    

Green Infrastructure
Design Principles and Considerations

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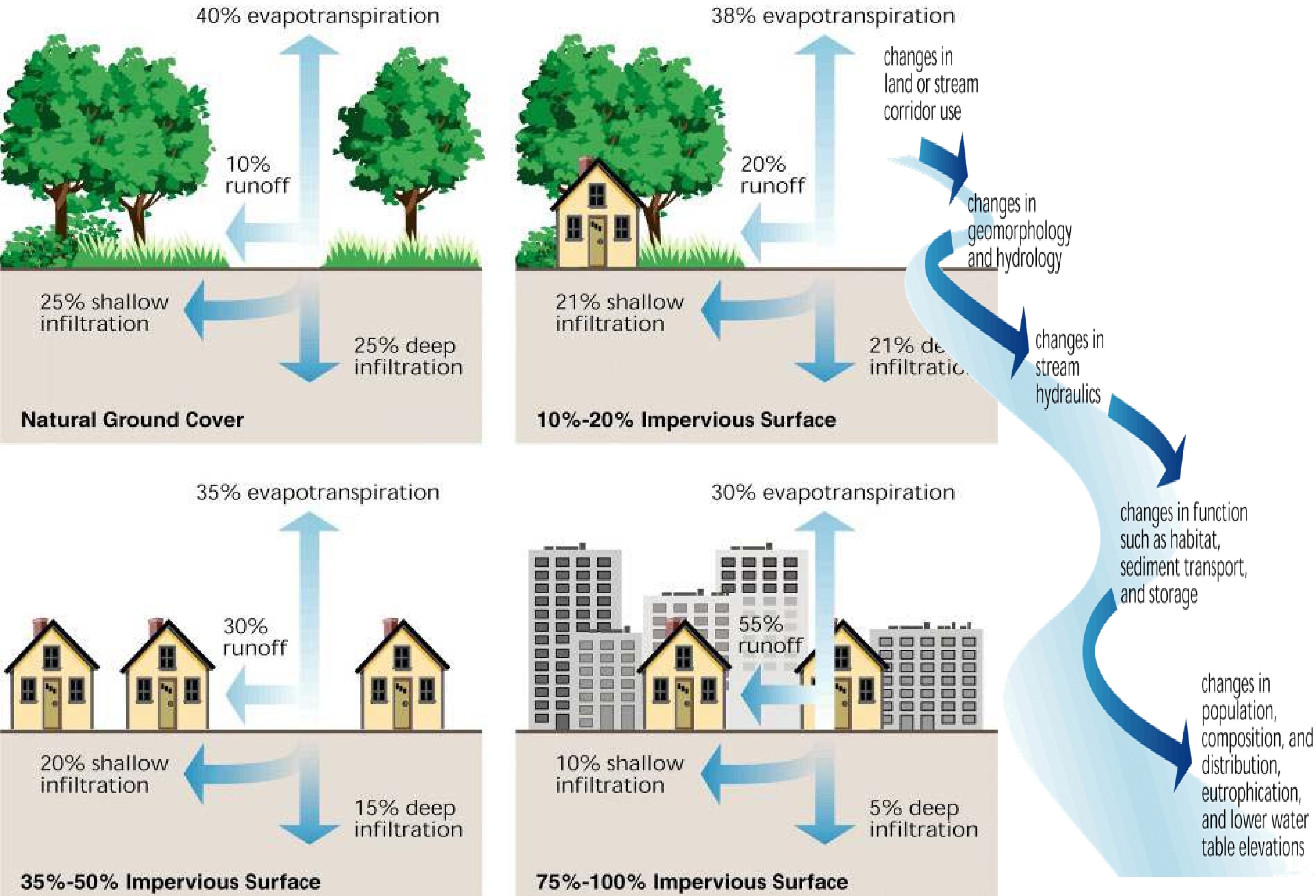
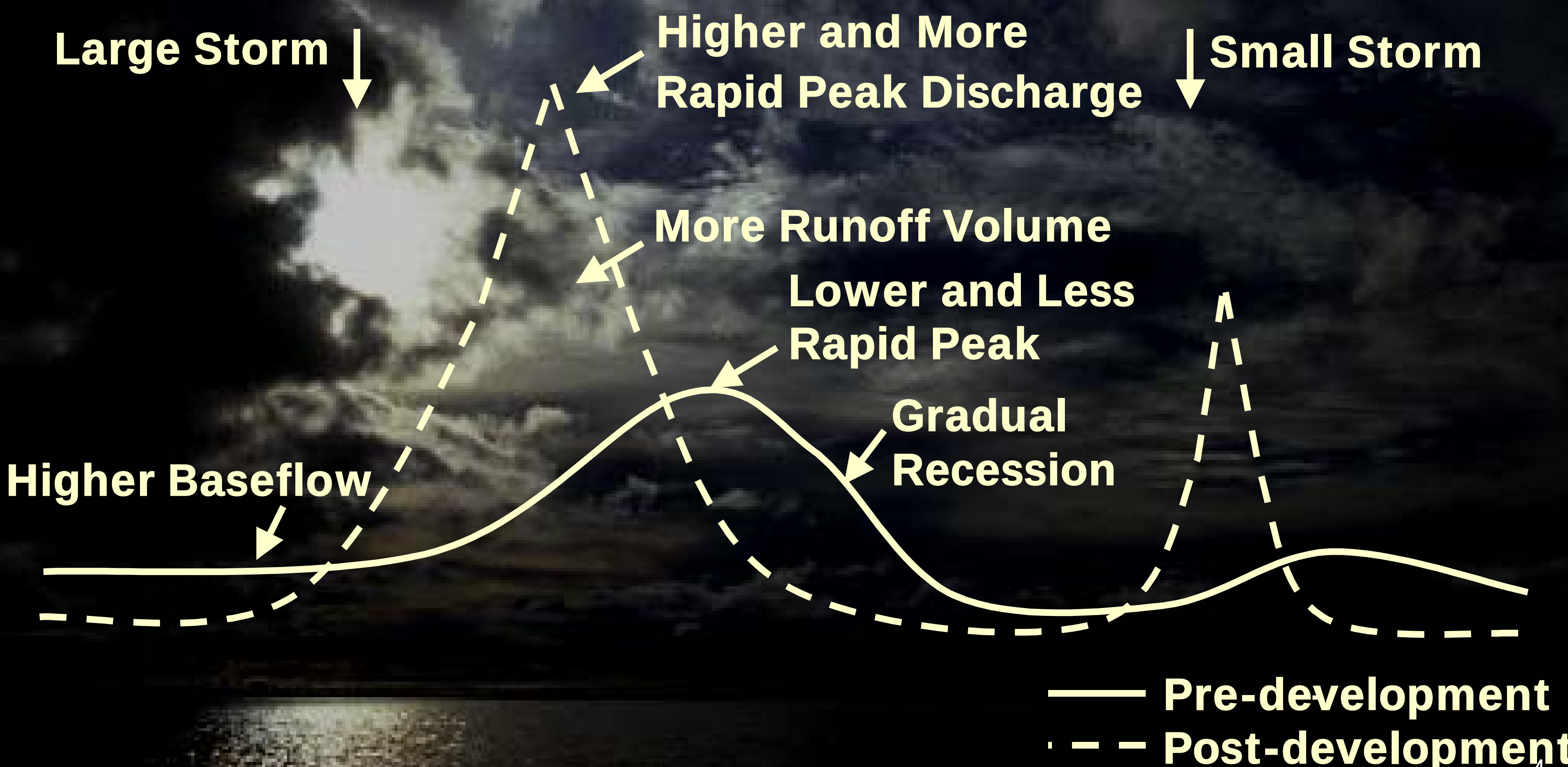
Agenda

- Introduction
- Types of Practices and What They Do
- Plants
- Soils
- Outlets
- Example Approach
- Strategies for Design/Implementation
- Implementation Examples
- Summary



Source: FISRWG 2001

Consequences of Development to Urban Streams












PRIVATE
KEEP OUT

Green Infrastructure

- Green Infrastructure management approaches and technologies infiltrate, evapotranspire, capture and reuse stormwater to maintain or restore natural hydrologies
- Benefits
  - Reduced and delayed stormwater runoff volume
  - Enhanced groundwater recharge
  - Reduced stormwater pollutants
  - Increased carbon sequestration
  - Urban heat island mitigation and reduced energy demands
  - Improved air quality
  - Additional wildlife habitat and recreational space
  - Improved human health
  - Increased land values

Source: USEPA Green Infrastructure website

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Water Storage - Surface

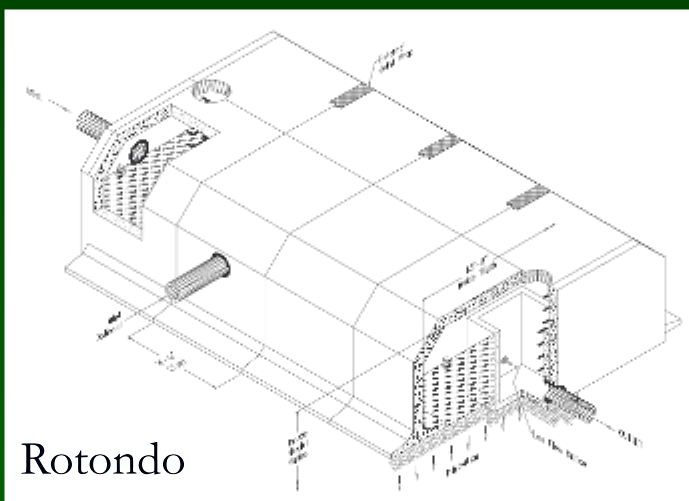
Bioretention (rain garden)
- Good infiltration
- Poor evaporation
- Good plant uptake and transpiration

Traditional Detention
- No infiltration
- Poor evaporation
- Poor plant uptake and transpiration

Traditional Retention
- Poor infiltration
- Good evaporation
- Poor plant uptake and transpiration

Green Roof
- No infiltration
- Good evaporation
- Good plant uptake and transpiration

Water Storage - Underground



Rainwater Harvesting and Conservation

Permeable Pavements

Other Stormwater BMPs

- Types
  - Sand filters
  - Hydrodynamic devices
  - Inlet Traps
  - Gross Solids Removal Devices
- Purpose
  - Target floatable trash and suspended solids
  - May be tailored to other pollutants (e.g. hydrocarbons)
- What they don’t do
  - Increase evapotranspiration and infiltration

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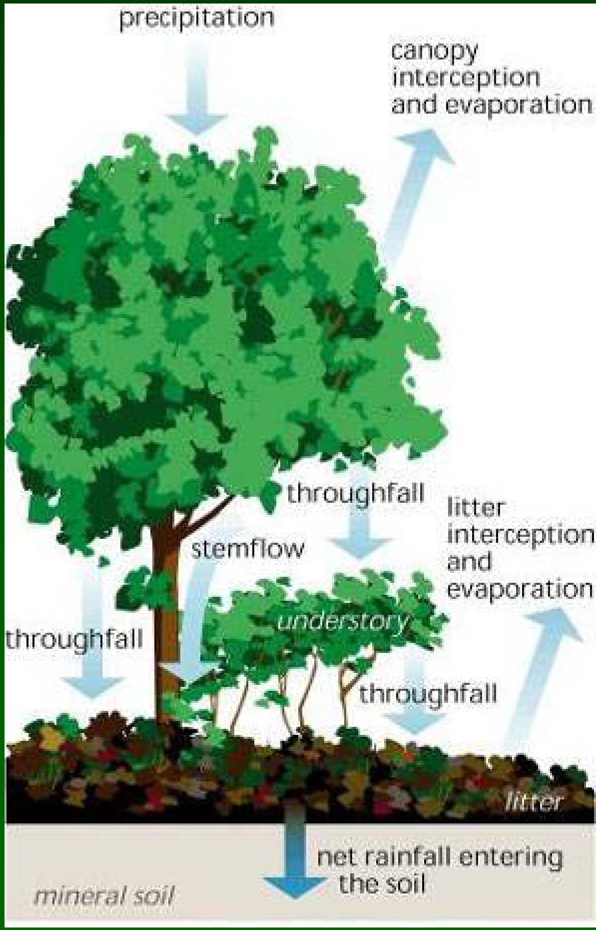
Plants

Role
- Water Uptake
- Stabilization
- Impeding Flow
- Filtration
- Infiltration
- Nutrient Uptake
- Toxin Uptake
- Pollutant Breakdown

Example Applications
- Nurse crop/cover crop
- Buffer strips
- Vegetated trenches
- Biofiltration/rain gardens
- Vegetated swales and ditches
- Stormwater ponds/wetlands
- Green roofs
- Native plant reconstruction

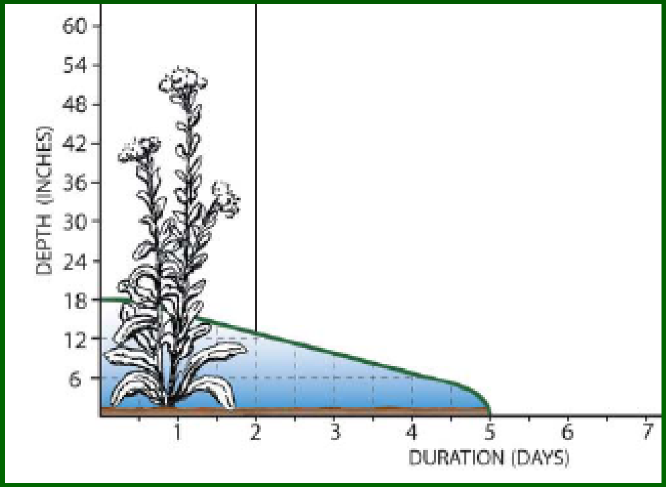


Source: FISRWG 2001

Plant Selection and Installation Considerations

Site Conditions to Investigate

- Texture, organic content and pH
- Water levels, soil moisture
- Adjacent plant communities
- Slopes
- Amount of sun/shade



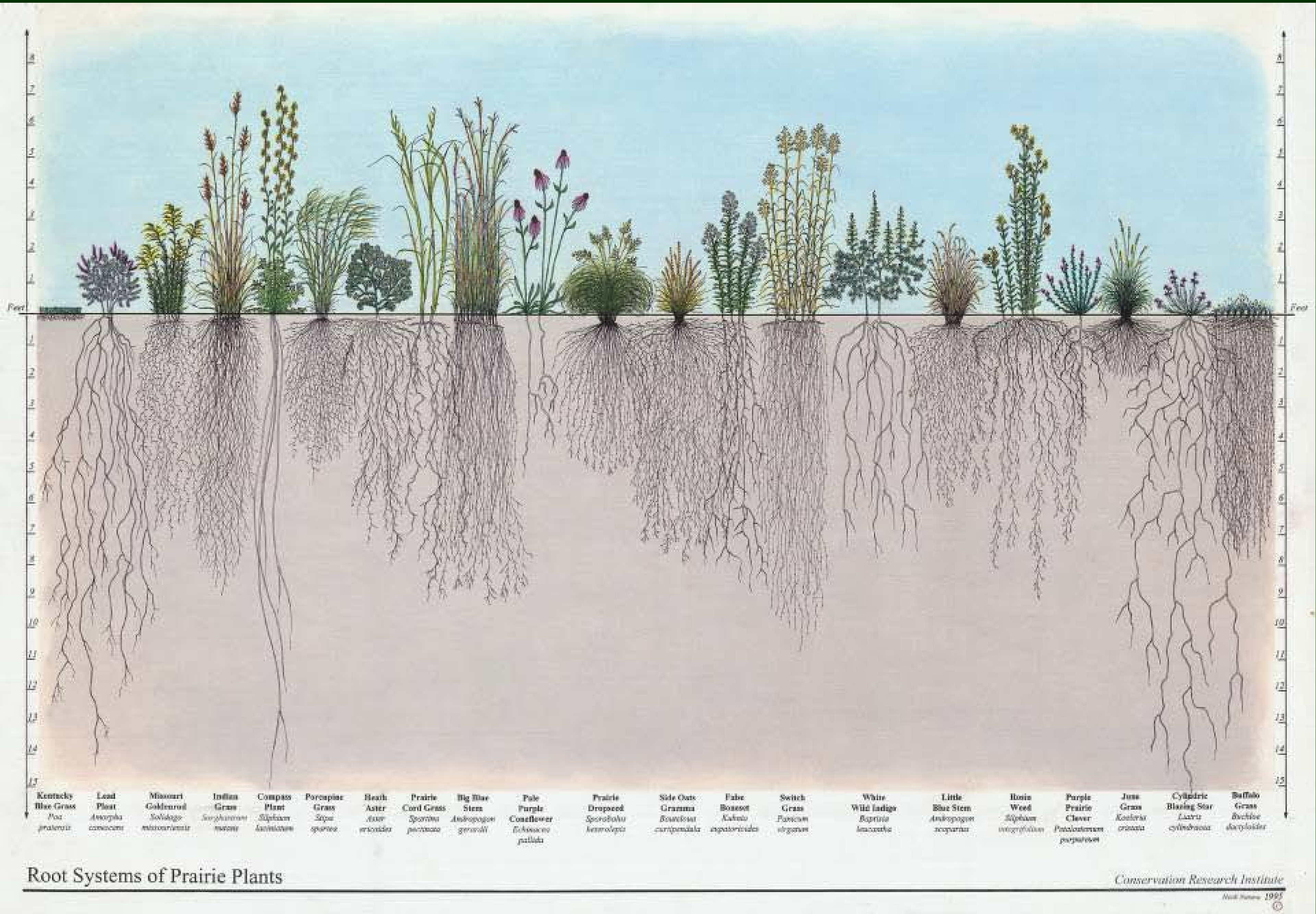
Environmental Threats

- Flood depth, duration and frequency
- Low water levels
- Sediment loads
- Pollutants and toxins
- Nutrients
- Salt
- Turbidity
- Erosion
- Invasive plants
- Herbivores

Transpiration Rates of Various Plants

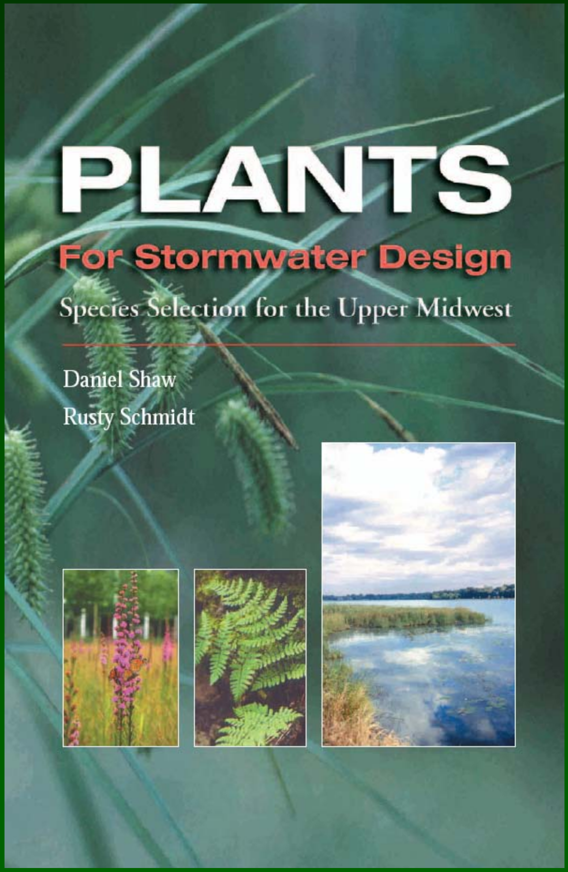
Plant Name	Plant Type	Transpiration Rate
Perennial rye	Lawn grass	0.27 in/day
Alfalfa	Agriculture crop	0.41 in/day
Common reed	Wetland species	0.44 in/day
Great bulrush	Wetland species	0.86 in/day
Sedge	Wetland/prairie species	1.9 in/day
Prairie cordgrass	Prairie species	0.48 in/day
Cottonwood	Tree (2 year old)	2-3.75 gpd/tree
Hybrid poplar	Tree (5 year old)	20-40 gpd/tree
Cottonwood	Tree (mature)	50-350 gpd/tree
Weeping Willow	Tree (mature)	200-800 gpd/tree

Source: Plants for Stormwater Design Volume II by D. Shaw and R. Schmidt (ITRC 2001)


Feet
Kentucky Blue Grass *Poa pratensis*
Lead Plant *Amorpha canescens*
Missouri Goldenrod *Solidago missouriensis*
Indian Grass *Sorghastrum nutans*
Compass Plant *Silphium laciniatum*
Porcupine Grass *Stipa spartea*
Heath Aster *Aster ericoides*
Prairie Cord Grass *Spartina pectinata*
Big Blue Stem *Andropogon gerardii*
Pale Purple Coneflower *Echinacea pallida*
Prairie Dropseed *Sporobolus heterolepis*
Side Oats Gramma *Bouteloua curtipendula*
False Boneset *Kuhnia eupatorioides*
Switch Grass *Panicum virgatum*
White Wild Indigo *Baptisia leucantha*
Little Blue Stem *Andropogon scoparius*
Rosin Weed *Silphium integrifolium*
Purple Prairie Clover *Petalostemum purpureum*
June Grass *Koeleria cristata*
Cylindric Blazing Star *Liatris cylindracea*
Buffalo Grass *Buchloe dactyloides*
Root Systems of Prairie Plants
Conservation Research Institute
1995

Native Vegetation Sources

- Michigan LID Manual
- Natural Resources Conservation Service (NRCS)
- US Forest Service
- State and Local Stormwater Manuals
- State Environmental and Natural Resource Agencies
- University Extension Services
- FHWA Roadside Use of Native Plants www.fhwa.dot.gov/environment/rdsduse/wv.htm
- Find a local native plant nursery www.plantnative.org



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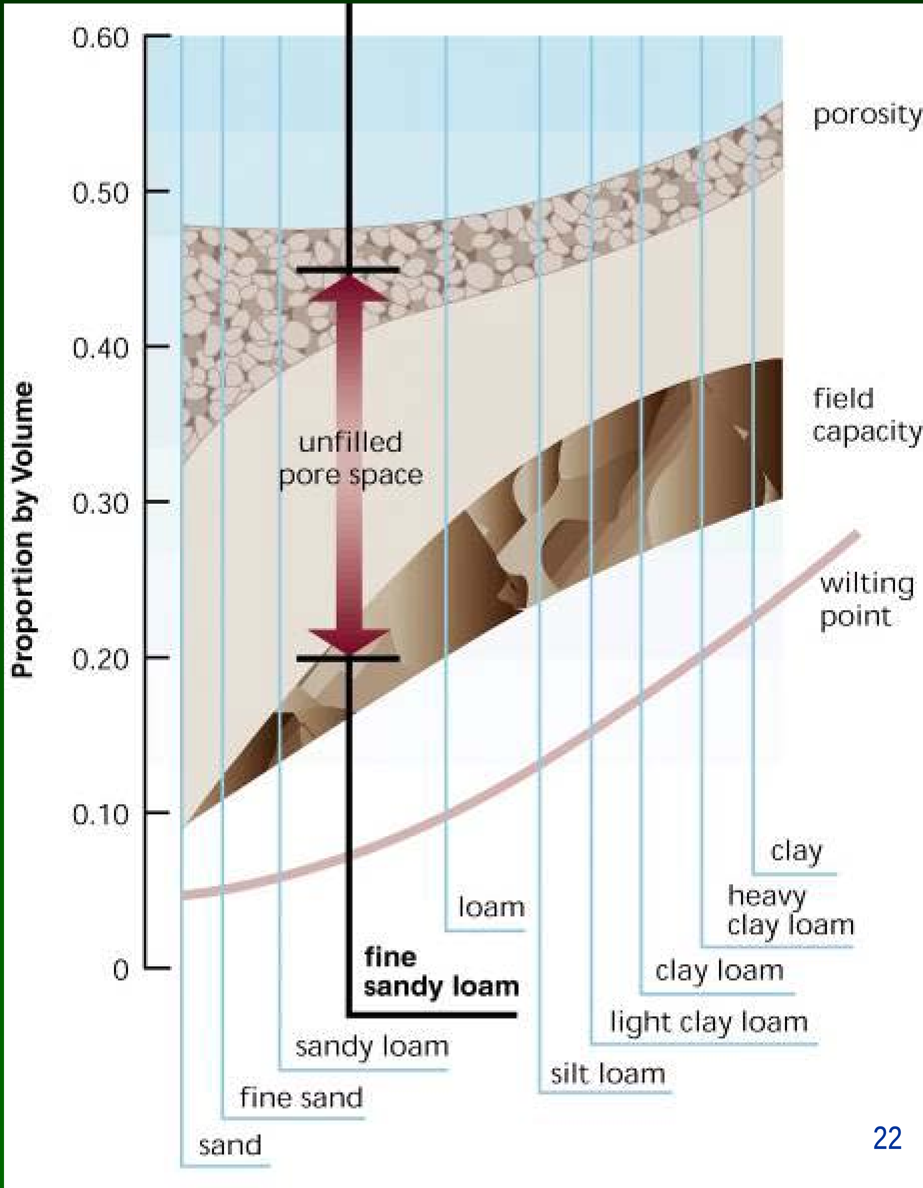
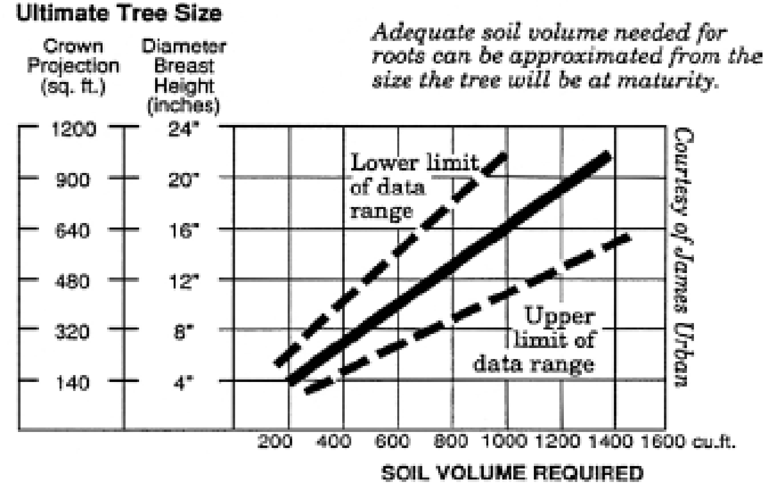
Soil Characteristics

- Porosity: void space of soil (space for water)
- Infiltration: movement of water through soil
- Field Capacity: proportion of void space that stays wet due to surface tension (i.e. after water drains by gravity)
- Wilting Point: point at which plants can no longer withdraw water fast enough to keep up with transpiration



Source: FISRWG

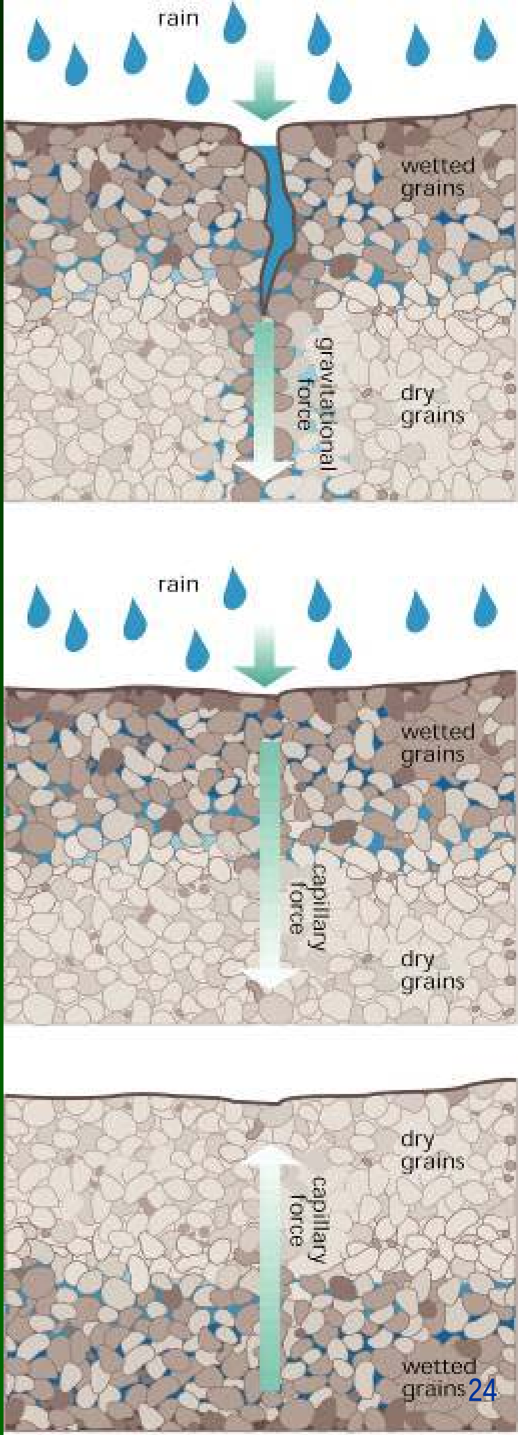


Consider this . . .

- Consider a tree box sized for a 16” caliper tree (1,000 cf of soil)
- Fine sandy loam soil with 25% unfilled void space (0.45 porosity – 0.2 field capacity)
- Volume = 250 cf (1,000 cf * 0.25)
- Area of impervious surface needed to generate 250 cf of stormwater from a 1-inch of runoff = 3,000 sf
- Assuming drainage from ½ a 66-ft ROW equates to one tree box every 91-ft
- *Ignored evaporation, infiltration, water uptake by plants, and depression storage*

Infiltration Capacity

- Dry Soils, Little or No Vegetation
  - Sandy soils: 5 in/hr
  - Loam soils: 3 in/hr
  - Clay soils: 1 in/hr
- Dry soils with Dense Vegetation
  - Multiply by 2
- Saturated Soils
  - Sandy soils: 1 to 4 in/hr
  - Loam soils: 0.25 to 0.50 in/hr
  - Clay soils: 0.01 to 0.06 in/hr



Source: Rawls, W.J., D.L. Brakensiek, and N. Miller, "Green-Ampt Infiltration Parameters from Soil Data" J. Hydr Engr. 109:62, 1983), EPA SWMM 5 Users Manual, and FISRWG

What if you combined

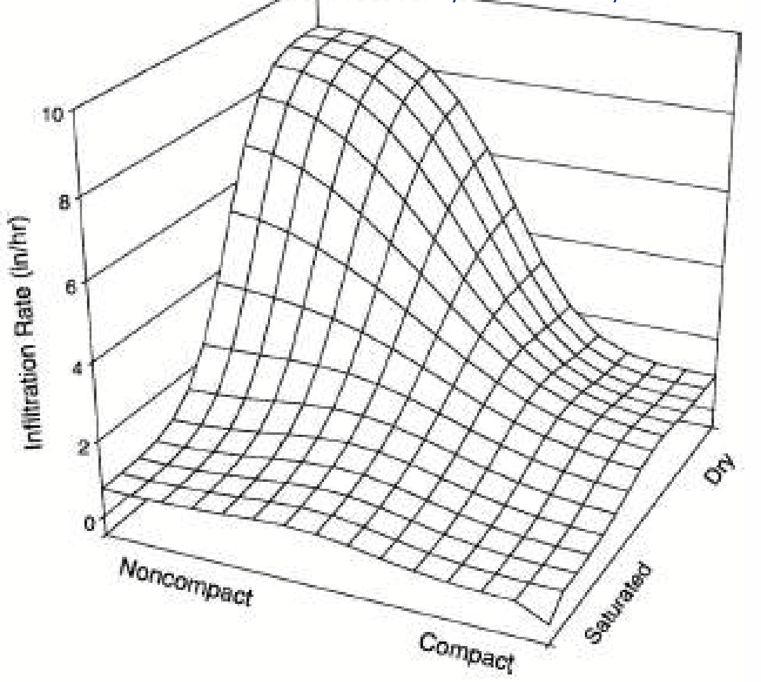
- a basin
- a water loving tree, and
- an engineered soil mix?

Effects of Compaction on Infiltration Rates

- Decreased infiltration
- Decreased root growth
- Increased runoff

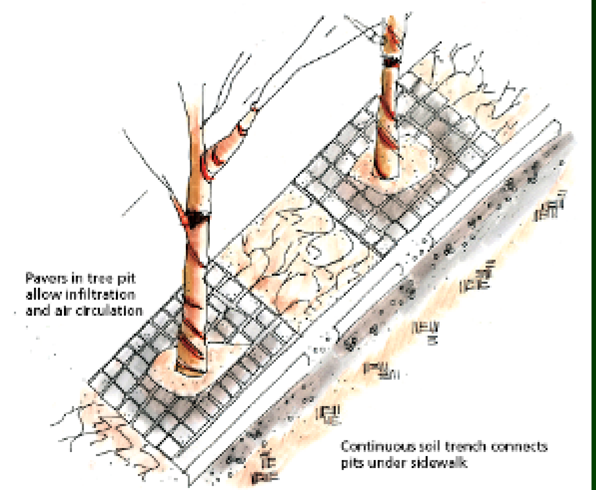
Source: R. Pitt, S.E. Chen, S. Clark	Number of tests	Avg Infil (in/hr)	COV
Noncompacted sandy soils	36	13	0.4
Compacted sandy soils	39	1.4	1.3
Noncompacted and dry clayey soils	18	9.8	1.5
All other clayey soils (compacted and dry, plus all wetter conditions)	60	0.2	2.4

Source: Pitt R., S.E. Chen, S. Clark



Engineered Soil Mix Examples

- Prince Georges Co. MD: 50-60% sand; 20-30% compost; 20-30% topsoil (Minnesota added <5% clay stipulation)
- NCSU: 85% sand; 12% fines; 3-5% organics
- Portland OR: 60-70% sand; 30-40% compost (35-65% organic); particle gradation specified
- Low Impact Development Center: 50% sand; 30% planting soil (50-85% sand, 0-50% silt, 10-20% clay, 1.5 -10% organic); 20% shredded hardwood mulch
- *Typical infiltration rate of soil mixes is 1 to 8 in/hr*



Urban Watershed Forestry Manual Part 3, 2006

Soil Strategies

- Protect native soil during construction by limiting access, grading/clearing
- Increase soil volume by connecting planting areas, thereby sharing rooting space
- Alternative Soil Strategies
  - Soil Trenches
  - Structural Soil (use of stone to provide load bearing integrity while preserving void space)
  - Suspended Pavements and Structural Cells
- Avoid conflicts between rooting and infrastructure subgrade by using soil free aggregate under hardscape surfaces or use of root barriers

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Outlet Controls

- Underdrains
- Liners
- Overflows
- Diversions
- Injection Wells

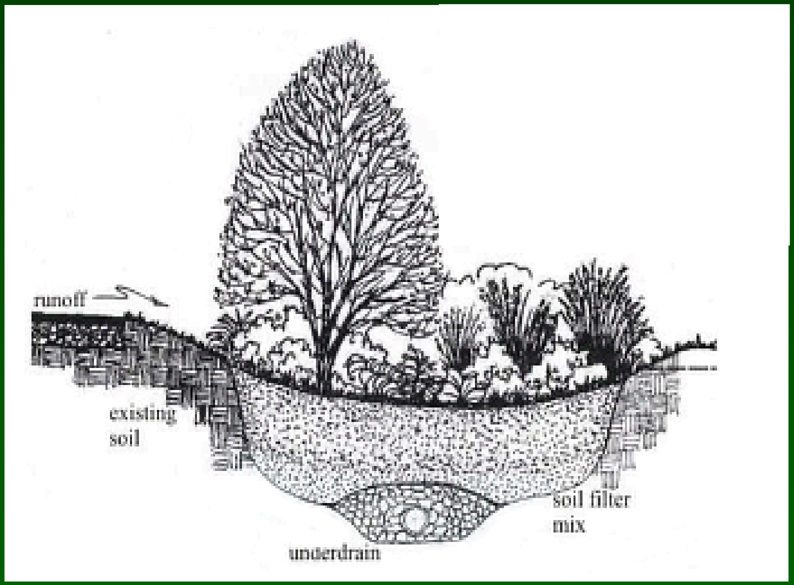


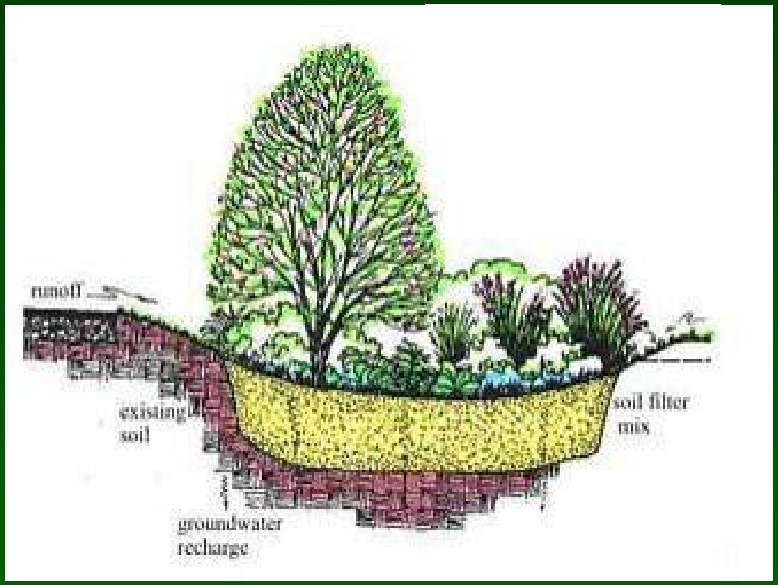





Outlet Controls

Filtration vs Infiltration





Underdrain

Overflow/Diversion

Underdrained systems are flow-through systems, and discharge water from even small ‘design storms’.

Reasons to Include Underdrains and Liners

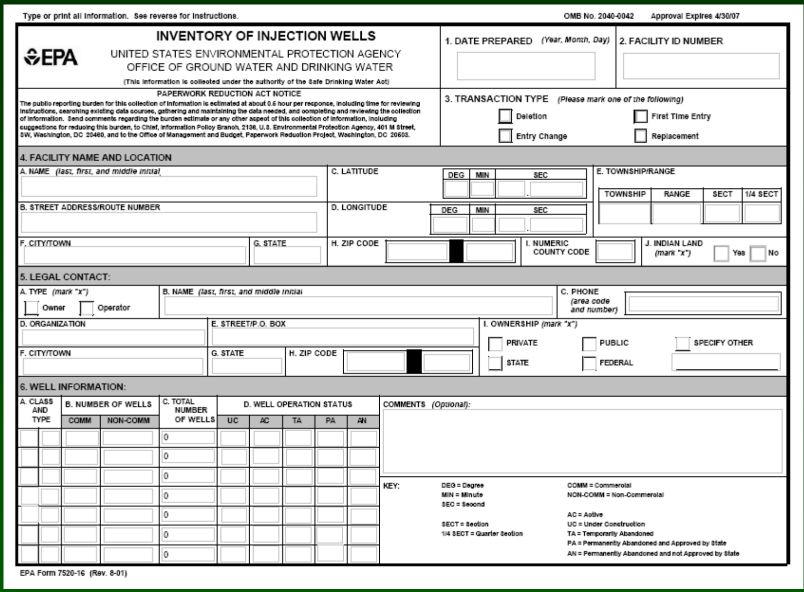
- Protect surrounding infrastructure
  - Basements
  - Roads/parking
- Isolate contaminated soils
  - Leaky underground storage tanks
- Prevent unwanted flora and fauna
  - Mosquitoes

Overflows and Diversions

- Think about big storms
- Inline Systems
  - Water forced to flow through system
- Offline System
  - Water diverted after capacity reached

Class V Injection Well

- Class V wells are shallow wells used to place a variety of fluids directly below the land surface.
- An “injection well” is a “well” into which “fluids” are being injected (40 CFR §144.3).
- Memo & guide issued June 13, 2008 by EPA clarifies which infiltration practices are generally considered class V wells
  - If stormwater directed into hole that is deeper than it’s widest point or
  - has a subsurface distribution system
- Potential examples
  - Infiltration trenches
  - Commercially manufactured stormwater infiltration devices
  - Dry wells and seepage pits
- Reporting requirements


Type or print all information. See reverse for instructions. OMB No. 2040-0042 Approval Expires 4/30/07

EPA

INVENTORY OF INJECTION WELLS
UNITED STATES ENVIRONMENTAL PROTECTION AGENCY
OFFICE OF GROUND WATER AND DRINKING WATER
(This information is collected under the authority of the Safe Drinking Water Act)

1. DATE PREPARED (Year, Month, Day)
2. FACILITY ID NUMBER

PAPERWORK REDUCTION ACT NOTICE
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3. TRANSACTION TYPE (Please mark one of the following)
Deletion
First Time Entry
Entry Change
Replacement

4. FACILITY NAME AND LOCATION
A. NAME (last, first, and middle initial)
C. LATITUDE DEG MIN SEC
E. TOWNSHIP/RANGE TOWNSHIP RANGE SECT 1/4 SECT
B. STREET ADDRESS/ROUTE NUMBER
D. LONGITUDE DEG MIN SEC
F. CITY/TOWN
G. STATE
H. ZIP CODE
I. NUMERIC COUNTY CODE
J. INDIAN LAND (mark "x") Yes No

5. LEGAL CONTACT:
A. TYPE (mark "x") Owner Operator
B. NAME (last, first, and middle initial
C. PHONE (area code and number)
D. ORGANIZATION
E. STREET/P.O. BOX
I. OWNERSHIP (mark "x")
PRIVATE
PUBLIC
SPECIFY OTHER
STATE
FEDERAL
F. CITY/TOWN
G. STATE
H. ZIP CODE

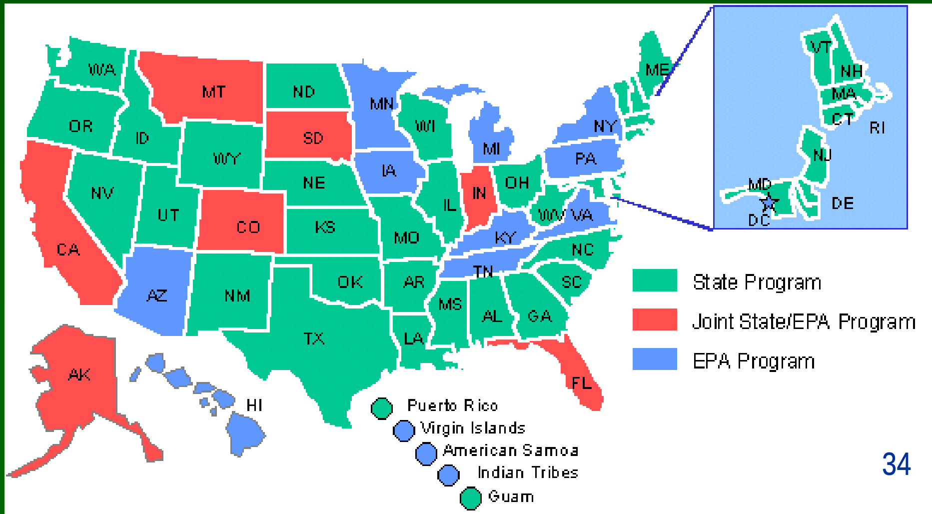
6. WELL INFORMATION:

A. CLASS AND TYPE		B. NUMBER OF WELLS: COMM	B. NUMBER OF WELLS: NON-COMM	C. TOTAL NUMBER OF WELLS	D. WELL OPERATION STATUS: UC	AC	TA	PA	AN
				0					
				0					
				0					
				0					
				0					
				0					
				0					

COMMENTS (Optional):

KEY:
DEG = Degree
MIN = Minute
SEC = Second
SECT = Section
1/4 SECT = Quarter Section
COMM = Commercial
NON-COMM = Non-Commercial
AC = Active
UC = Under Construction
TA = Temporarily Abandoned
PA = Permanently Abandoned and Approved by State
AN = Permanently Abandoned and not Approved by State

EPA Form 7520-16 (Rev. 8-01)



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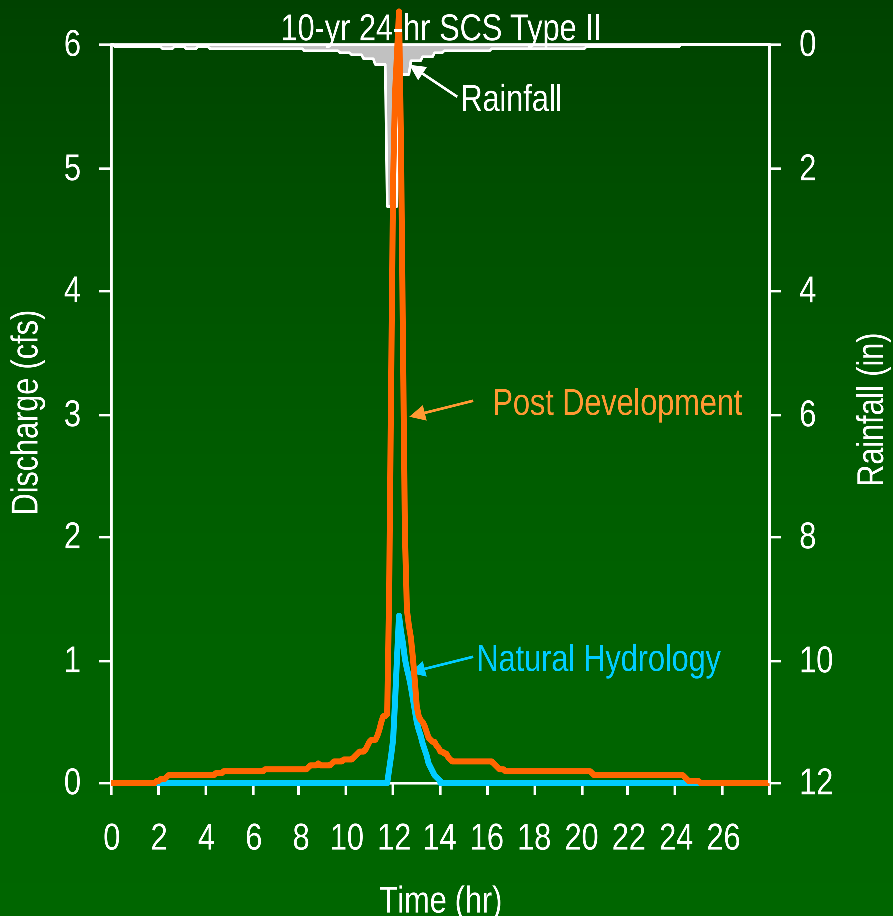
Consider a typical development example

- Area = 2.98 ac
  - Building Footprint = 20.9%
  - Parking/sidewalk = 36.5%
  - Turf grass = 42.6%
- B/C soil
- Flat
- EPA-SWMM V5 model

No Stormwater Controls

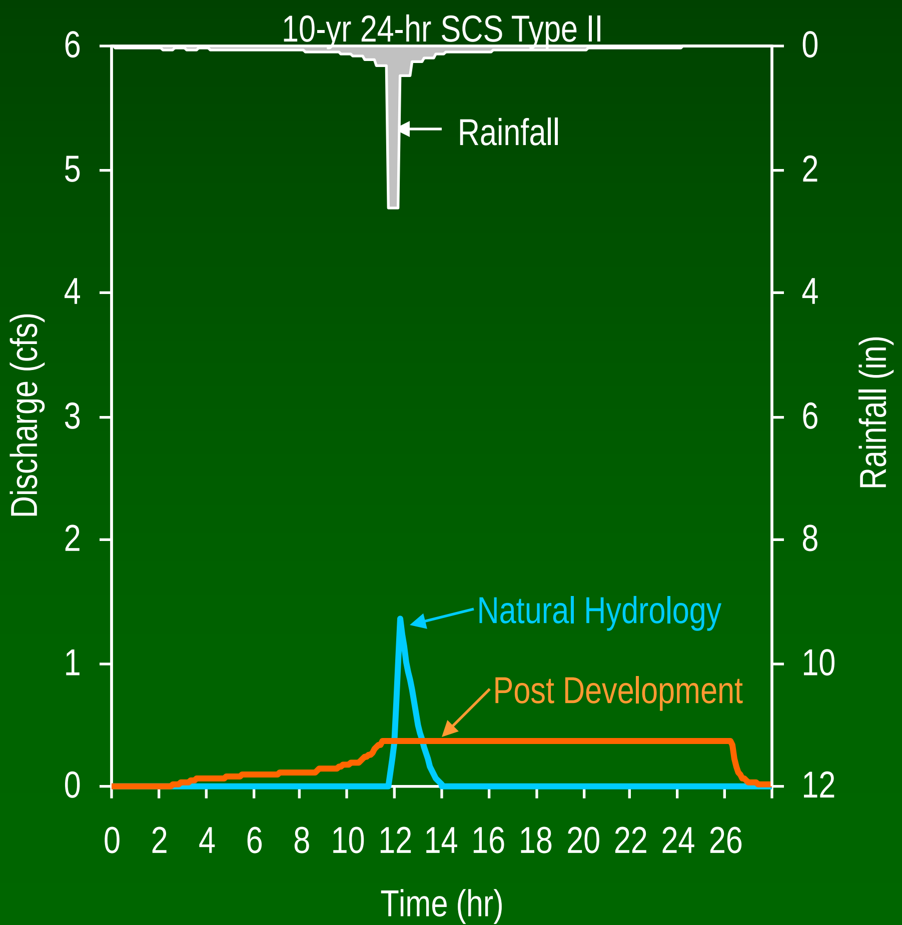
- Traditional development with no stormwater controls



Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	19%
Infiltration	90%	38%
Surface Runoff	<1%	43%

Traditional Detention

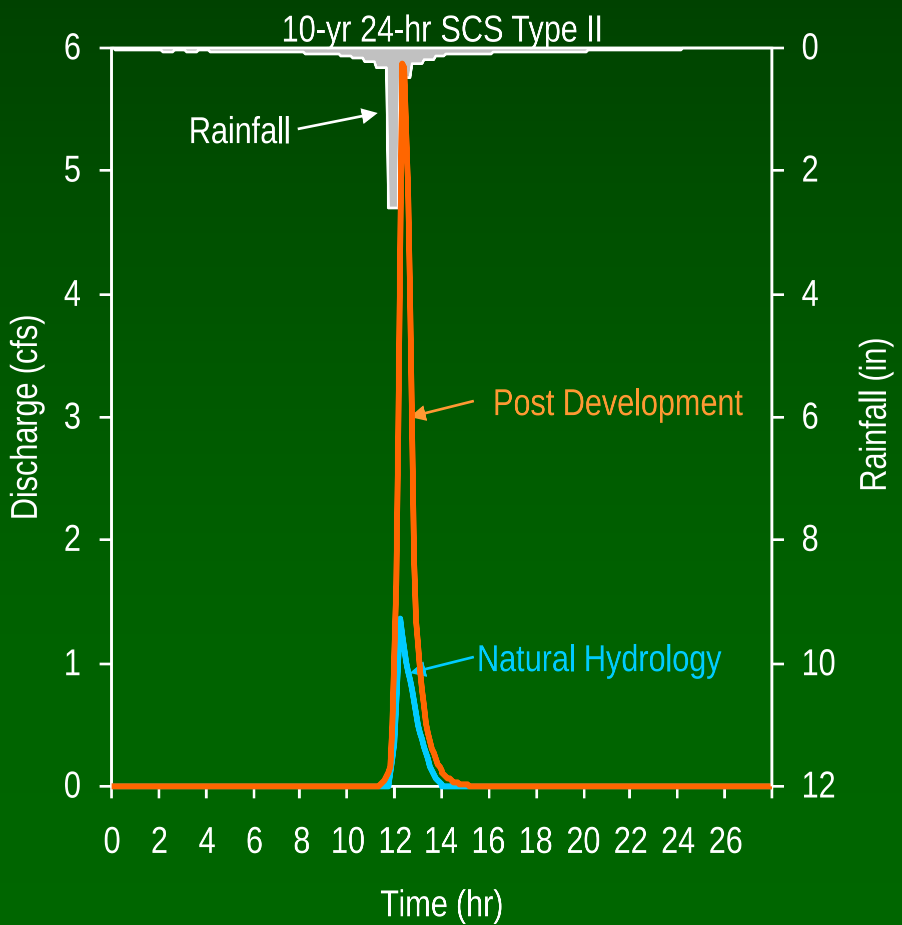
- Traditional drainage system
- Detention sized with 0.15 cfs/acre maximum release rate
- No change in average annual surface runoff

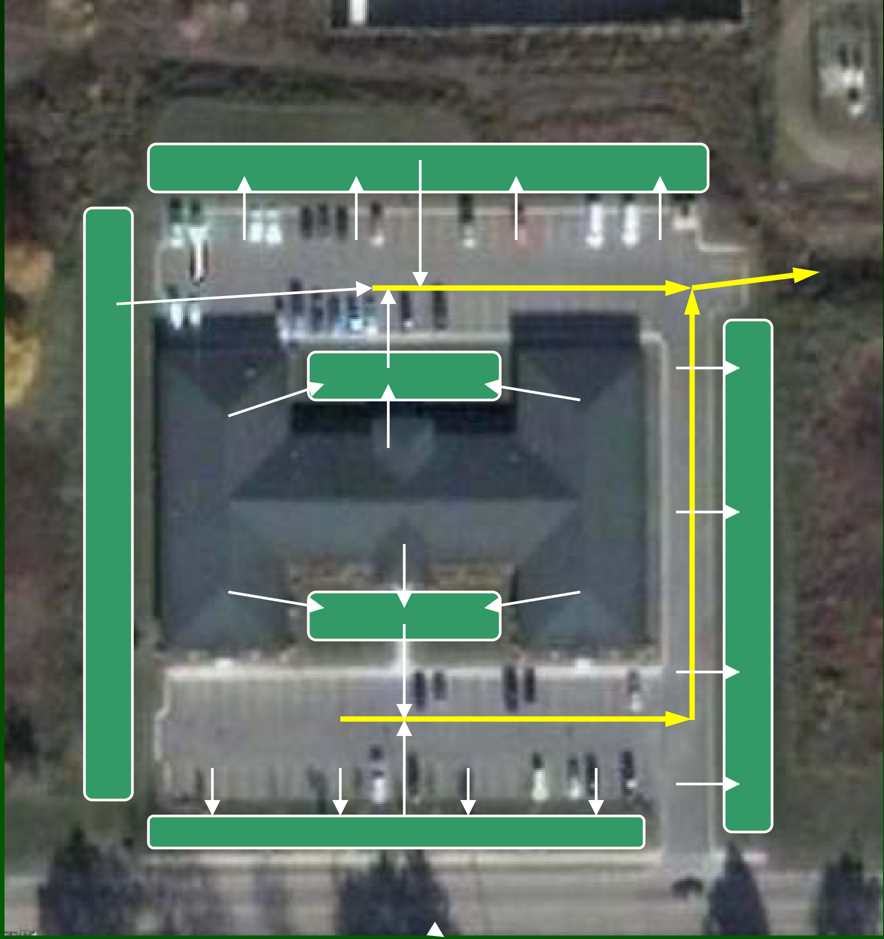


Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	19%
Infiltration	90%	38%
Surface Runoff	<1%	43%

Impervious → **Pervious**

- Impervious surfaces discharge to green areas
- Green areas discharge to drainage system
- Decreased average annual surface runoff from 43% to 9%

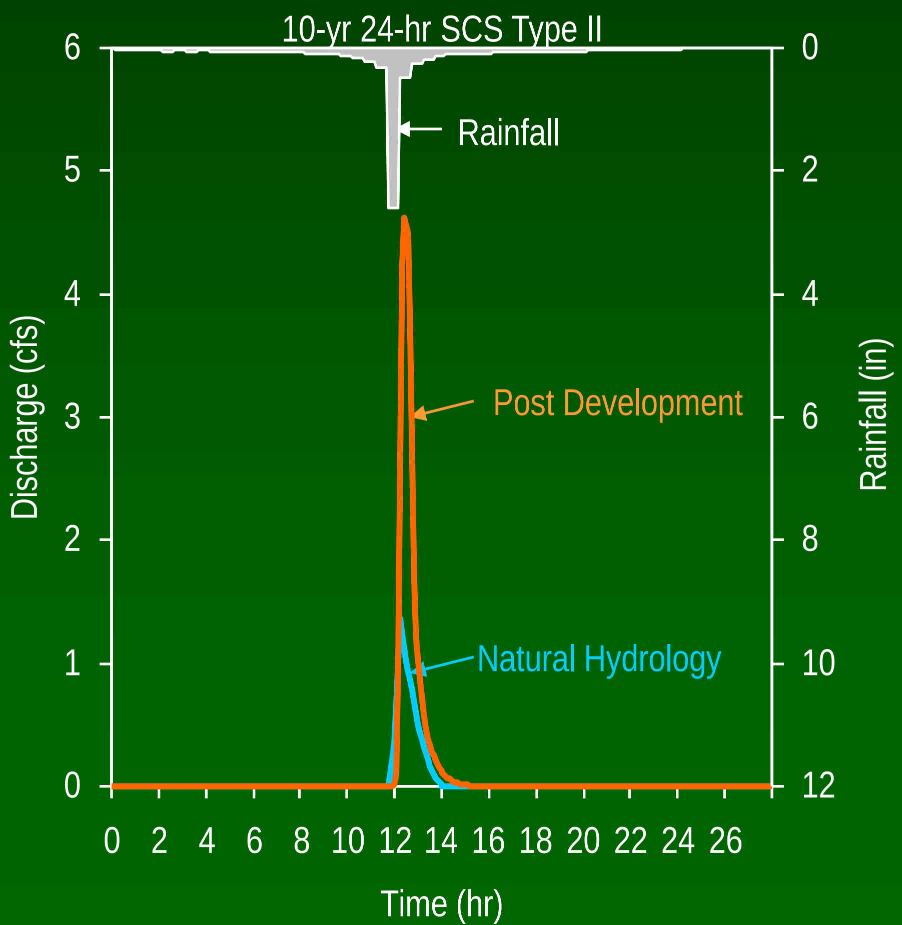


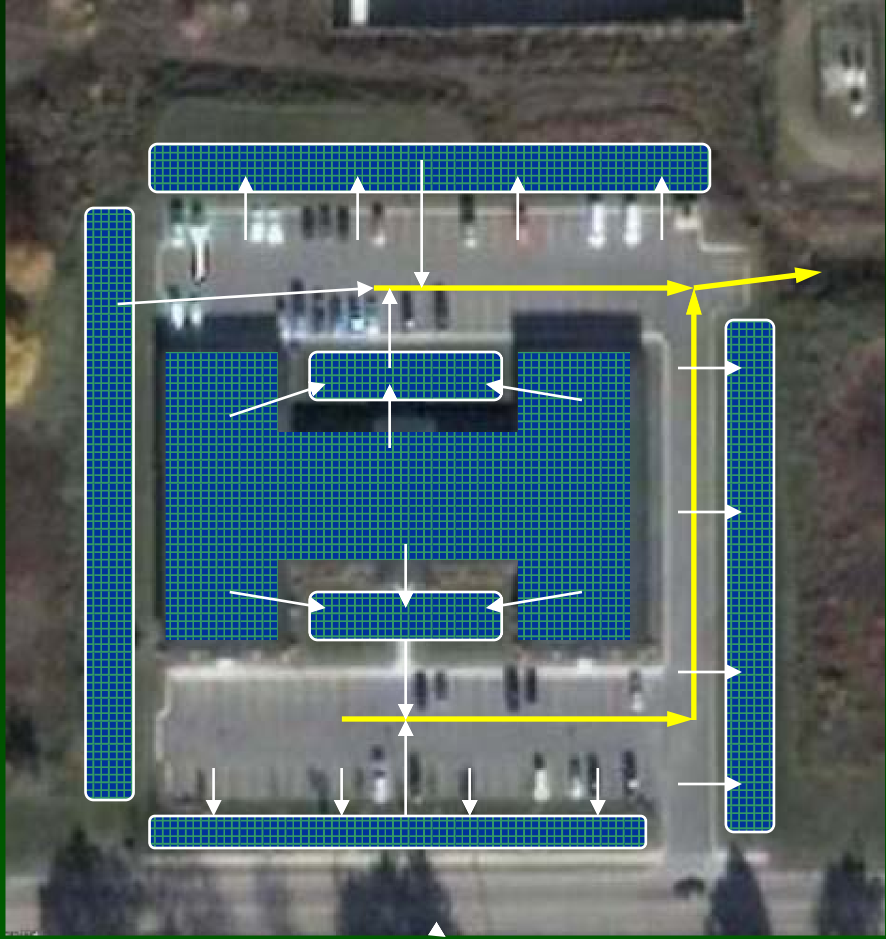


Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	20%
Infiltration	90%	72%
Surface Runoff	<1%	9%

Added Storage

- Impervious → Pervious
- 1-inch roof storage (or equiv)
- 1-inch storage on pervious areas

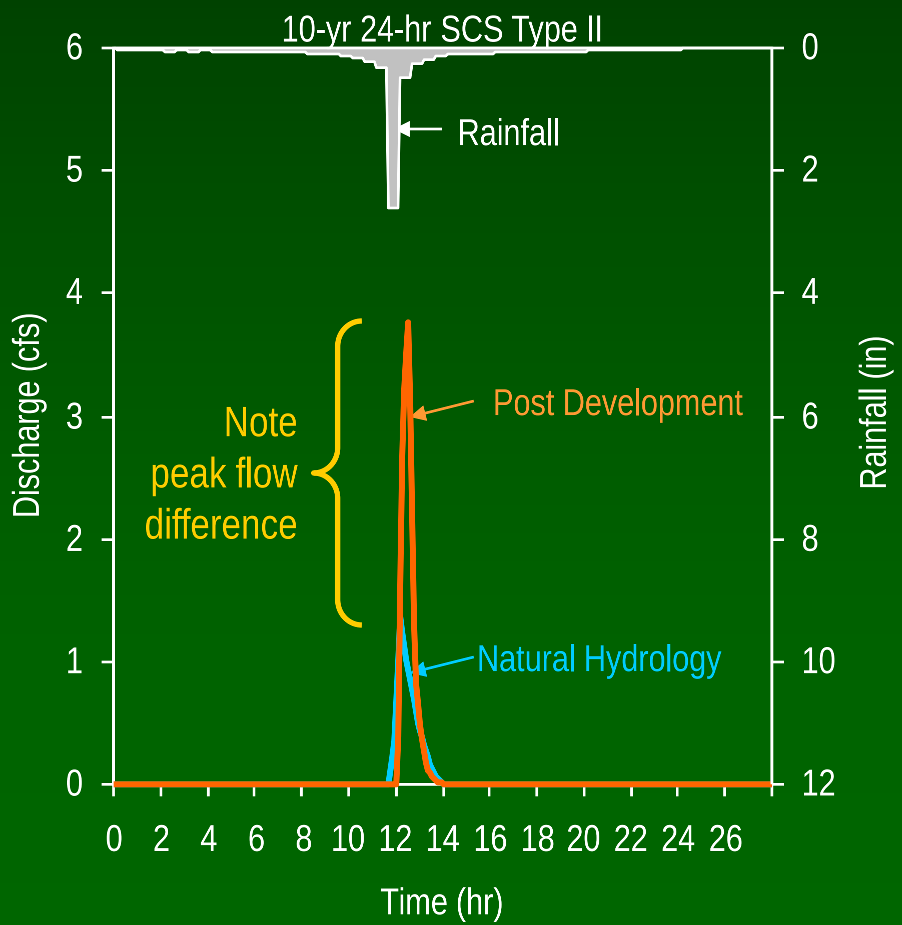


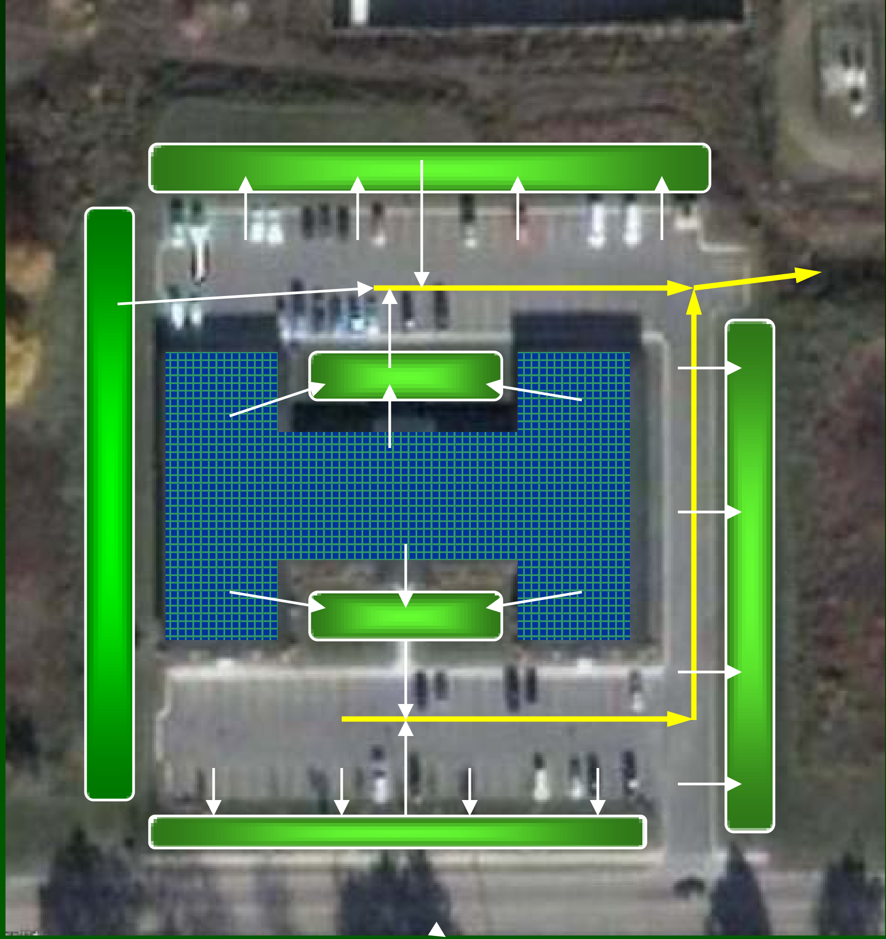


Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	32%
Infiltration	90%	66%
Surface Runoff	<1%	3%

Enhanced Infiltration and Evapotranspiration

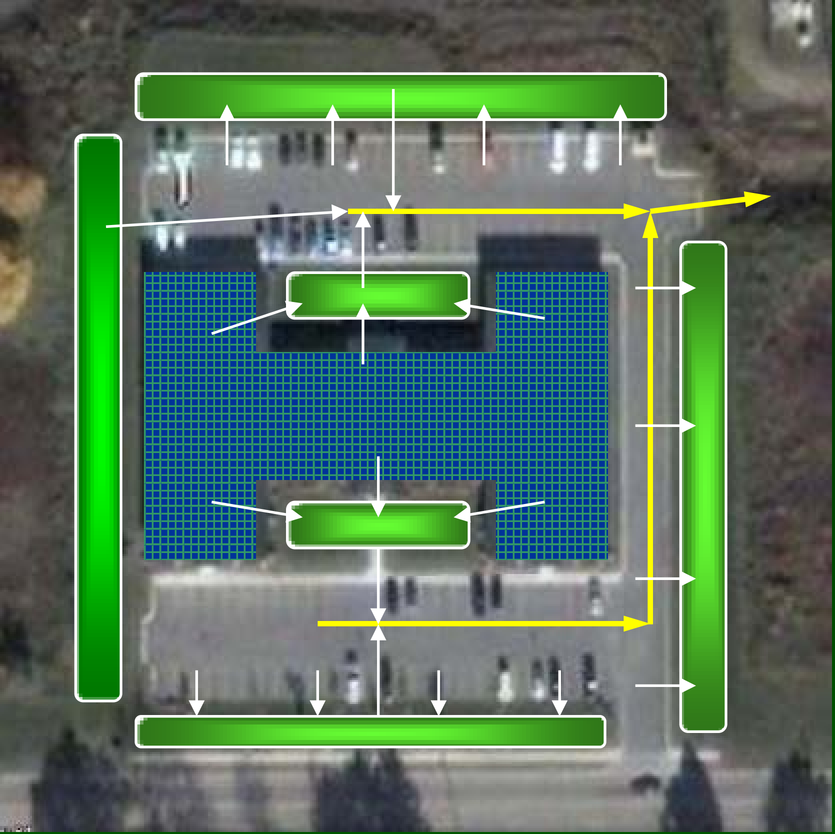
- Impervious → Pervious
- 1-inch roof storage (or equivalent)
- 1-inch storage on pervious areas with enhanced rates

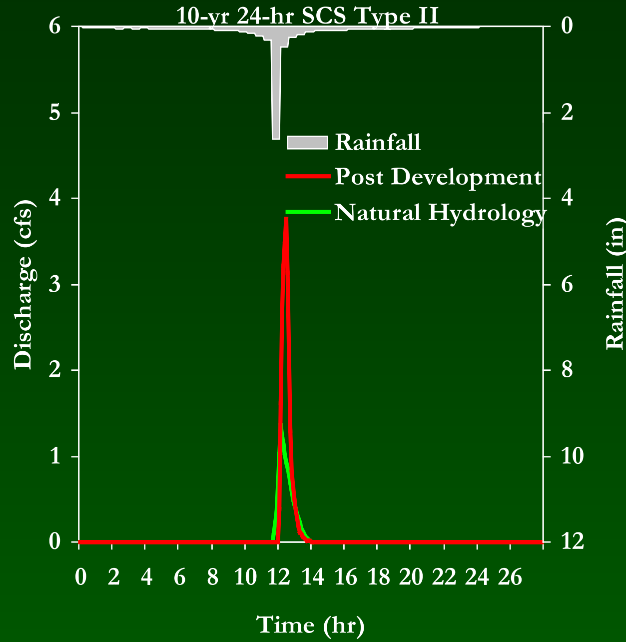




Average Annual (from 50-years)	Natural Hydrology	Post Development
Evaporation	10%	32%
Infiltration	90%	67%
Surface Runoff	<1%	1%

Development Example





Description (cumulative BMPs)	Average Annual Surface Runoff
Natural Hydrology (prior to development)	<1%
Post Development (no stormwater controls)	43%
Detention for 10-yr storm with 0.15 cfs/ac outlet	43%
Discharge the impervious surfaces to green surfaces before piping	9%
Add 1-inch of storage on roof and green spaces	3%
Improved/amended soils and vegetation	1%

Continuous simulation of 50-years of rainfall data. Modeling done with EPA SWMM

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Design Strategies

- Preserve natural systems
- Engineer systems to mimic natural functions
  - Evapotranspiration ↑
    - Plants (water uptake and transpiration)
    - Surface water (evaporation)
  - Infiltration ↓
    - Soils
    - Storage (provides additional time to infiltrate)
  - Surface Runoff ⟶
    - Pipes, gutters, swales, ditches, underdrains
    - Time of concentration (longer is better)
- “Treat” raindrop as close as possible to where it fell
- Lots of little BMPs instead of few regional systems
- BMPs in series not parallel

Planning
During Design

- Design BMPs with maintenance in mind
  - ROW, easements, vehicle access, cleanouts, manholes
  - At what depth should sediment be removed?
  - Involve maintenance staff on BMP selection and design
- Prepare a site specific maintenance guide
- Think about
  - Staff gauges or offset points
  - Dewatering pipes and valves
  - Geese, mosquitoes, rodents, etc.

Design Details

- Test infiltration capacity, don't assume it
- Observation ports for water levels
- Underdrains designed to be cleaned
- Ponding depth in bio-systems approximately 6-12 inch
- Extend time of concentration

Ideas to Consider

- Roto-till pervious surfaces before topsoil/seed
- Amend soils
- Loosen up compacted soils with a ditchwitch/auger and leaf compost
- Valves on underdrains
- If you need an underdrain, don't put it at the bottom
- Take every opportunity to educate the public
- Adopt-a-rain garden
- Try something. Anything is better than nothing.

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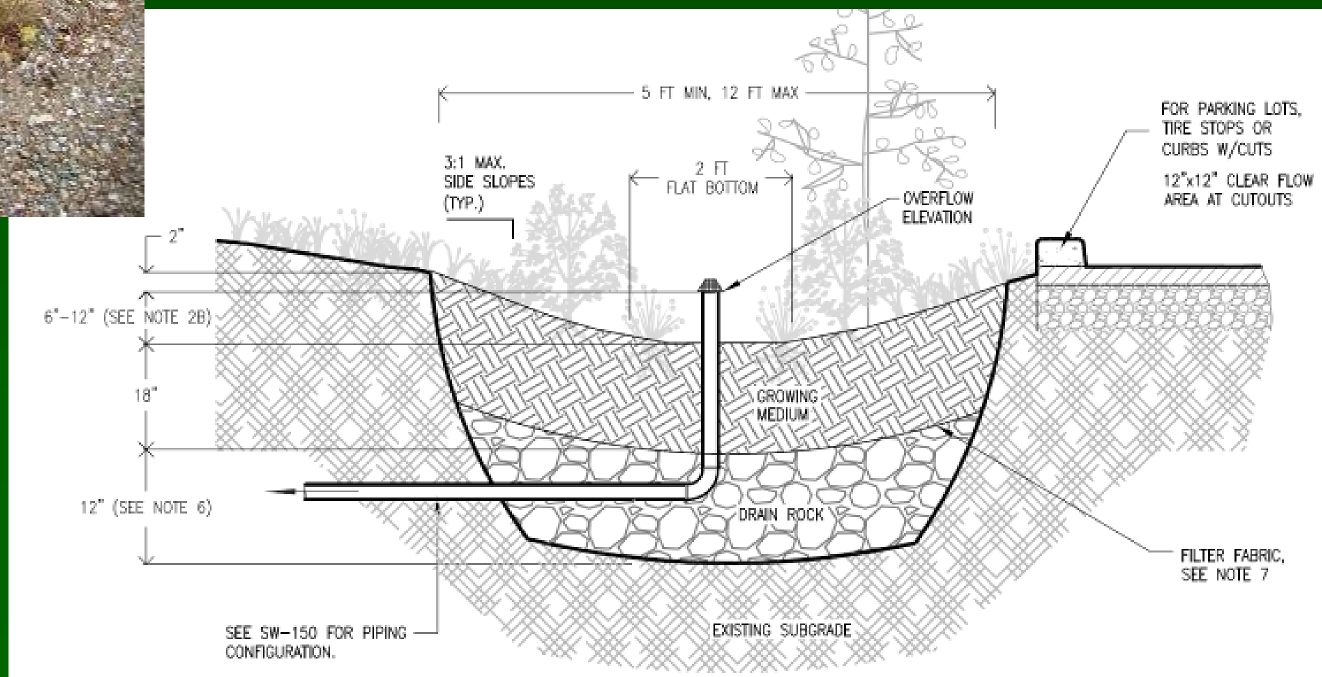
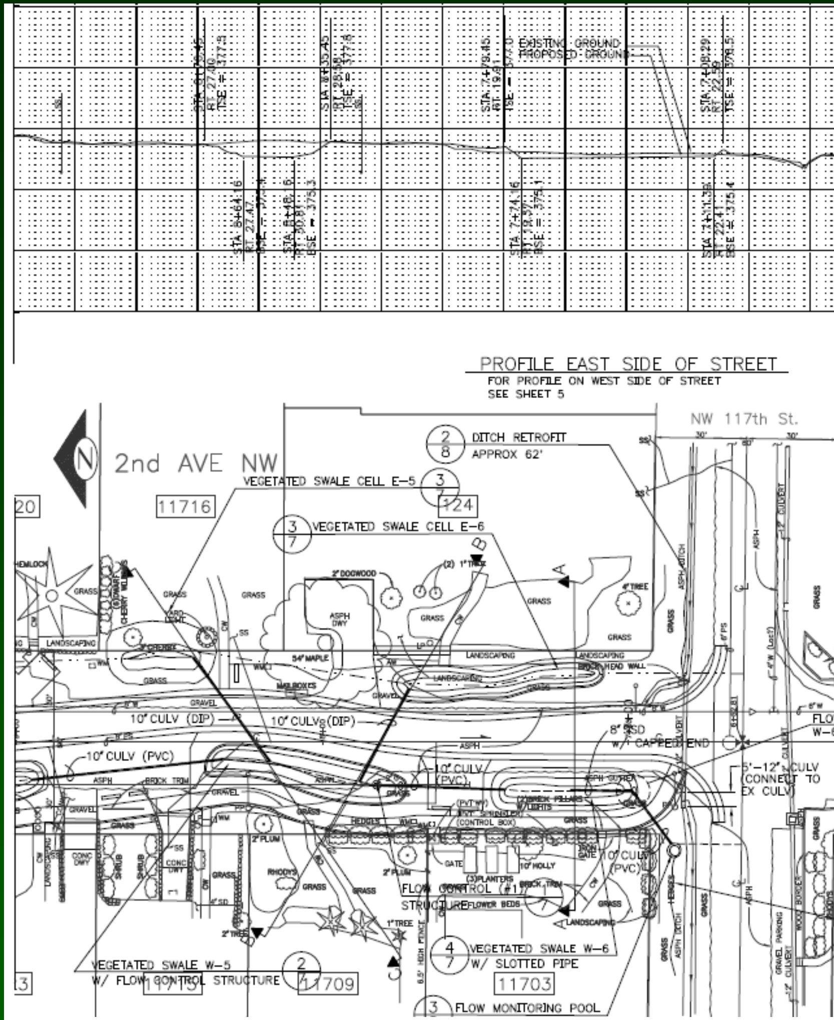
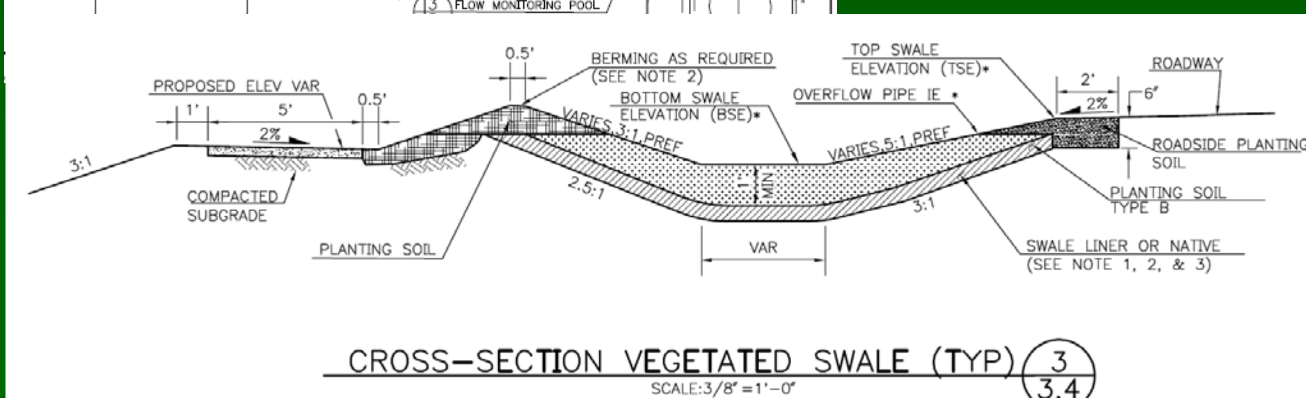
Residential Rain Gardens

Bioretention Swale

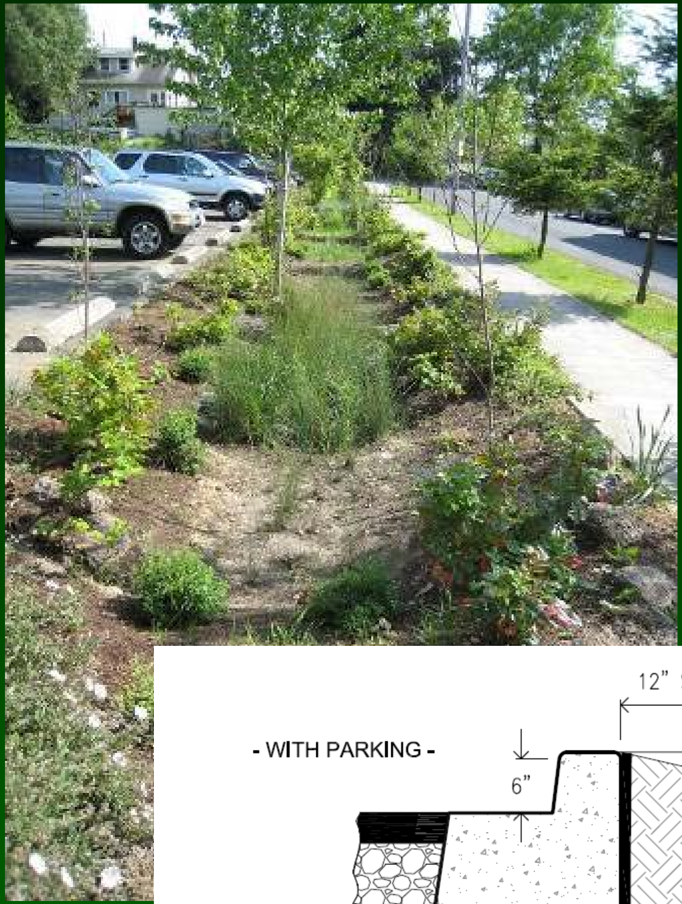


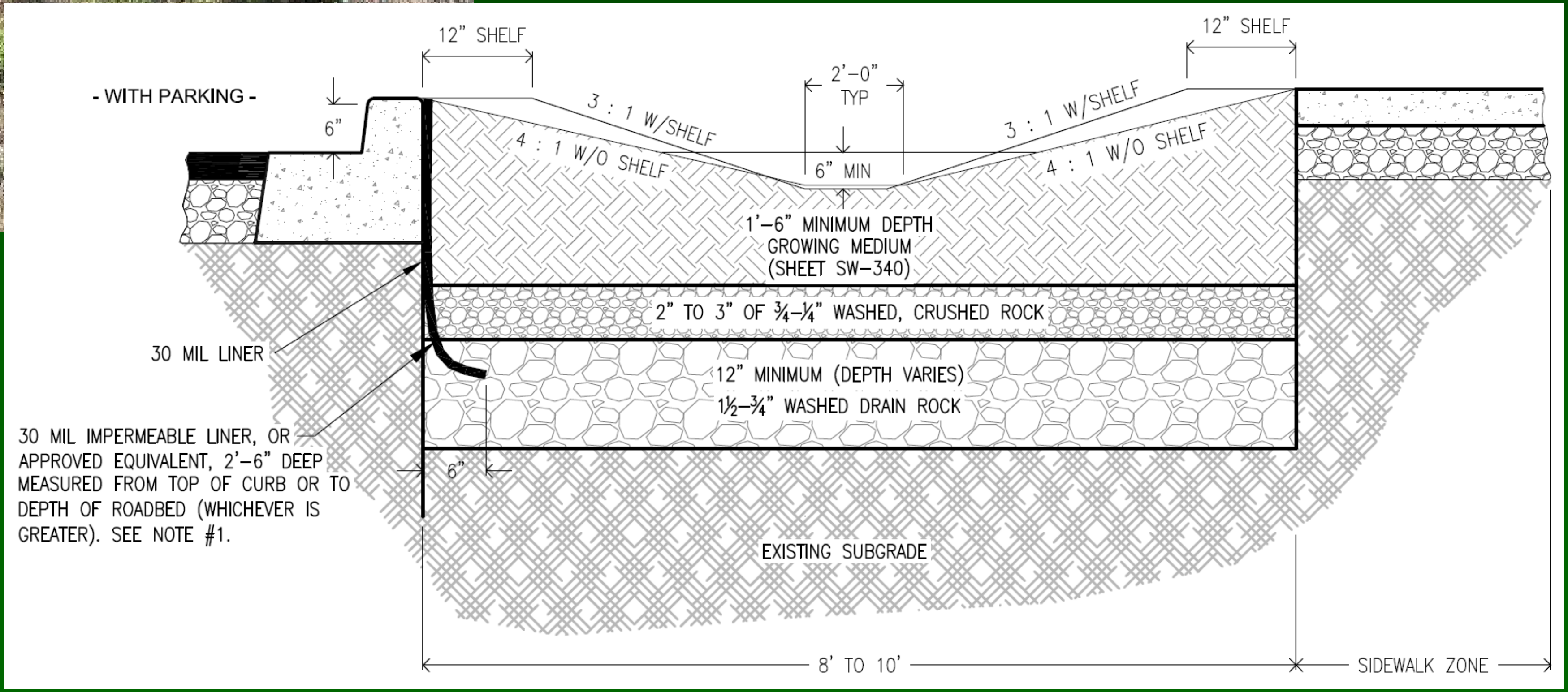
Bioretention Swale





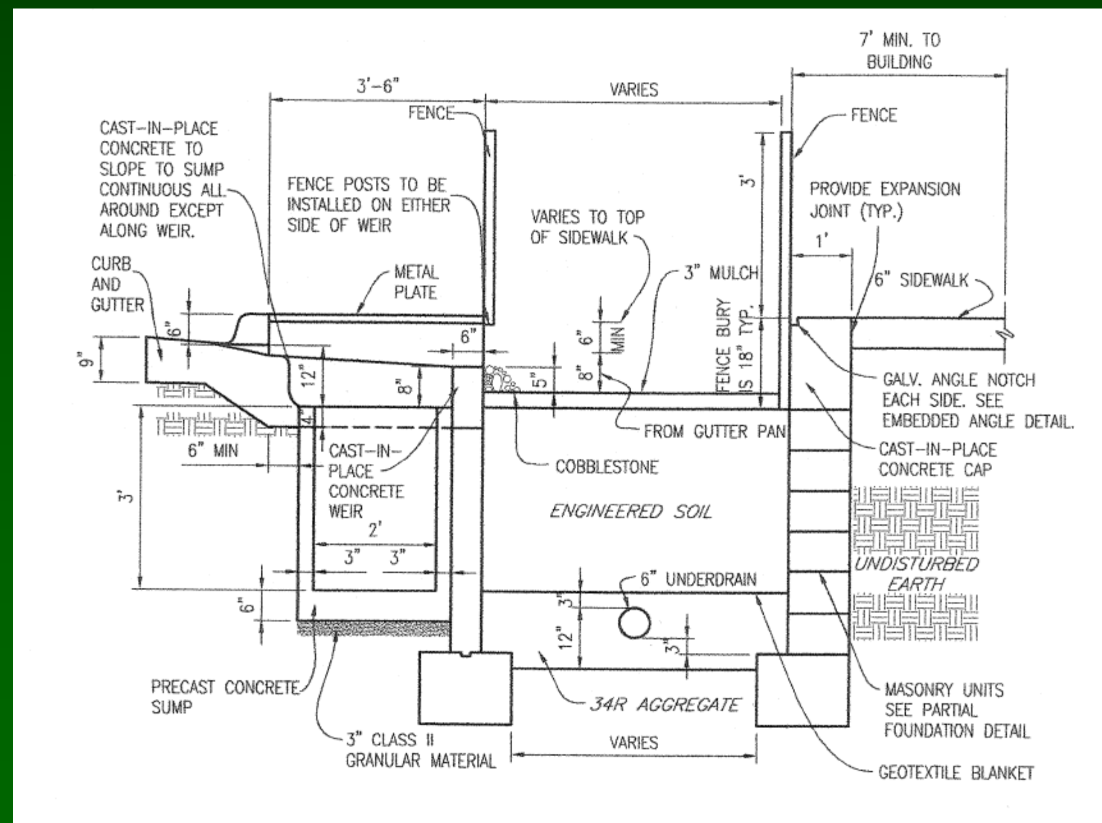
Bioretention Swale with Parking



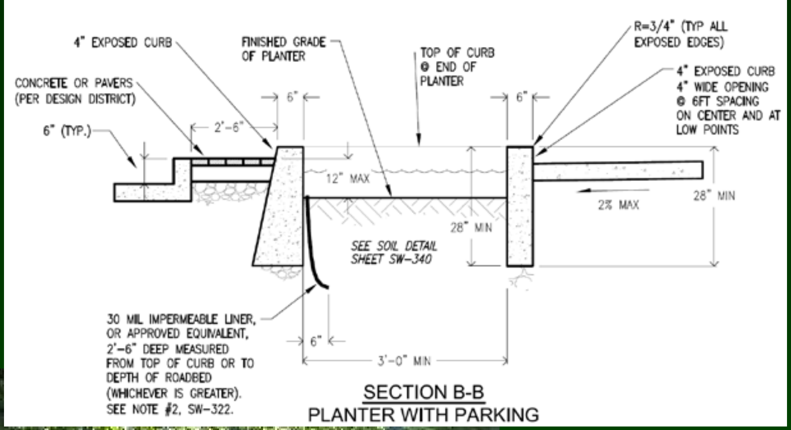


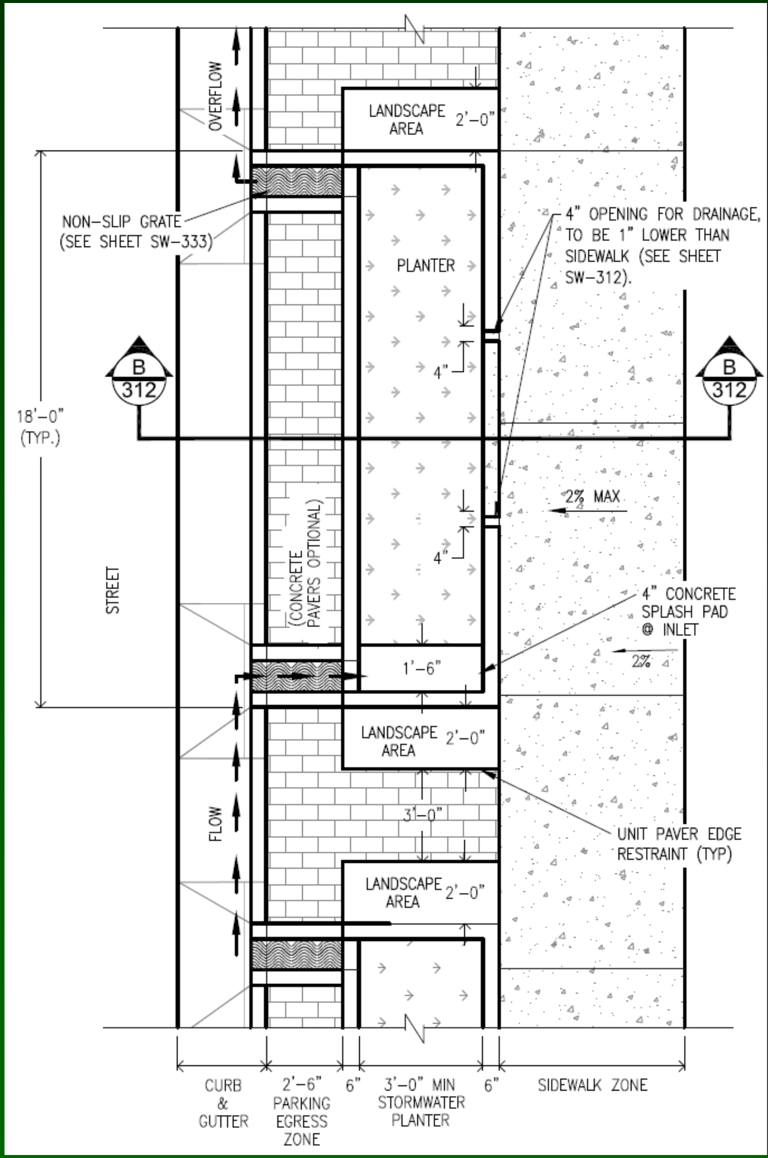
Bioretention at Office Complex

Bioretention Planter

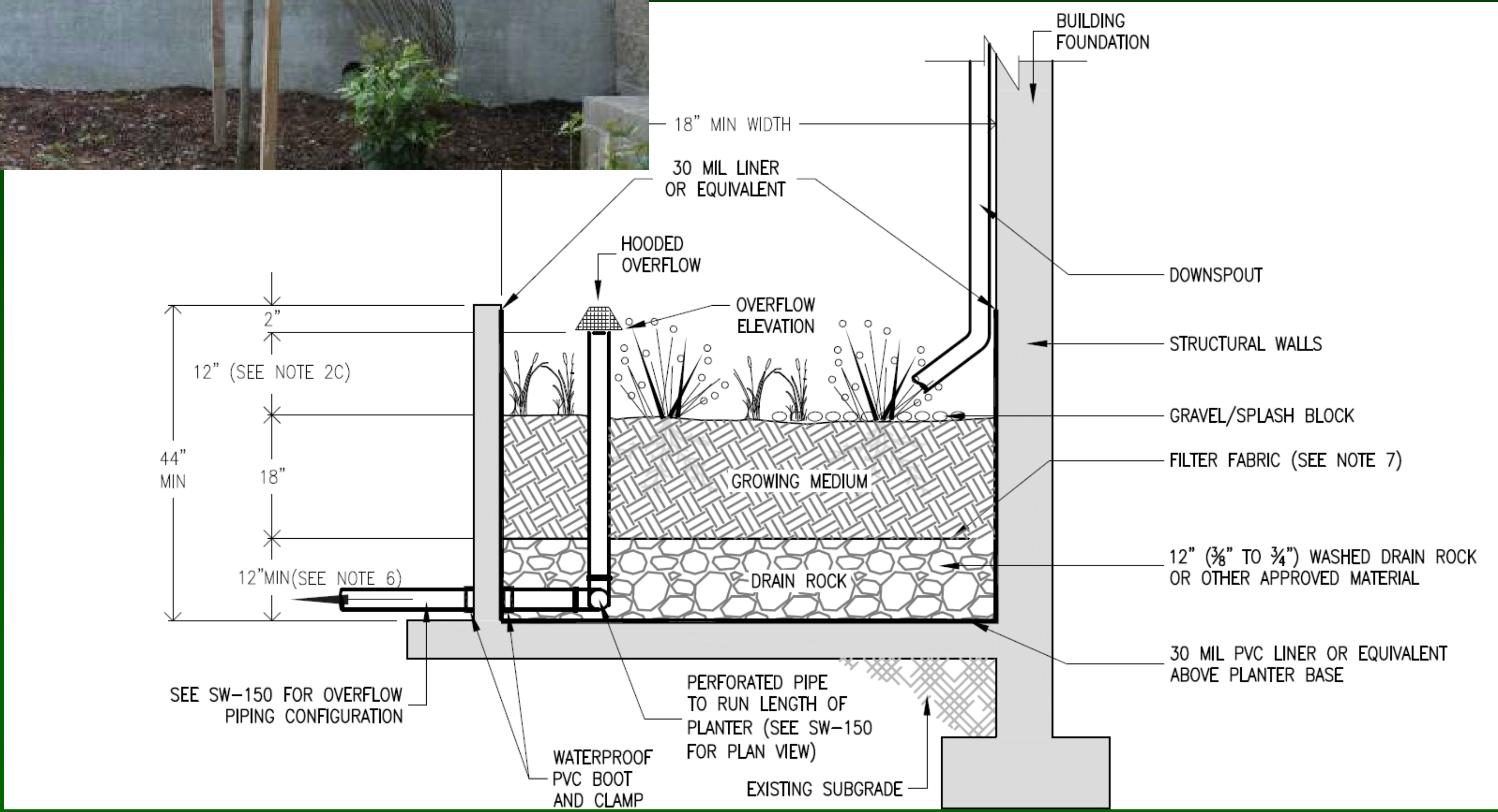


Bioretention Planter

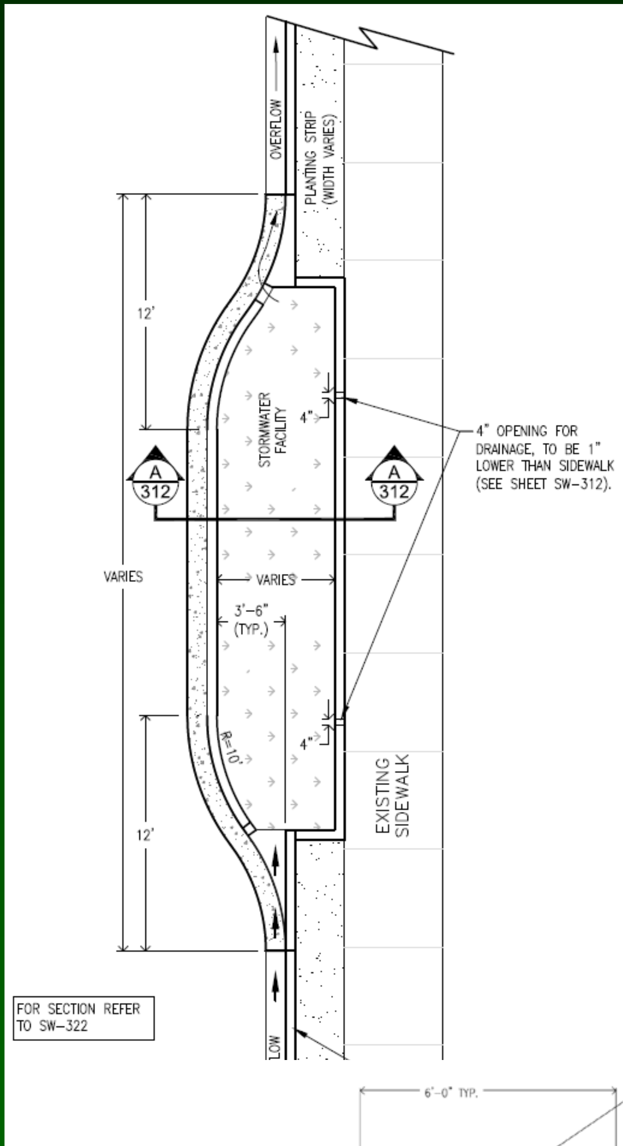


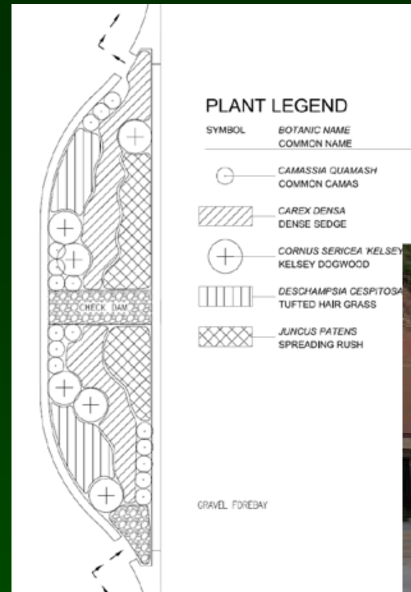


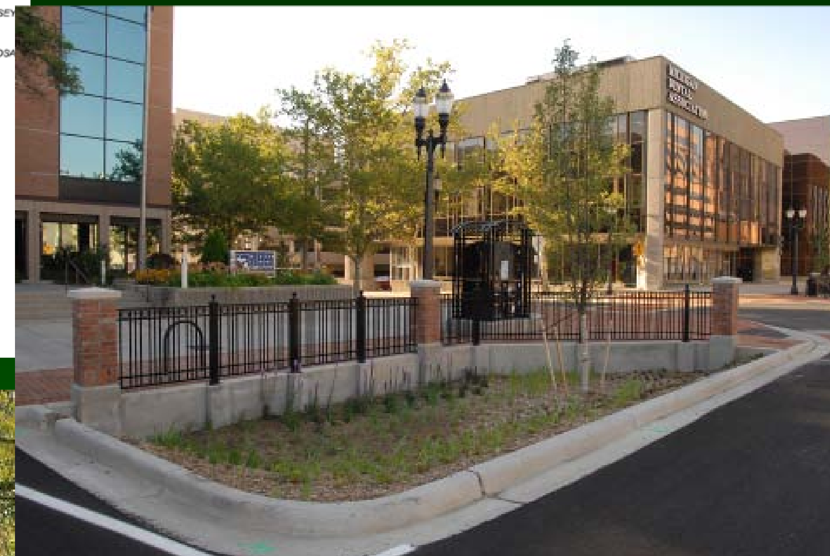
Planter Box Style Bioretention

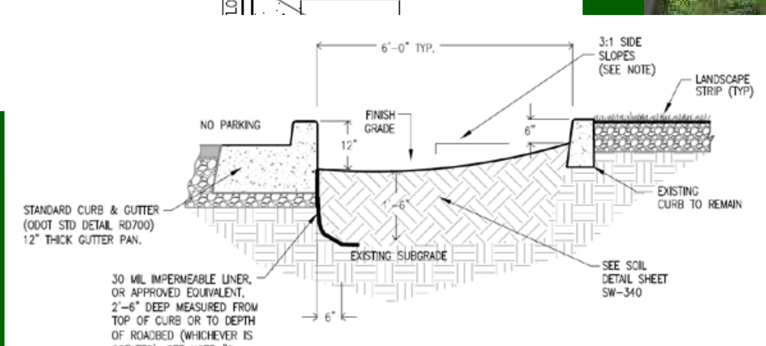


Curb Extension

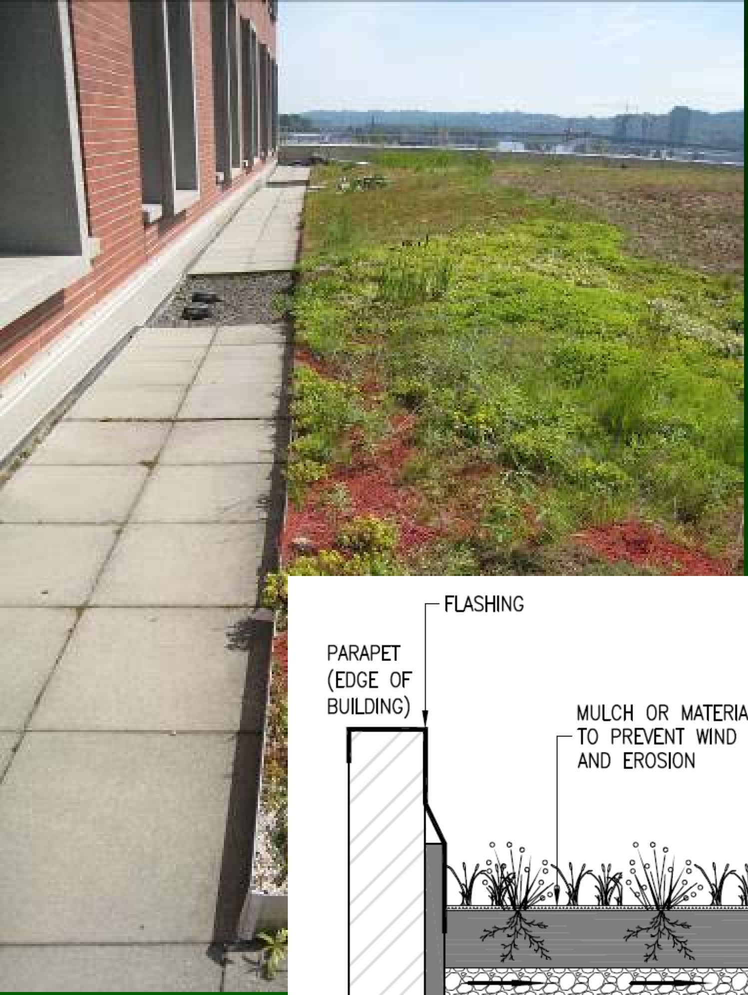


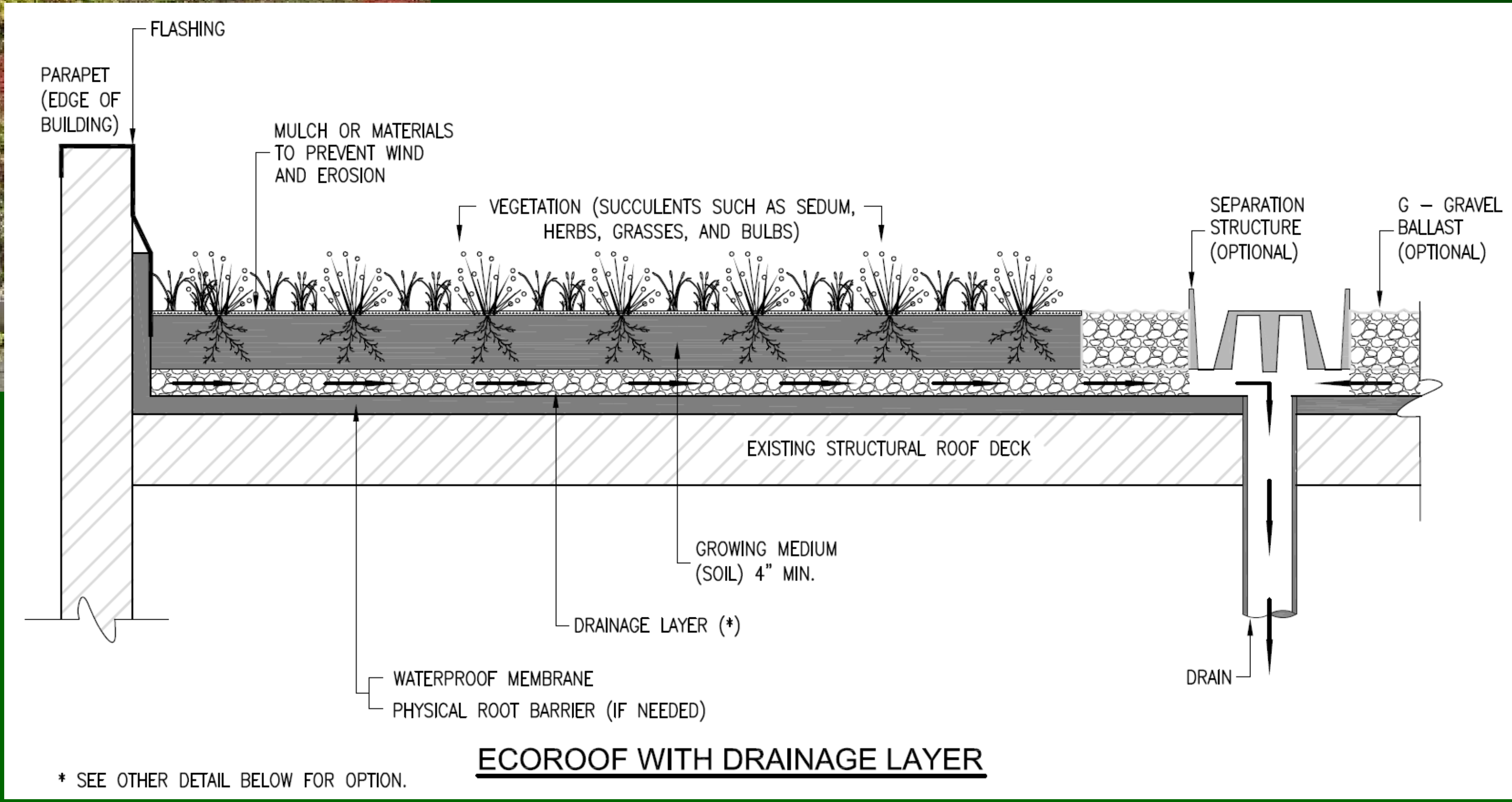




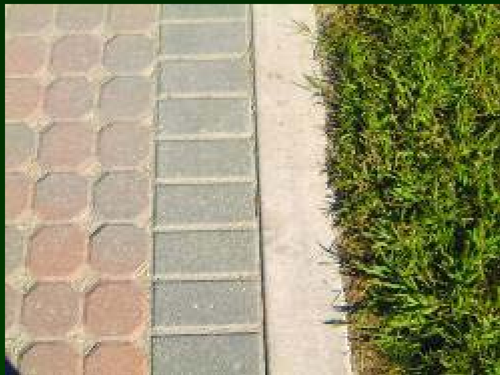


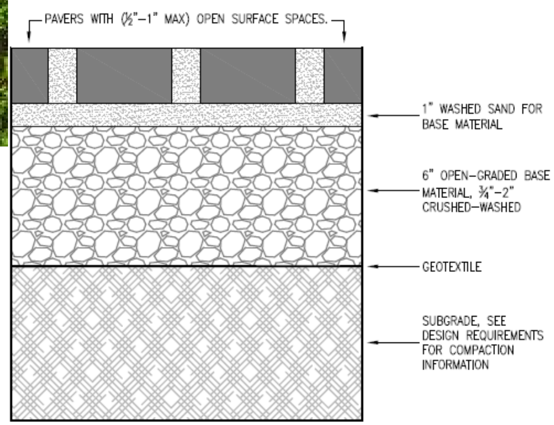
Green Roof




FLASHING
PARAPET (EDGE OF BUILDING)
MULCH OR MATERIALS TO PREVENT WIND AND EROSION
VEGETATION (SUCCULENTS SUCH AS SEDUM, HERBS, GRASSES, AND BULBS)
SEPARATION STRUCTURE (OPTIONAL)
G – GRAVEL BALLAST (OPTIONAL)
EXISTING STRUCTURAL ROOF DECK
GROWING MEDIUM (SOIL) 4" MIN.
DRAINAGE LAYER (*)
WATERPROOF MEMBRANE
PHYSICAL ROOT BARRIER (IF NEEDED)
DRAIN
ECOROOF WITH DRAINAGE LAYER
* SEE OTHER DETAIL BELOW FOR OPTION.

Porous Pavement

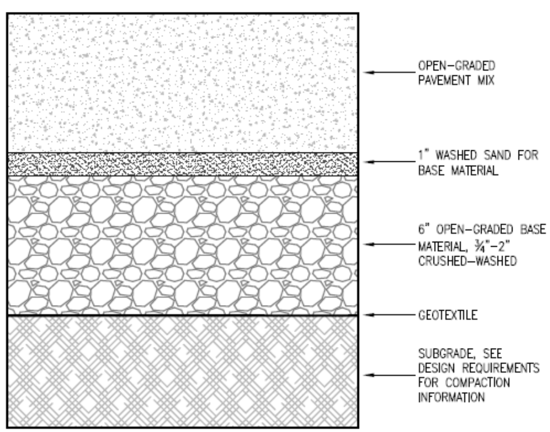




PERMEABLE CONCRETE BLOCK OR "PAVER" SYSTEMS

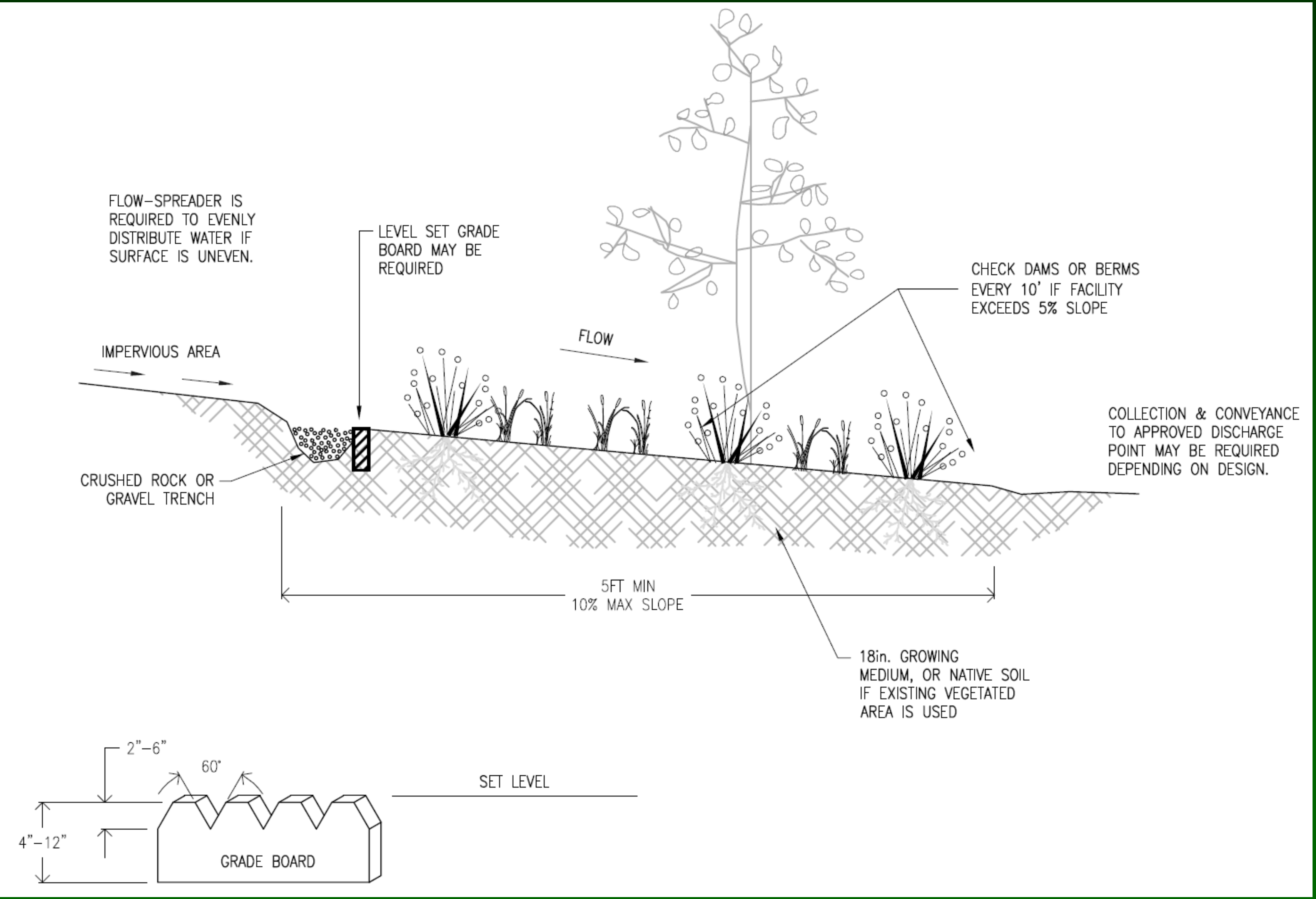
	RESIDENTIAL DRIVEWAY OR PEDESTRIAN ONLY	PRIVATE STREET, PARKING LOT, OR FIRE LANE	PUBLIC STREET
CONCRETE	4"	4"	7"
ASPHALT	2 ½"	3"	6"
PAVERS	2 ⅜"	3 ⅛"	3 ⅛"
ENGINEERING REQ'D	NO	YES	YES
COMPACTION REQ'D	NO	YES	95%

EXHIBIT 2-8
PERVIOUS PAVEMENT REQUIREMENTS FOR TOP LIFT DEPTH, ENGINEERING, AND COMPACTION.

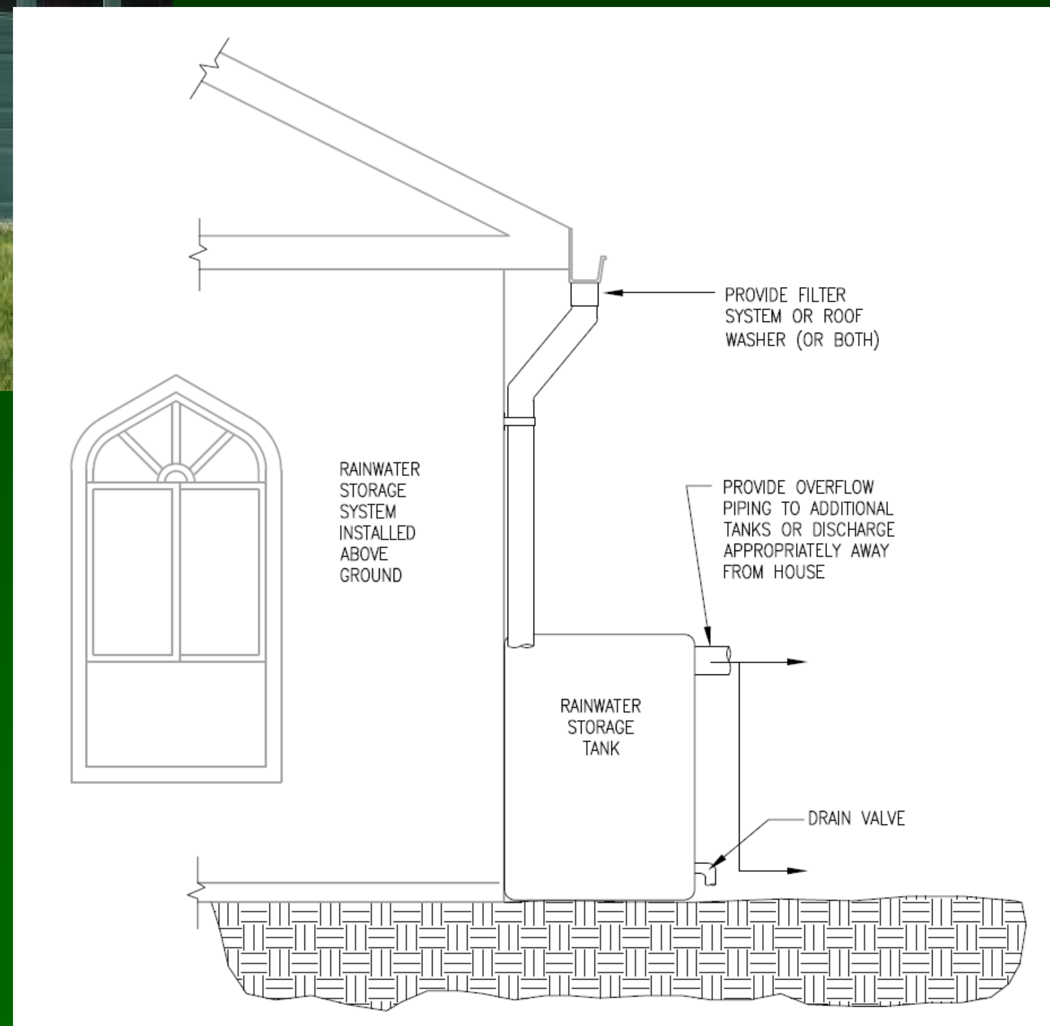


PERVIOUS (OPEN GRADED) CONCRETE AND ASPHALT SYSTEMS

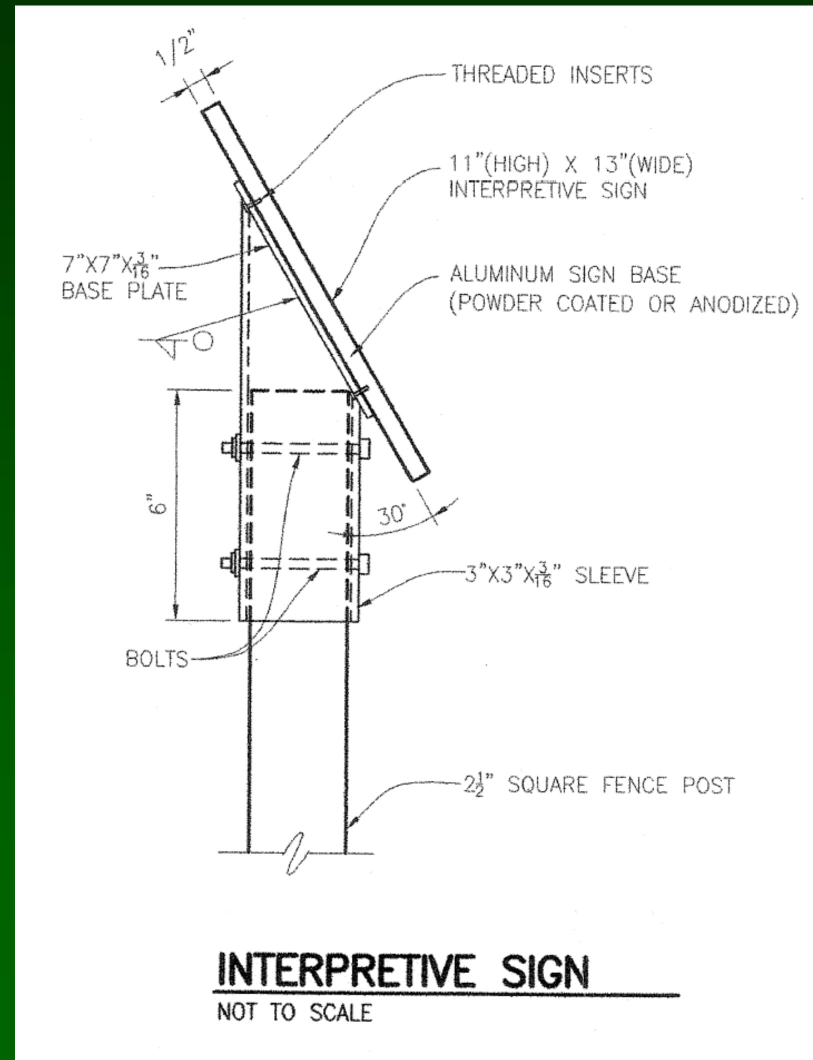
Filter Strip

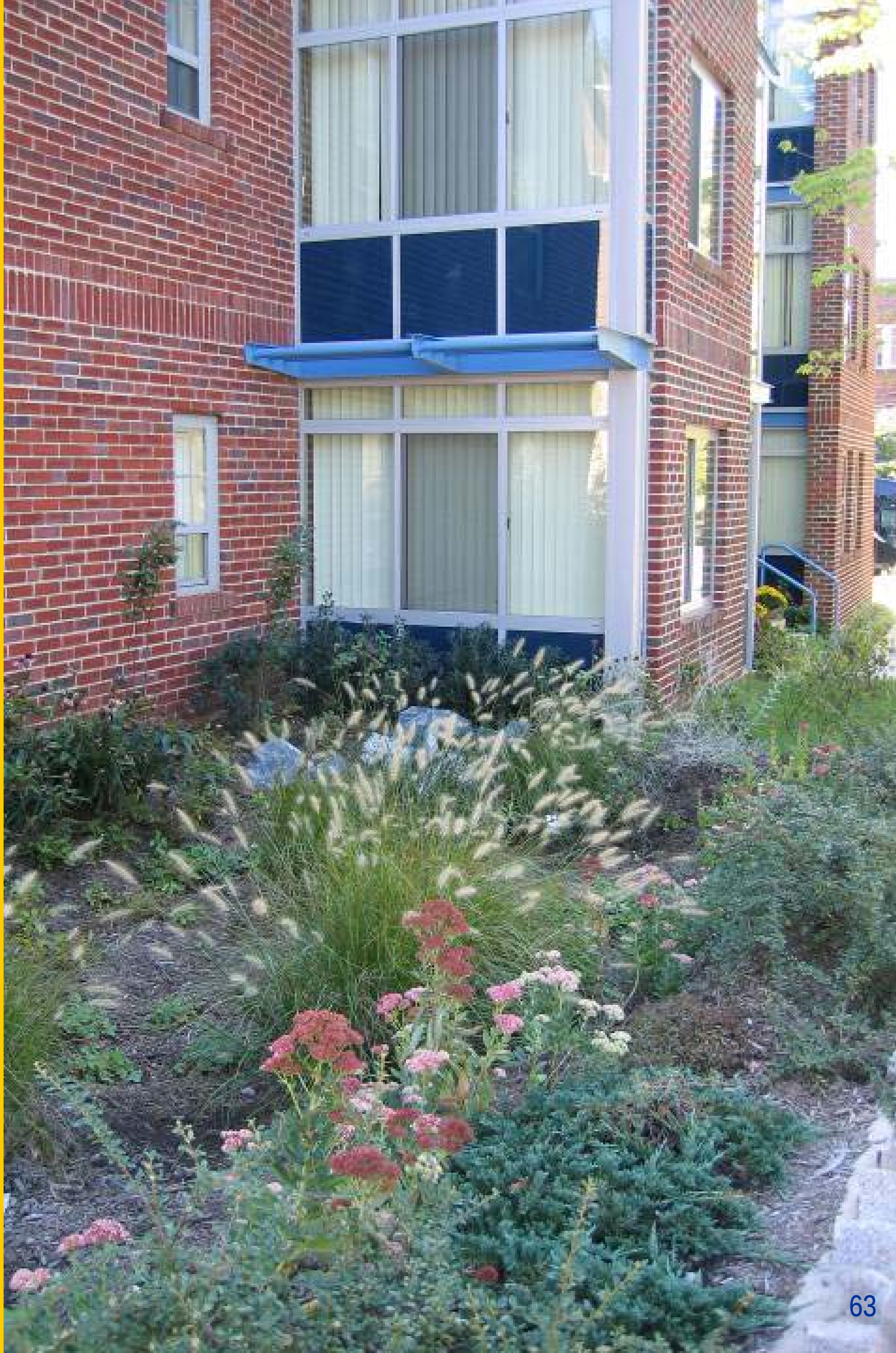


Rainwater Harvesting



Interpretive Sign





Agenda

- Introduction
- Types of Practices and What They Do
- Plants
- Soils
- Outlets
- Example Approach
- Strategies for Design/Implementation
- Implementation Examples
- Summary

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Putting it All Together . . . Recreating Natural Hydrology

- Protect natural features
- Let pervious be pervious
- Minimize impervious surfaces
- Route grey to green
- Promote vigorous plant growth
- Slow the water down
- Design for stormwater as an asset and amenity

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Think outside the pipe!