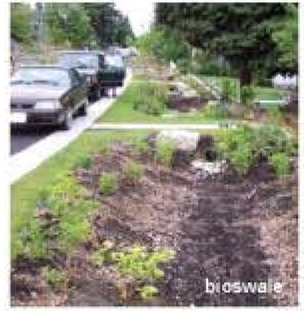



curb cuts


flush curbs

soft infrastructure

The flow rate of stormwater runoff should be reduced before it enters the treatment network. Streets can accomplish this through pervious paving systems that attenuate and filter water for sediment removal. At the street edge, LID facilities such as curb extensions, which house new rain gardens in reclaimed street space, reduce flow rates by treating and infiltrating stormwater runoff.


bioswale


rain garden

curb alternatives

Conventional urban streets employ curbs to channel stormwater runoff to catch basins where untreated water is dispatched to another location. LID curb alternatives evenly redistribute runoff to adjacent treatment facilities, retaining as much stormwater on site as possible. This is achieved by cutting curbs or eliminating them altogether. Curb choice depends on land use and stormwater volume to be managed. Curbs can be used as a safety feature in high traffic areas to separate pedestrians from vehicles.

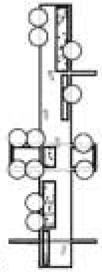

pervious parking

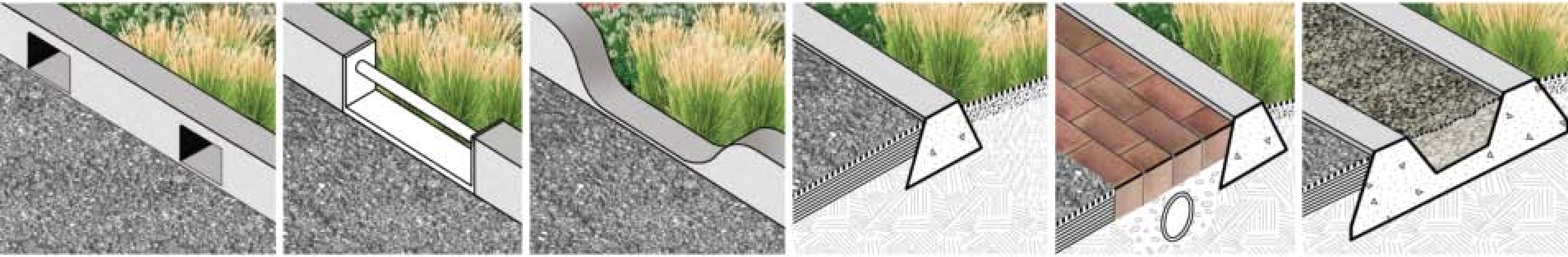

LID curb extensions

plants, not pipes

LID replaces pipe-and-pond systems with facultative planting—or a community of wetland plants—to metabolize pollutants in stormwater runoff. Instead of transporting polluted stormwater elsewhere, LID planting attenuates and treats water on site, allowing for retention and infiltration. Other benefits include mitigation of the heat island effect, cost savings for treatment, and preservation of water quality.

Curb Alternatives





perforated pre-cast curbs
Perforated pre-cast curbs can be installed in new developments to allow water flow.

- Sediment Capture: Low
- Traffic Level: Moderate/High
- Maintenance: High

pre-fabricated curb inserts
These inserts can be used in a retrofit of an existing curb or new construction, while maintaining the curb's structural integrity. Water energy-dissipating measures are not necessary to prevent erosion if the inlets are close together.

- Sediment Capture: Low
- Traffic Level: Moderate/High
- Maintenance: High

curb cut
Curbs can be cut in a retrofit or new construction. Curb cuts can vary in length, allowing for greater flow control.

- Sediment Capture: Low
- Traffic Level: Moderate
- Maintenance: Moderate

flush curb
A flush curb maximizes uniform distribution of water from the street to the treatment facility. When used with a shallow, half inch lip, water can pond, allowing sediment to settle for eventual removal by street sweepers.

- Sediment Capture: Low
- Traffic Level: Moderate/Low
- Maintenance: Low

paving strip with sediment trench
Pervious pavers can filter sediment from street runoff, and serve as a tactile warning for straying automobiles.

- Sediment Capture: Moderate
- Traffic Level: Moderate/Low
- Maintenance: Low

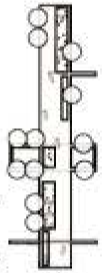
double flush curb with sediment trench
An aggregate trench between flush curbs captures sediment, keeping it out of the treatment facility.

- Sediment Capture: High
- Traffic Level: Low
- Maintenance: High

*All information on these two pages from Metro Portland's *Green Streets: Innovative Solutions for Stormwater and Stream Crossings*

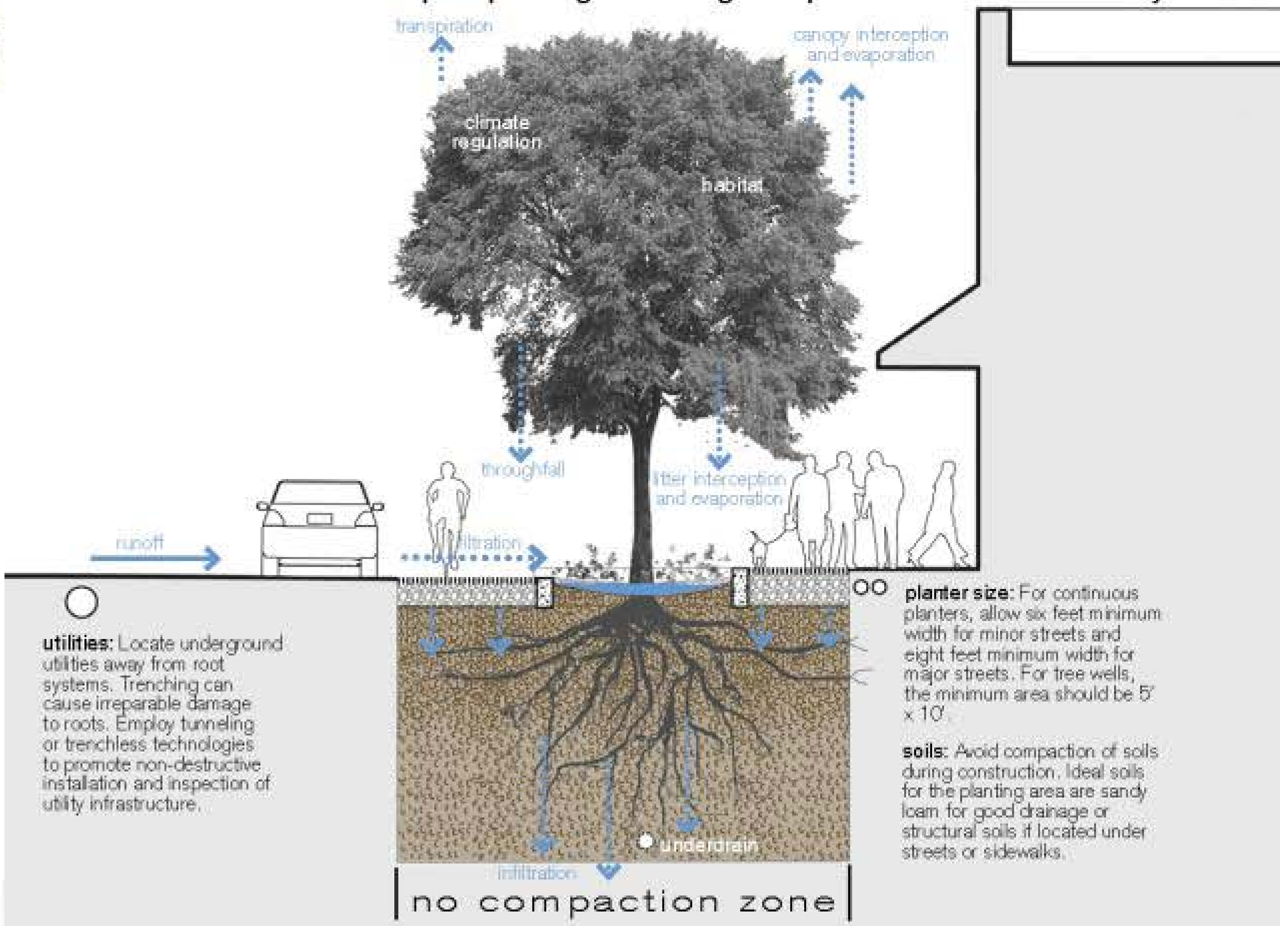
from point source flow → to distributed sheet flow

Designing for Urban Trees



Streets should be designed to accommodate tree root growth—the most critical factor in implementing tree lined streets.

Due to compaction and poor planning the average lifespan of an urban tree is 13 years.

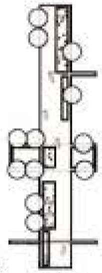


utilities: Locate underground utilities away from root systems. Trenching can cause irreparable damage to roots. Employ tunneling or trenchless technologies to promote non-destructive installation and inspection of utility infrastructure.

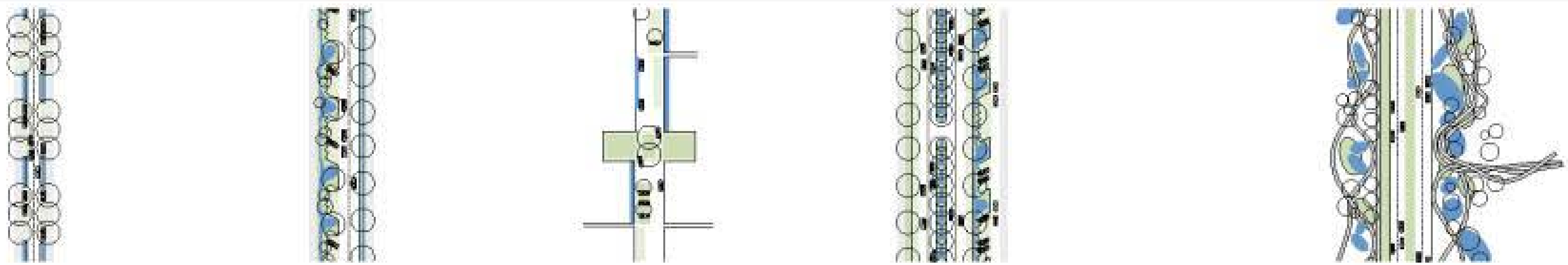
planter size: For continuous planters, allow six feet minimum width for minor streets and eight feet minimum width for major streets. For tree wells, the minimum area should be 5' x 10'.

soils: Avoid compaction of soils during construction. Ideal soils for the planting area are sandy loam for good drainage or structural soils if located under streets or sidewalks.

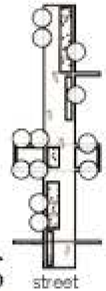
Street Types



skinny streets | green streets | shared streets | eco-boulevards | parkways

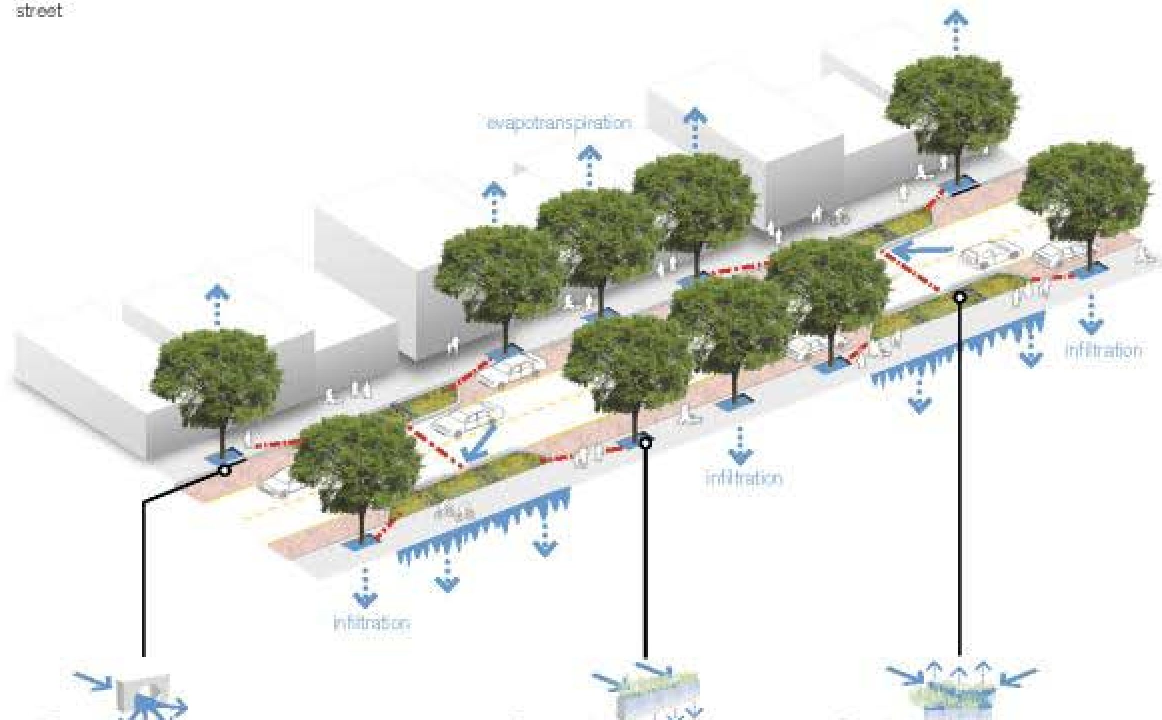


from local streets → to arterial streets



Skinny Streets

Create narrower streets to reduce runoff loading and substitute pervious paving for impervious surfaces to encourage stormwater infiltration.



Slow

Cut curbs to allow for stormwater flow into curb extensions or other LID facilities. *Flow Control Devices* pp. 148-149

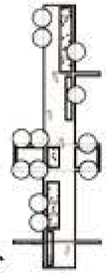
Spread

Construct tree box filters along the right-of-way to filter and attenuate stormwater runoff during **one to two-year storm events**. Connect in a series or to rain gardens using perforated pipe to handle larger events. *Tree Box Filter* pp. 176-177

Soak

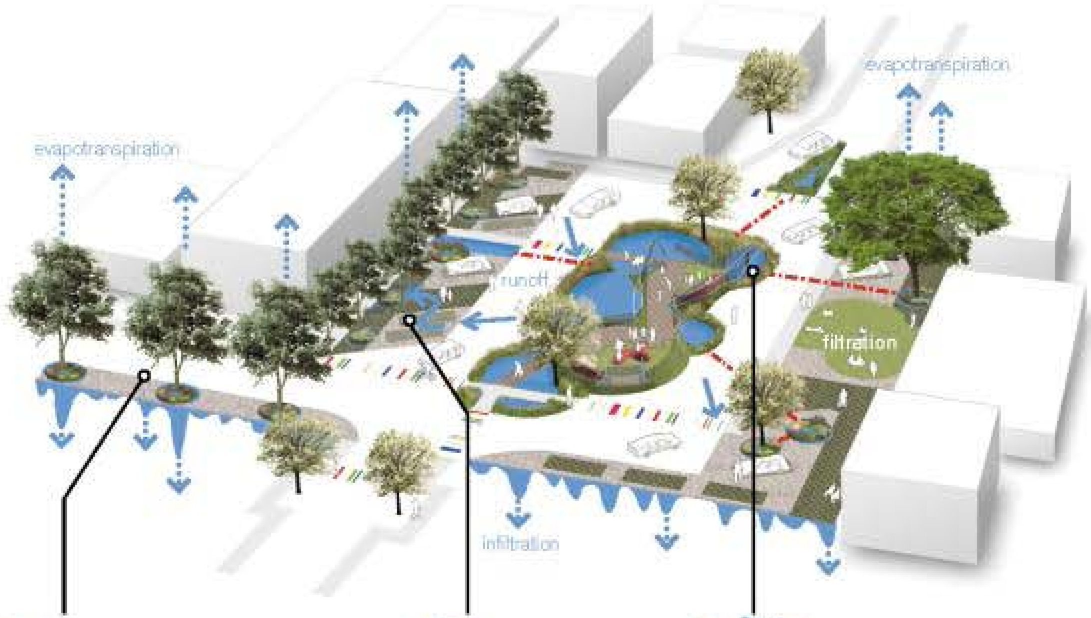
Use curb extensions to retrofit existing parking lanes with rain gardens. This reduces impervious surface area, and encourages infiltration during **10 to 25-year storm events**. *Rain Garden* pp. 178-179


heat island mitigation
climate regulation
curb extension
infiltration
non-invasive facultative landscapes
erosion control and
sediment retention
Siskiyou Street
Portland, Oregon



Shared Streets

Design local streets as landscapes that balance the social needs of pedestrians, transit, and stormwater management.



Slow

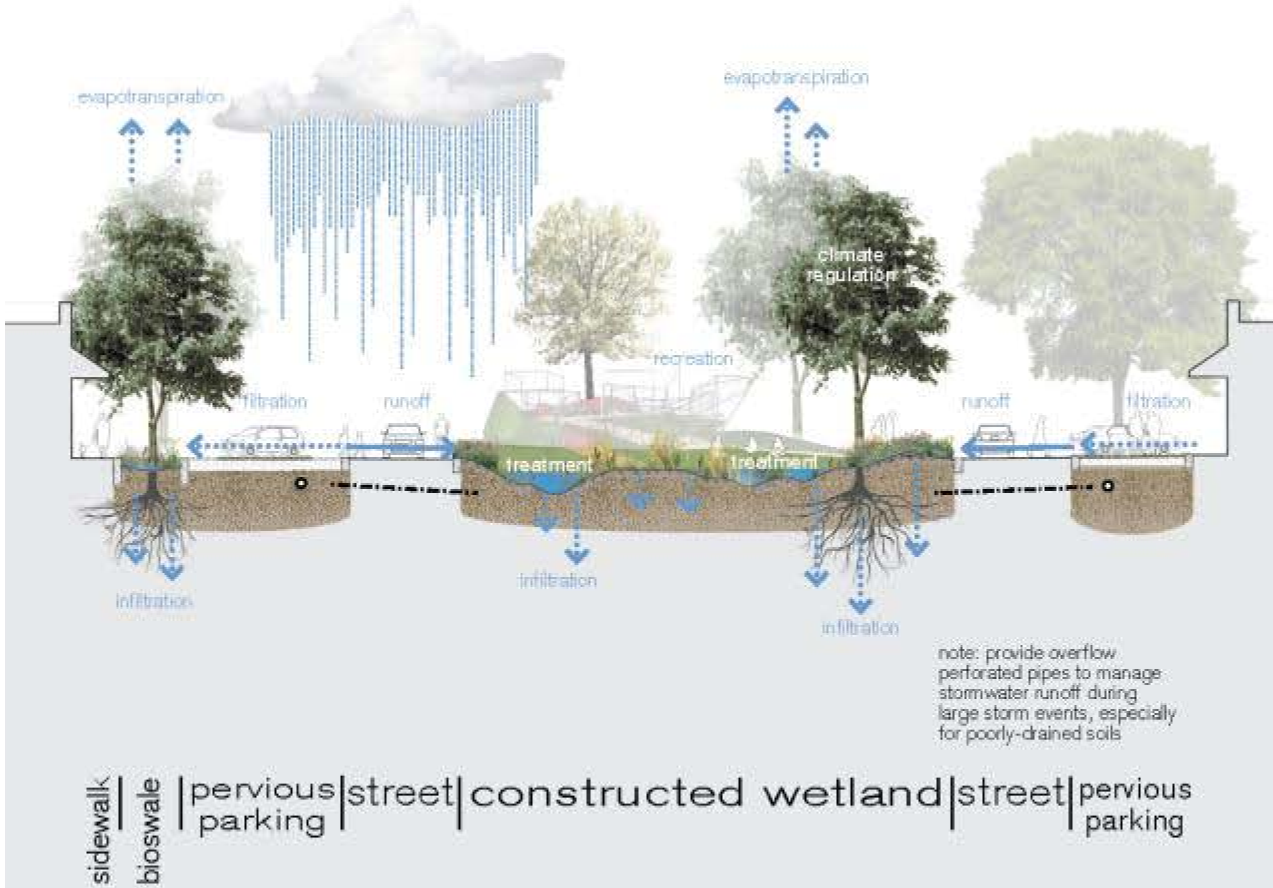
Instead of creating channelized flow, remove curbs to allow sheet flow, which reduces the velocity of runoff. *Flow Control Devices* pp. 148-149

Spread

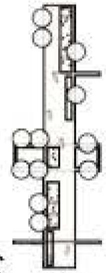
Use pervious paving, filter strips and rain gardens at the shared street's edge to create areas for parking and recreation that can filter and infiltrate **one to ten-year storm events**. *Filter Strip* pp. 162-163

Soak

Use constructed wetlands to infiltrate and treat runoff during **10 to 50-year storm events** and create opportunities to combine stormwater management with pedestrian social spaces. *Constructed Wetland* pp. 186-187

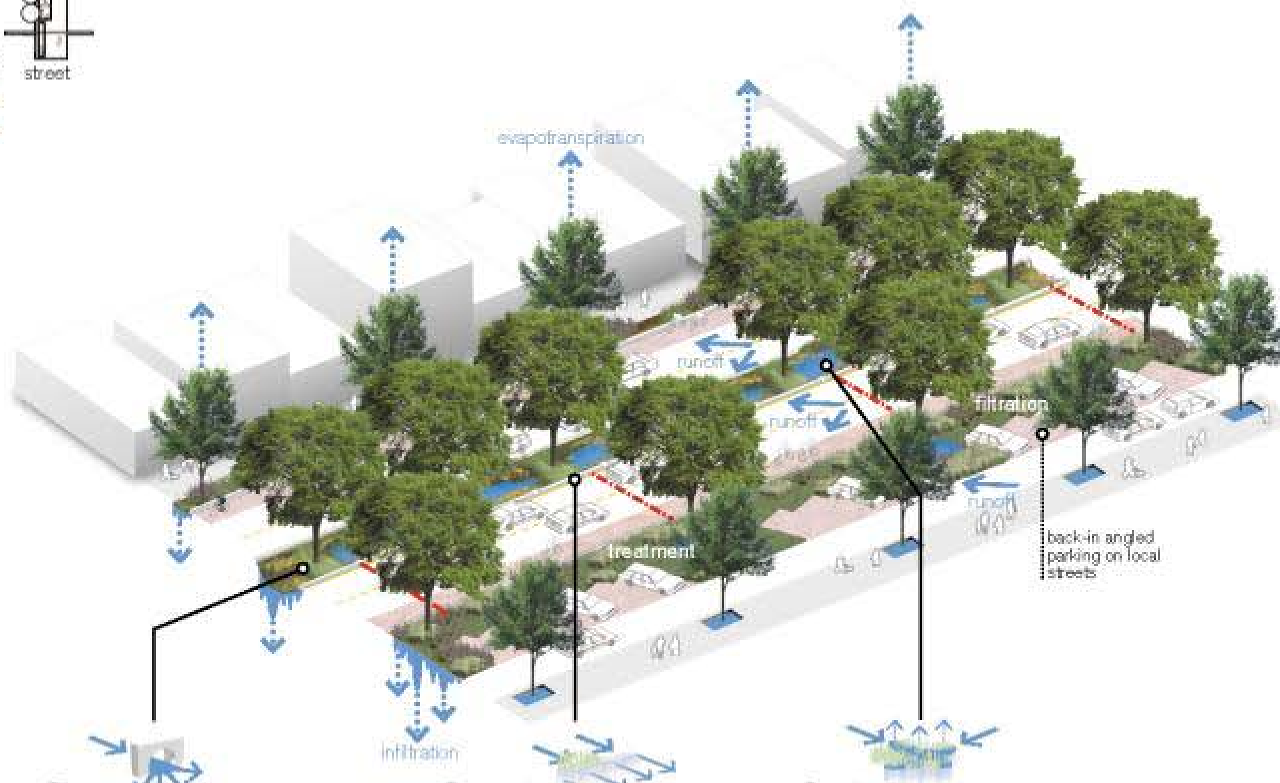

evapotranspiration
evapotranspiration
climate regulation
recreation
filtration
runoff
runoff
filtration
treatment
treatment
infiltration
infiltration
infiltration
note: provide overflow perforated pipes to manage stormwater runoff during large storm events, especially for poorly-drained soils
sidewalk
bioswale
pervious parking
street
constructed wetland
street
pervious parking


heat island mitigation
climate regulation
infiltration
rain garden
flush curbs
parallel parking
shared throughway
(single ground surface)
rain garden
infiltration
flush curbs
Willamette Street
Eugene, Oregon



Eco-Boulevards

Create streets with green medians that also deliver water treatment services.



Slow

Use tree mounds or check dams in medians to attenuate and detain runoff, allowing stormwater a chance to infiltrate during **one to ten-year storm events**. *Flow Control Devices* pp. 148-149

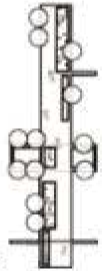
Spread

Implement curb cuts or other curbing strategies to allow water to flow into median LID facilities. *Curb Alternatives* pp. 96-97

Soak

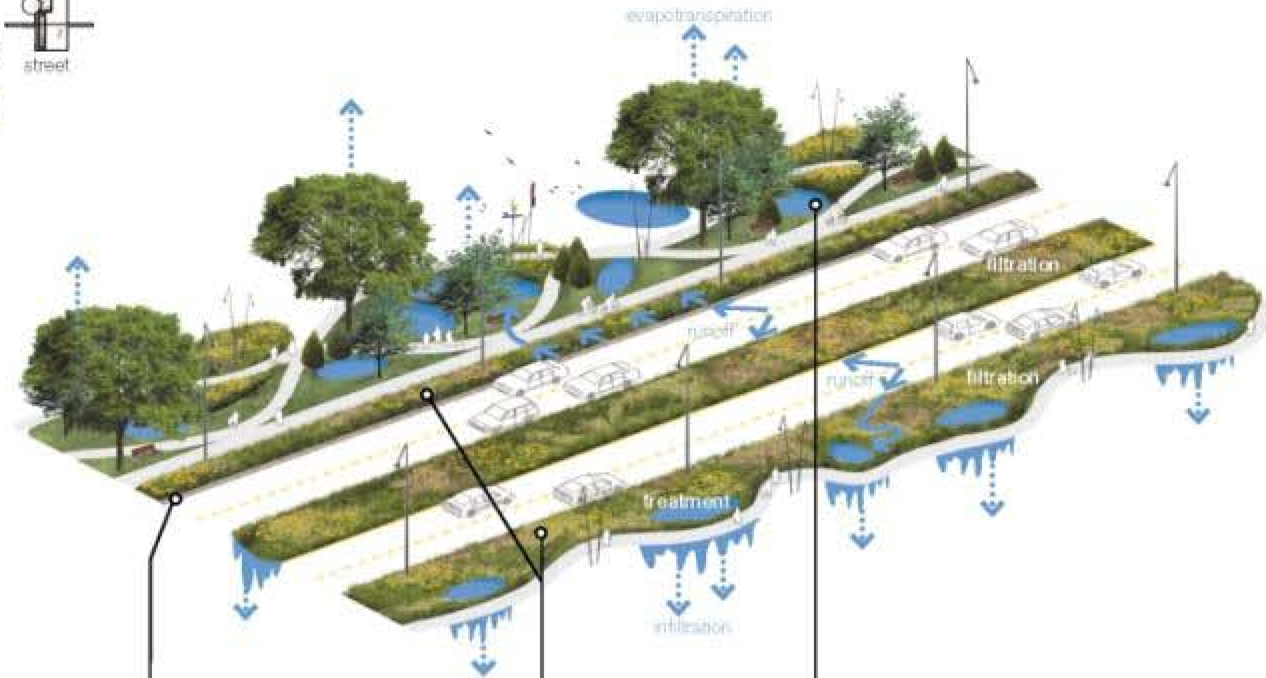
Integrate bioswales in boulevards to treat stormwater runoff before it enters conventional systems during **10 to 50-year storm events**. *Bioswale* pp. 182-183


heat island mitigation
atmospheric regulation
rain garden
central arterial
shared local street
shaded sidewalk
Octavia Boulevard
San Francisco, California
pervious paving



Parkways

Improve the street right-of-way akin to a greenway landscape.



Slow

Use a level spreader to transform concentrated stormwater runoff into sheet flow for distribution over a filter strip. *Flow Control Devices* pp.148-149

Spread

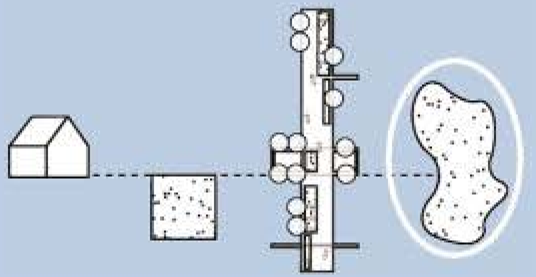
Use filter strips to filter pollutants out of stormwater runoff and safely separate bicycle lanes from faster automobile traffic. *Filter Strip* pp. 162-163

Soak

Design infiltration facilities along the highway that encourage outdoor exercise and alternative modes of transportation, managing stormwater runoff from **25 to 50-year storm events.** *Infiltration Basin* pp. 184-185


evapotranspiration
filter strip
non-invasive facultative landscapes
filter strip
erosion control and sediment retention
flow attenuation
climate regulation
heat island mitigation
treatment
infiltration
soil formation
LID Parkway
Chicago, Illinois

open space

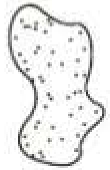


conventional
drain, direct, dispatch

low impact
slow, spread, soak


How can we transform **parks**?
How can we develop to ensure **conservation**?
How can we transform **greenways**?

Conservation Development



Preserve native vegetation, sensitive ecological habitat, and open space by using conservation development techniques.

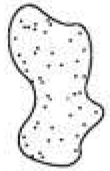
conventional development

25 houses and 4 commercial buildings on 5 acres

conservation development

25 houses and 4 commercial buildings on 5 acres

Treatment Parks



Introduce stormwater management as another ecological service delivered by urban parks.

Slow

Use filter strips at the edge of parks to filter and attenuate stormwater runoff from impervious surfaces during **one to ten-year storm events**. *Filter Strip* pp. 162-163

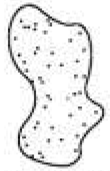
Spread

Use rain gardens as links between filter strips and larger treatment facilities to capture, filter, and infiltrate stormwater runoff from **10 to 25-year storm events**. *Rain Garden* pp. 178-179

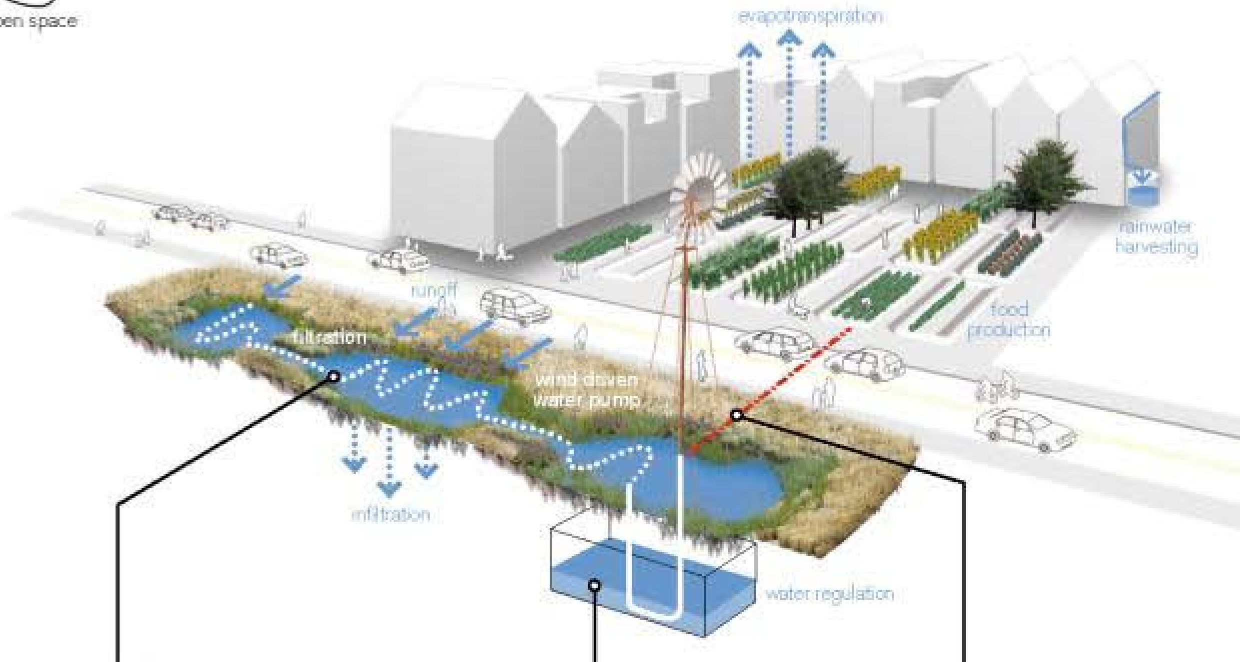
Soak

Use infiltration basins and constructed wetlands to treat and infiltrate urban stormwater runoff during **25 to 50-year storm events**. *Constructed Wetland* pp. 186-187

Water Harvesting Parks


open space

Recycle stormwater runoff as irrigation for high maintenance parks, such as community gardens and sports fields.



Slow

Use bioswales to capture and filter stormwater runoff from impervious surfaces during **one to ten-year storm events**. *Bioswale* pp. 182-183

Spread

After filtering, store water from **10 to 25-year storm events** in an underground cistern for future irrigation uses. *Rainwater Harvesting* pp. 158-159

Soak

Pump treated rainwater through an irrigation system to community gardens or sports fields during dry periods.

Greenways

Connect open spaces to create an urban greenway that maintains nutrient, natural resource, and habitat flows through the city.

Slow

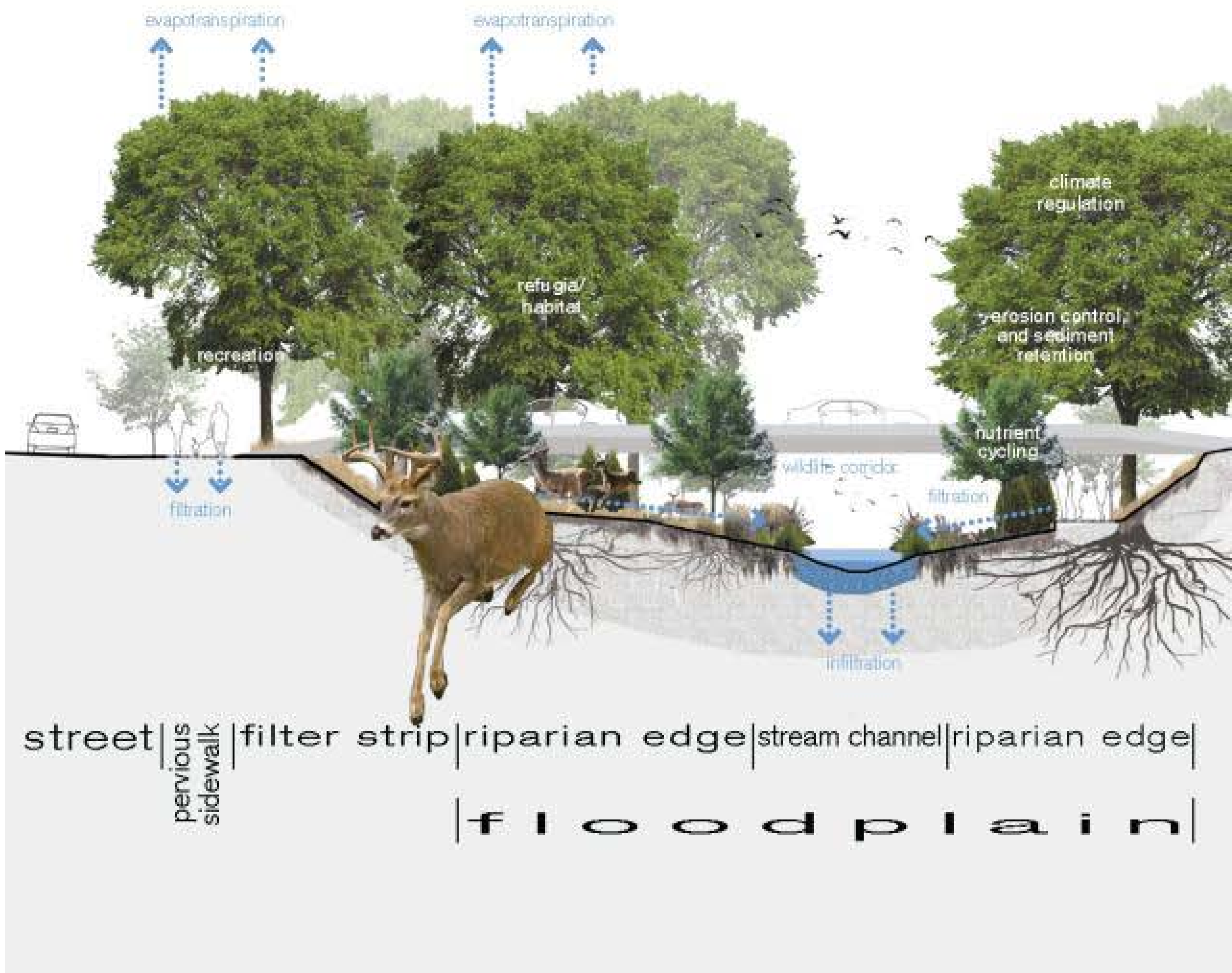
Implement flow control devices such as curbs and level spreaders to slow the flow of water before reaching the greenway. *Flow Control Devices* pp. 148-149

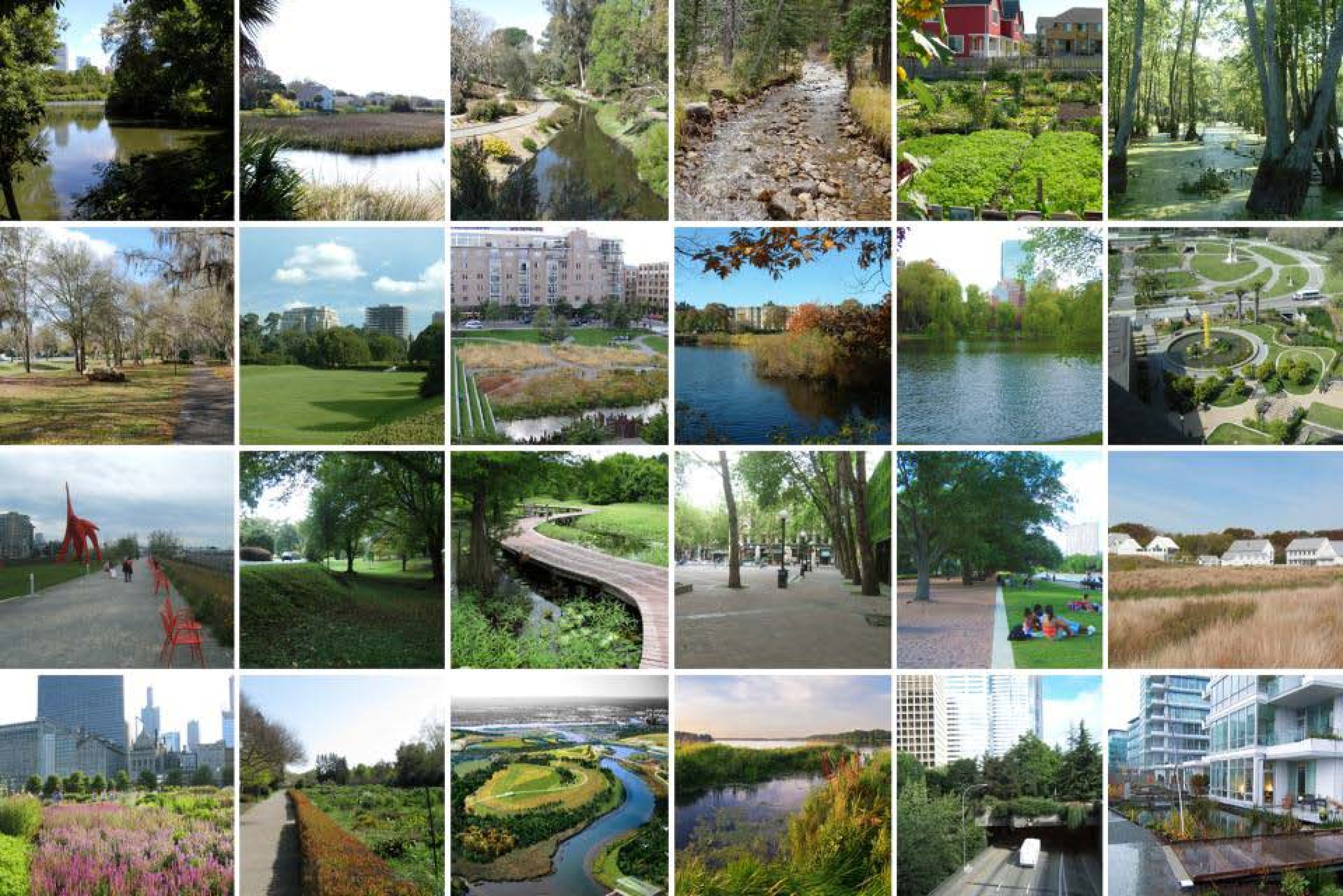
Spread

Use vegetated riparian buffers to filter and attenuate urban stormwater runoff before reaching sensitive stream corridors. *Riparian Buffer* pp. 180-181

Soak

Maintain natural sinuosity in streams to create erosion and deposition zones that regulate stream flow and sedimentation.


evapotranspiration
evapotranspiration
climate regulation
refugia/ habitat
erosion control, and sediment retention
recreation
nutrient cycling
wildlife corridor
filtration
filtration
infiltration
street
pervious sidewalk
filter strip
riparian edge
stream channel
riparian edge
floodplain



What are the LID facilities?

The Facilities Menu organizes the LID facilities based on increasing level of treatment service (quality) as well as increasing level of volume reduction (quantity). Therefore, number one (1), flow control devices offer the least amount of treatment services while number twenty-one (21), constructed wetland offers the most. Most municipalities require drainage infrastructure to manage 100-year storm events. Though one facility alone will likely not satisfy performance requirements, facilities with varying levels of service in a treatment network will provide superior levels of treatment and volume reduction.

LID facilities menu

optimal level of service
flow control

location in LID network
utilize where piping can not be avoided, under impervious surfaces like driveways and sidewalks

scale
applicable anywhere within LID network

management regime
occasional trash and sediment removal

Oversized Pipes

Oversized pipes are subsurface pipe systems sized larger than required to reduce peak flow rates.

While oversized pipes are more costly, they eliminate larger pressure drops and high velocities associated with undersized, or even correctly sized pipes during larger storm events. Lower velocities reduce outlet erosion and scouring. Larger volume pipe allow water to be detained, without creating problematic backwater effects. The location of oversized pipes can vary within the LID network.

As with any pipe infrastructure, oversized pipes require trash and sediment removal annually.

References:
Minnesota Urban Small Sites BMP Manual

optimal level of service
flow control

location in LID network
downstream from concentrated stormwater runoff

scale
from small residential application to larger commercial site

management regime
trash and sediment removal as needed

2

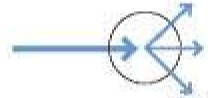
flow control devices

Flow Control Devices

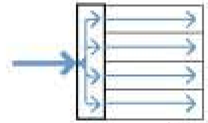
Flow control devices, such as flow splitters, are used to reduce peak discharge, attenuating concentrated stormwater flows.

These devices are placed in areas of concentrated sheet flow, channel flow, or pipe flow to attenuate stormwater runoff prior to it entering a stormwater management system. Flow control devices slow concentrated surface runoff and pipe discharge, thus allowing large debris and sediments to drop out of suspension. These devices are intended to improve the function of other LID facilities and prevent scouring from excessive flow energy. Damaging runoff, peak flow rates, and sediment loads that overwhelm stormwater management systems, are reduced as a result of using flow control devices.

These facilities require regular management and inspection to remove excess sediment, trash, and debris.


plan

flow splitter
self-activating flow control device in either a manhole or catch basin for restricting or redistributing site runoff to meet the pre-development rate


plan

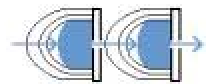
level spreader and rock swale
level spreaders and rock swales convert concentrated runoff, typically from stormwater pipe outlets, into sheet flow


section

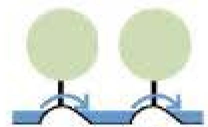
permeable weir
typically constructed from treated lumber, with spaces between each timber to provide slow passage of stormwater through long, narrow openings


plan

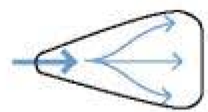
curb
street curbs typically line street edges; however, they can be cut and shaped to allow for water passage into a LID facility *Curb Alternatives* pp. 96-97

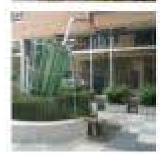

plan

check dam
small dams constructed across a ditch or swale to slow and temporarily hold water during larger storm events


section

tree mound
trees planted on mounds within a swale, bioswale, or ditch can act as natural check dams, attenuating stormwater flow


plan



splash block and riprap
splash blocks and riprap absorb the energy from concentrated runoff caused by rain leaders and pipes

References:
Low Impact Development Design Strategies–An Integrated Design Approach
Low Impact Development Manual for Michigan

optimal level of service
detention/infiltration

location in LID network
optimally placed after filtration facilities to prevent excessive sedimentation

scale
maximum watershed runoff area is 25 acres

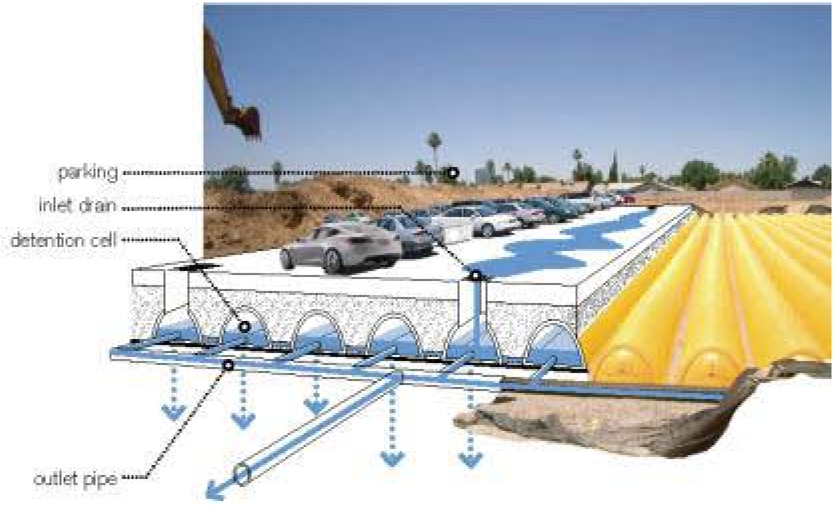
management regime
inspection and sediment cleanout

Underground Detention

Underground detention systems detain stormwater runoff prior to its entrance into a conveyance system.

Underground storage systems store and slowly release runoff into the LID network. Some systems can infiltrate stormwater if the soil beneath is permeable. Underground storage is employed in places where available surface area for on-grade storage is limited.

Underground storage reduces peak flow rate through metered discharge and has potential for infiltration. Improved water quality is achieved by sedimentation, or the settling of suspended solids. Though at first costly, underground detention systems are easy to access and maintain.



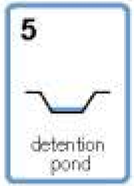
References:
Low Impact Development Manual for Michigan
Urban Design Tools–Low Impact Development
Minnesota Urban Small Sites BMP Manual

optimal level of service
detention

location in LID network
downstream of catchment and runoff, upstream from off-site stormwater management systems

scale
watershed runoff area of 10 acres and greater

management regime
regular trash and intermittent sediment removal, pollutants accumulate in soils and may require amendments and clean out

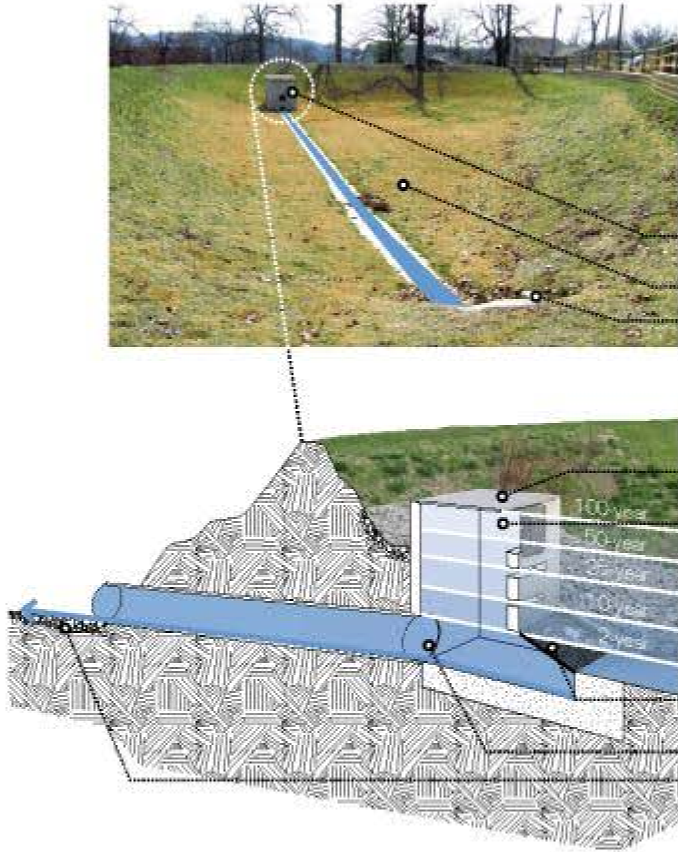


Detention Pond

Detention ponds, or dry ponds, are stormwater basins designed to intercept stormwater runoff for temporary impoundment and gradual release to a conveyance system or a receiving waterbody.

Detention ponds are designed to completely evacuate water from storm events, usually within 24 hours. They primarily provide runoff volume control reducing peak flows that cause downstream scouring and loss of aquatic habitat. As a general rule, detention ponds should be implemented for drainage areas greater than 10 acres. On smaller sites it may be difficult to provide control since outlet diameter specifications needed to control small storm events are small and thus prone to clogging. Also, treatment costs per acre are reduced when implemented at larger scales.

Re-suspension of settled material is a large concern in these systems, requiring periodic sediment, debris, and pollutant removal. Detention ponds do not provide infiltration and are therefore best used within a network that provides biological treatment.



References:
Low Impact Development Manual for Michigan
Minnesota Urban Small Sites BMP Manual

optimal level of service
retention

location in LID network
beginning of treatment train, directly at the source of runoff

scale
from a small 50-gallon rain barrel for a residential application to larger 25,000-gallon commercial scale cisterns

management regime
seasonal debris removal, storage tank inspection

Rainwater Harvesting

Rainwater harvesting involves collection, storage, and reuse of runoff from roofs.

Rainwater harvesting reduces runoff volume and peak flows. Cisterns, bladder tanks, and precast ferrocement septic tanks are generally larger than rain barrels and slim tanks, and are used for domestic water supply, rather than irrigation for landscaping. Most rainwater harvesting devices are modulated and can be connected to provide increased storage. Consider that in areas with rainfall more than 25 inches annually, a 1,000 square foot roof will produce a minimum of 15,000 gallons of rainwater per year. To capture this water for irrigation during the peak months approximately 10 rain barrels or one 500-gallon cistern are needed.

Maintenance needs are moderate compared to other LID technologies, however, water must be used periodically between rain events to maximize storage capacity, minimize runoff, and avoid odors. Gutter screens prevent the accumulation of debris in runoff. Filtration and purification equipment must be incorporated when using stormwater runoff for potable uses.

rain barrel
typically a 50-gallon barrel that can be utilized at each downspout of a building

slim tank
a slim tank provides smaller storage facilities that can be distributed around the building

plastic, fiberglass, metal, or wood cistern
most common means of rainwater storage and typically used in above grade applications

precast ferrocement septic tank
cement septic tank used instead for rainwater harvesting and can be installed below grade or above the ground

bladder tank
bladders do not require structure and can be placed in any location, thus are an affordable and attractive alternative to other fixed tank systems

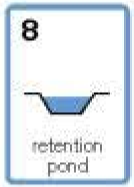
References:
Low Impact Development Manual for Michigan
Low Impact Development Technical Guidance Manual for Puget Sound
United States Department of Housing and Urban Development
Minnesota Urban Small Sites BMP Manual
http://www.harvestingrainwater.com

optimal level of service
retention/treatment

location in LID network
downstream of catchment and runoff, usually constructed at the lowest point of the site

scale
can be used for residential, commercial, and industrial sites, with watershed runoff areas no smaller than 10 acres depending on regional precipitation

management regime
inspected semiannually to confirm that drainage is functioning properly and to remove sediment, accumulated trash, and debris

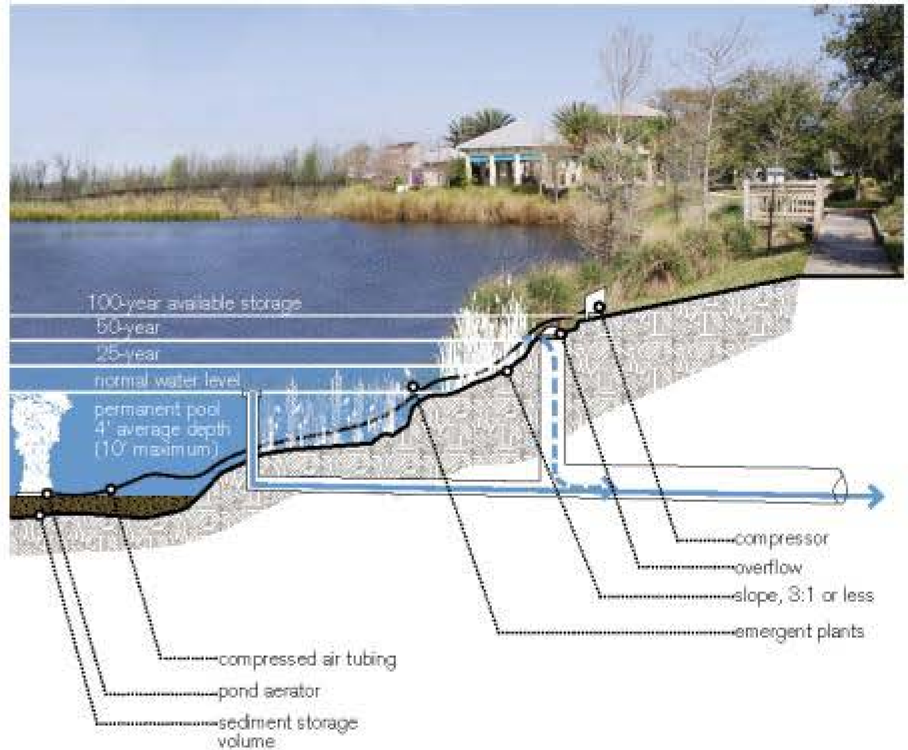


Retention Pond

A retention pond, also known as a wet pool or wet pond, is a constructed stormwater pond that retains a permanent pool of water, with minor biological treatment.

Wet ponds remove pollutants through biological uptake processes and sedimentation. The amount of pollutants that are removed from stormwater runoff is proportionate to the length of time runoff remains in the pond, as well as the relation of runoff to retention pond volume. Since retention ponds must maintain a permanent pool, they cannot be constructed in areas with insufficient precipitation or highly permeable soils, unless the soil is compacted or overlain with clay. Generally, large contributing watersheds are required to maintain permanent pool levels.

One advantage of a retention pond is the presence of aquatic habitat when properly planted and maintained. The use of a pond aerator is necessary to avoid stagnation and prevent algae growth that can lead to eutrophication, or an anaerobic environment. A heathy aerobic environment is a necessary condition for aquatic life and Integrated Pest Management (IPM). Regular maintenance inspections are needed to ensure proper drainage, aerobic functioning and aeration, and vegetative health. Trash, debris, and sediment will need to be removed periodically.



References:
Low Impact Development Manual for Michigan
Minnesota Urban Small Sites BMP Manual
EPA Storm Water Technology Fact Sheet-Wet Detention Ponds

optimal level of service
filtration

location in LID network
upstream of major treatment systems

scale
from a small slope at streetside
to the size of a large field

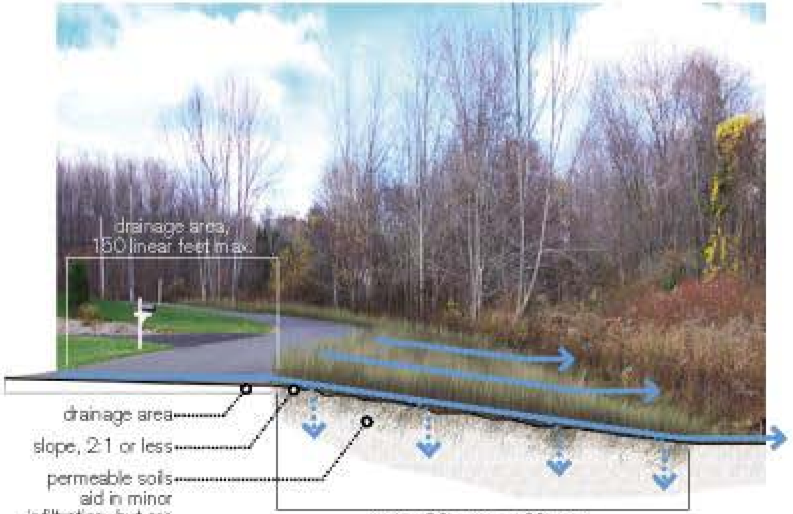
management regime
trash and sediment
removal, and mowing

Filter Strip

A filter strip is a grassy slope located parallel to an impervious surface such as a parking lot, driveway, or roadway.

Filter strips use vegetation to slow runoff, allowing suspended sediment and debris loads to drop out of runoff flow. This prevents clogging of stormwater drainage systems or receiving waterbodies. Stormwater runoff should be uniformly distributed along the top of the entire filter strip using a flow control facility such as a level spreader. Other treatment facilities, such as a swale, should be used for channelized flows. The drainage area should not exceed 150 linear feet to ensure proper functioning of the filter strip. The lateral slope of the filter strip should be one to two percent. A series of stepped level spreaders could compensate for slightly steeper slopes.

Filter strip areas cannot be used for construction material storage or activities that could disturb the ground surface. Regular inspection and maintenance are required to prevent clogging by sediment and/or debris. Filter strips should be located in sunny areas to dry out between rain events.



References:
Low Impact Development Design Strategies–An Integrated Design Approach
Low Impact Development Manual for Michigan
United States Department of Housing and Urban Development
Minnesota Urban Small Sites BMP Manual

optimal level of service
filtration/treatment

location in LID network
beginning of network,
directly within the runoff source

scale
from small residential applications to
large industrial buildings

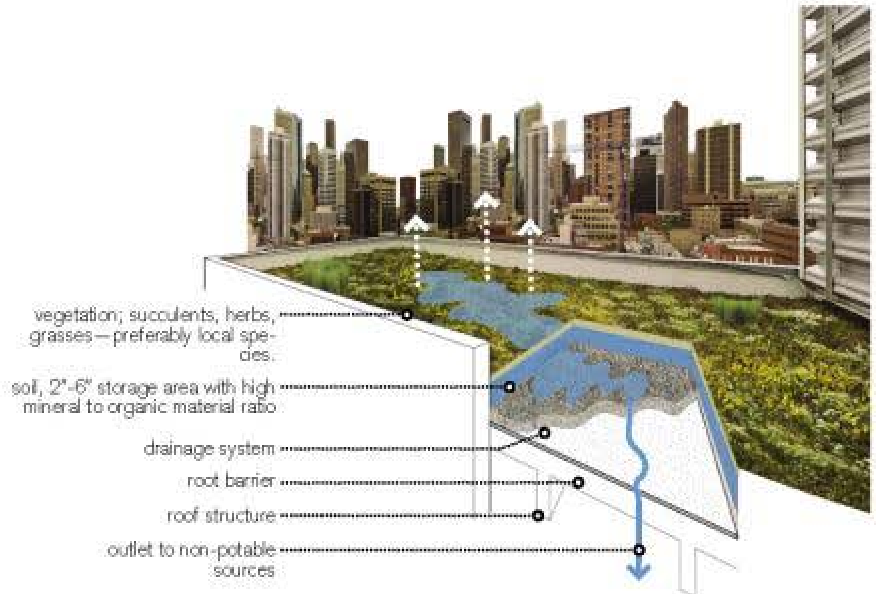
management regime
inspection of the roof membrane,
as well as routine vegetation inspection and
maintenance of the drainage flow paths

Vegetated Roof

Vegetated roofs, or green roofs, are garden ecologies installed atop buildings, from small to large buildings.

Intended to be closed loop systems, vegetated roofs collect rainwater at its source, slow its release, and reduce its volume through evapotranspiration from plants. Vegetated roofs also regulate building temperature through additional thermal insulation, reducing heating and cooling loads. Vegetated roofs are especially effective in controlling intense, short-duration storms, and have been shown to reduce cumulative annual runoff by 50 percent in temperate climates. Vegetated roofs are desirable in flood-prone climates with regular flash storm events.

Vegetated roofs can be built on flat roofs or sloped roofs, however flat roofs are easier to install. Roofs with steep slopes usually require the addition of cross-battens to secure drainage layers and to control soil erosion.



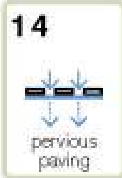
References:
Low Impact Development Design Strategies–An Integrated Design Approach
Low Impact Development Manual for Michigan
Low Impact Development Guidance Manual for Puget Sound
Stormwater Management Handbook
Minnesota Urban Small Sites BMP Manual

optimal level of service
filtration/infiltration/treatment

location in LID network
apply upstream of treatment systems to provide sediment removal and to reduce runoff volume

scale
as small as a single parking stall or as large as an entire lot or street

management regime
vacuum-based sediment removal from paving; grass systems may need to be mowed and may need to be irrigated to maintain vegetation

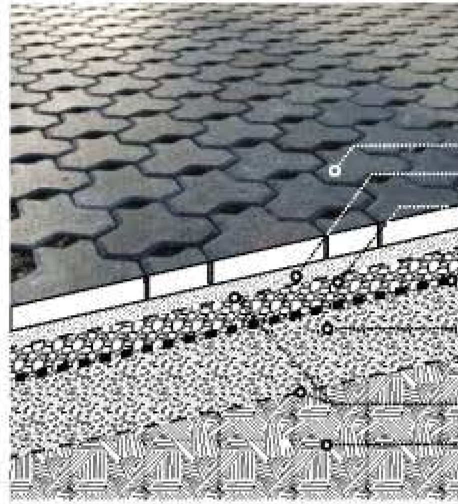


Pervious Paving

Pervious, or permeable, paving allows water to vertically flow through hard surfaces. As substitutes for impervious paving, they support both pedestrian and vehicular traffic.

A pervious paving system includes a subsurface base made of course aggregate for stormwater storage. In some designs, pervious pavement is supported by underground layers of soil, gravel and sand to increase storage and maximize infiltration rates. Pervious paving removes sediment and other pollutants. It acts to reduce and distribute stormwater volume, encouraging groundwater infiltration. There are multiple types of pervious paving, including modulated precast pavers, poured in place systems, porous asphalt, porous concrete, and gravel. Reduction of the urban heat island effect is possible when using high-albedo, lightly colored systems.

Large scale vacuums must be used to clean out gravel, paver, and porous systems. Grass systems may need occasional mowing and irrigation(see "Surface Materials" pp. 78-79).



pervious surface materials


porous asphalt /concrete


open grid pavers


gravel paving


grass concrete paving


turf pavers

References:
Low Impact Development Manual for Michigan
Stormwater Management Handbook
Minnesota Urban Small Sites BMP Manual
Low Impact Development Technical Guidance Manual for Puget Sound

optimal level of service
infiltration/treatment

location in LID network
downstream of filtration components, but upstream of major treatment facilities

scale
from a small strip to a sand field with a maximum catchment area of two acres

management regime
annual removal of trash and raking to maintain permeability

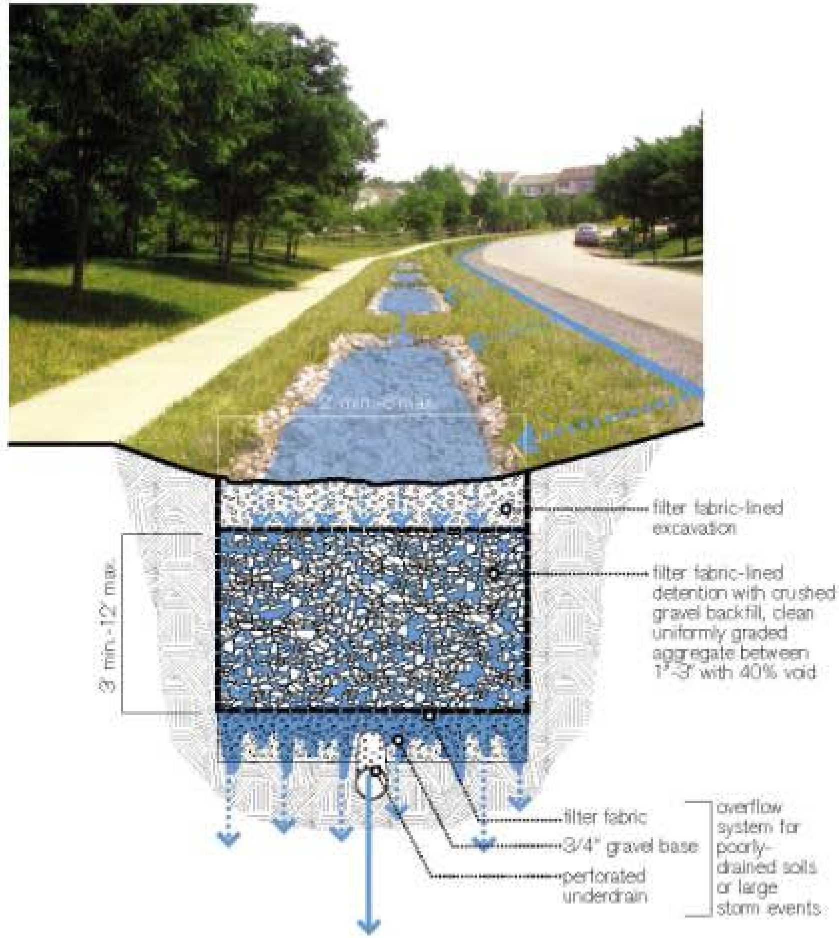
15
infiltration trench

Infiltration Trench

Infiltration trenches are laminated systems with fabric-lined excavations atop, fabric-lined detention to increase infiltration.

Infiltration trenches are particularly useful for sites with poorly-drained soils. Runoff gradually percolates through an engineered trench with amended soil over a period of days. Infiltration trenches filter particulates as stormwater runoff moves through the media. These facilities promote algae growth that serves as pollutant digesters. Since the maximum catchment area for infiltration trenches is two acres, it is necessary to incorporate other LID facilities into the stormwater management plan.

Infiltration trenches require less maintenance if upstream pre-treatment facilities like filter strips are used. No trees should be planted near infiltration trenches. These two actions reduce the potential for clogging the trench. Annual inspection is recommended to remove large debris and/or trash.



References:
Low Impact Development Design Strategies–An Integrated Design Approach
Low Impact Development Manual for Michigan
United States Department of Housing and Urban Development
Minnesota Urban Small Sites BMP Manual

optimal level of service
filtration or infiltration
(depends on which system is used)

location in LID network
upstream of major treatment systems, and in place of street trees
(not in swales or other filter devices)

scale
a single tree box to a large urban tree box network

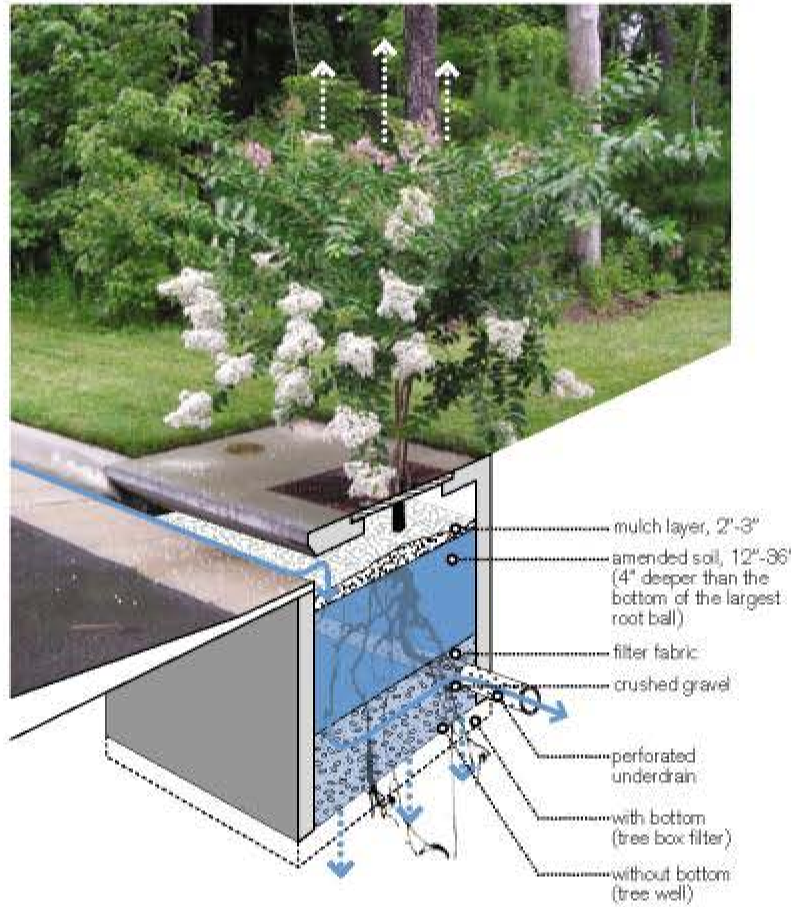
management regime
occasional removal of trash and raking of surface to maintain permeability; replacement of tree after seven years

Tree Box Filter

A tree box filter or well consists of a container filled with amended soil and planted with a tree, underlain by crushed gravel media.

Tree root systems treat and uptake stormwater runoff captured from the street into the box filter. An underdrain carries treated runoff to either a surface discharge location or a larger retention system for secondary treatment. The life of the tree is short as trees will need to be replaced every five to ten years. The unit can also be planted with hardy shrubs and herbaceous plants tolerant of inundations.

Tree box filters and wells can be incorporated into urban retrofits with the added benefits of water quality improvement and reduction of the urban heat island effect. As with other filtration devices, tree box filters require occasional inspection to remove large debris and/or trash.



References:
Low Impact Development Manual for Michigan
Urban Design Tools-Low Impact Development
Minnesota Urban Small Sites BMP Manual

optimal level of service
filtration/infiltration/treatment

location in LID network
downstream of filtration facilities,
but upstream of primary treatment facilities

scale
500 sq ft, to allow for adequate
irrigation between small storm events

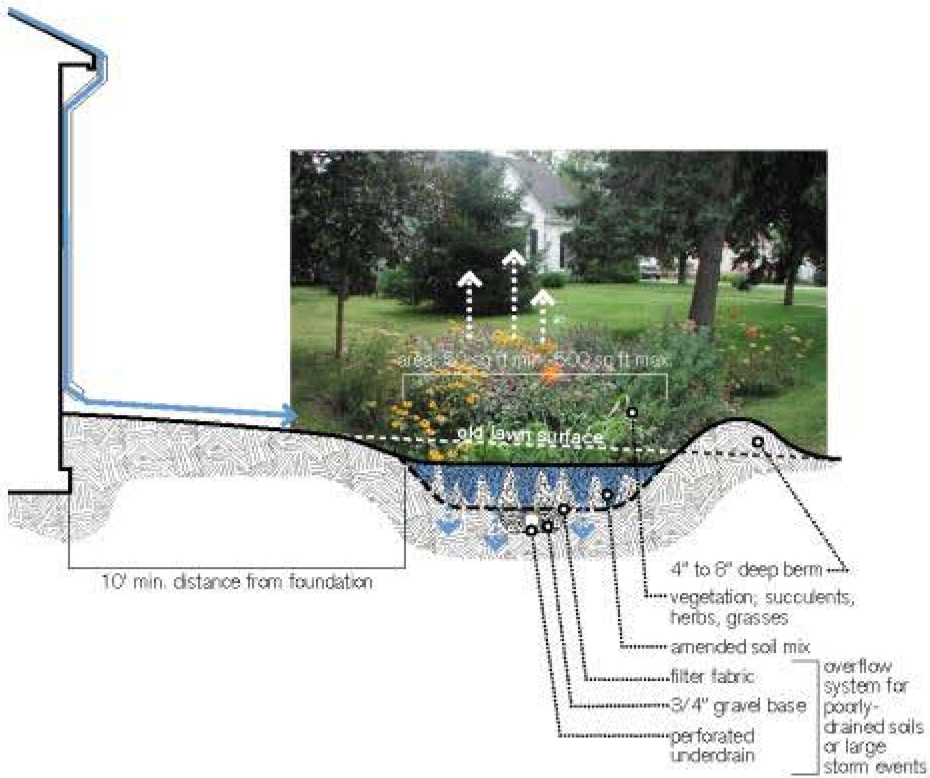
management regime
occasional removal of trash and
pruning of vegetation

Rain Garden

A rain garden is a planted depression designed to infiltrate stormwater runoff, but not hold it.

A rain garden is a type of treatment facility, commonly known as bioretention. The primary pollutant removal mechanisms are filtration by native vegetation through phytoremedation processes that clean water as it passes through the facility. Rain gardens contain layers of organic sandy soil, and mulch for vegetation. Low-maintenance plants are recommended for rain gardens based on their suitability to local climate, soil, and moisture conditions without the use of fertilizers and chemicals. Rain gardens are best applied on a relatively small scale. They work well along driveways and in low lying areas of a property.

Rain gardens should be located at least 10 feet away from buildings to prevent water seepage into foundations or underneath houses, causing mold and mildew problems. Also, location away from large trees allows exposure to sunlight so that rain gardens may dry out between storm events.



References:
Low Impact Development Design Strategies–An Integrated Design Approach
Low Impact Development Manual for Michigan
Low Impact Development Technical Guidance Manual for Puget Sound
United States Department of Housing and Urban Development
Minnesota Urban Small Sites BMP Manual

optimal level of service
filtration/infiltration/treatment

location in LID network
downstream of filtration components, but upstream of larger detention, retention, or treatment facilities

scale
2'-8' wide with 2"-4" optimal water depth

management regime
occasional removal of trash and pruning of vegetation

19

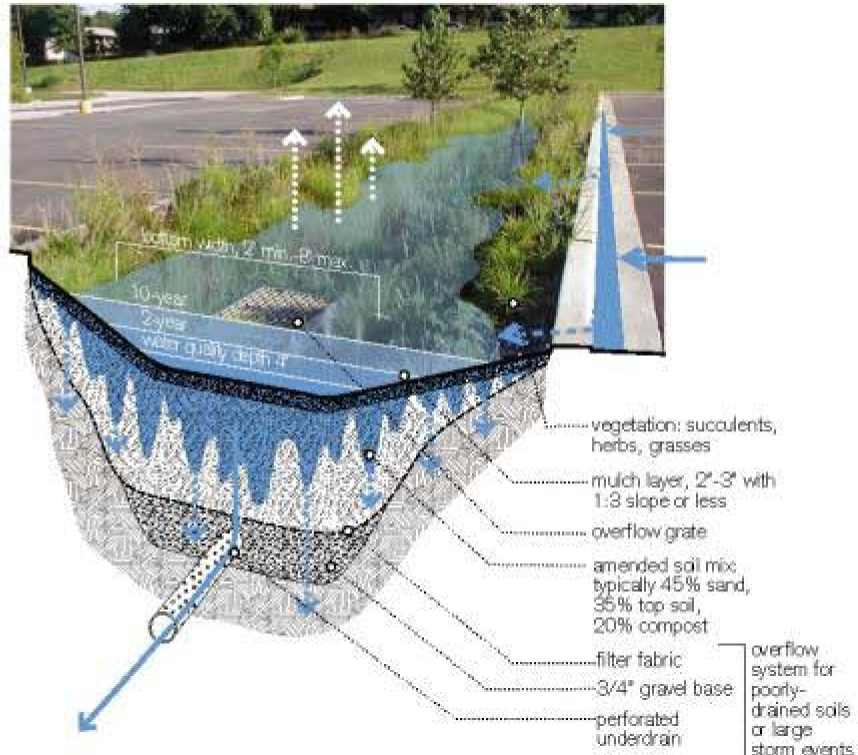
bioswale

Bioswale

A bioswale is an open, gently sloped, vegetated channel designed for treatment and conveyance of stormwater runoff.

Bioswales are a type of bioretention device in which the primary pollutant removal mechanisms are filtration by grass blades and other facultative vegetation that enhance sedimentation through adhesion of pollutants to the grass and thatch. Bioswales combine treatment and conveyance functions, reducing development costs by eliminating the need for separate conveyance systems. Their main function is to treat stormwater runoff, while the main function of rain gardens is to infiltrate runoff. Bioswales are usually located along roads, drives, or parking lots where the contributing acreage is less than five acres.

Bioswales require curb cuts, gutters or other devices that direct flow to them. They may require an underdrain where soil permeability is limited, as well as an overflow grate for larger storm events.



References:
Low Impact Development Design Strategies–An Integrated Design Approach
Low Impact Development Manual for Michigan
Low Impact Development Technical Guidance Manual for Puget Sound
United States Department of Housing and Urban Development
Minnesota Urban Small Sites BMP Manual

optimal level of service
retention/filtration/infiltration/treatment

location in LID network
end-of-line facility, upstream of overflow basins or receiving waterbodies

scale
from pocket wetlands managing up to 10 acres of watershed runoff to shallow marshes managing more than 25 acres of watershed runoff

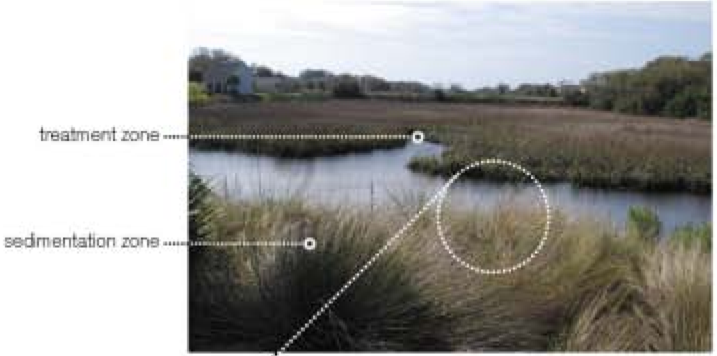
management regime
system requires removal of trash and sediment between two and ten years, and semiannually during first three years

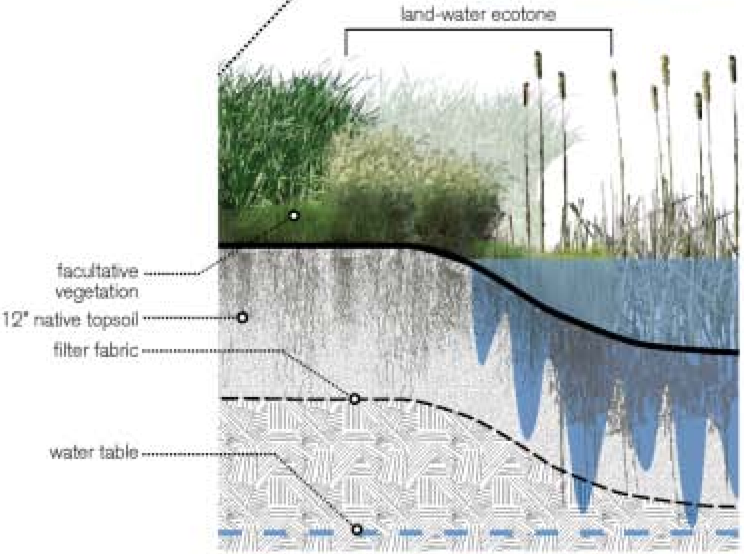
Constructed Wetland

Constructed wetlands have a permanent pool of water designed to treat polluted stormwater through microbial breakdown of pollutants, phytoremediation, retention, settling, and adsorption (surface assimilation).

Considered to be a comprehensive treatment system, constructed wetlands can be re-established in historically drained wetland areas or low areas of a site. Plants and wetland geometry reduce stormwater velocity, allowing sediment to settle out. As with other infiltration systems, pre-treatment systems upstream help to remove sediment that may clog a wetland system, resulting in eutrophication or an oxygen deprived system.

Constructed wetlands are land rich facilities and differ from retention ponds in their shallower depths and greater vegetation coverage. They require relatively large contributing drainage areas to maintain a shallow permanent pool. Minimum contributing watershed runoff area should be at least 10 acres, although pocket wetlands may be appropriate for smaller sites if sufficient water flow is available.





References:
Low Impact Development Manual for Michigan
United States Department of Housing and Urban Development
Minnnesota Urban Small Sites BMP Manual

"Our space planning should take its cue from the patterns of nature itself—the water table, the floodplains, the ridges, the woods, and above all, the streams."
William Whyte, *The Last Landscape*

You can download and purchase the publication from our website

http://uacdc.uark.edu