DESIGN

Post-Construction Stormwater Design Considerations

Design Objective

How do we make this . . .

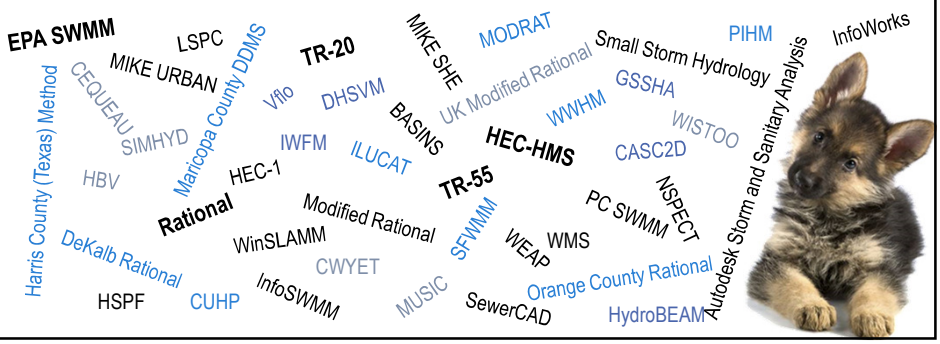
function like this . . .

Design Criteria

- Water Quality Treatment Volume
  - ~90% non-exceedance, ~1.0 inch rainfall
  - Typically focus on runoff retention
- Channel Protection
  - Purpose – maintain stable channel hydrology
  - Typically designed for 2-year event (3.0 in)
  - Commonly volume and peak flow control
- Municipal Sewer Conveyance
  - Used to size sewer pipes and open channels
  - 5 to 10-year events commonly used (3.7 - 4.2 in)
  - Commonly sizing pipes for post-development peak flow
- Local Flood Control
  - Manage local drainage to prevent problem flooding
  - 25 to 100-year events commonly assumed (5.1 – 6.6 in)
  - Commonly detention storage with peak flow limited to pipe capacity

Sizing

- How do you size these things for all the different criteria?
  - Hand calculations
  - Spreadsheets
  - Dedicated hydrologic modeling software
- Calculating complete hydrographs is important



Drainage Area

- Practices are sized for the drainage area
- Know the intended drainage area
- Field changes may necessitate design changes

Storage Volume of Practice

- Drainage area equates to a volume of runoff
- Build practices to meet design volume

Category	% of Design Volume	% of Practices in Category
Severely Undersized	<-25%	28%
Moderately Undersized	-25% to -10%	22%
Adequate	**-10% to 10%**	**17%**
Moderately Oversized	10% to 25%	17%
Severely Oversized	>25%	17%

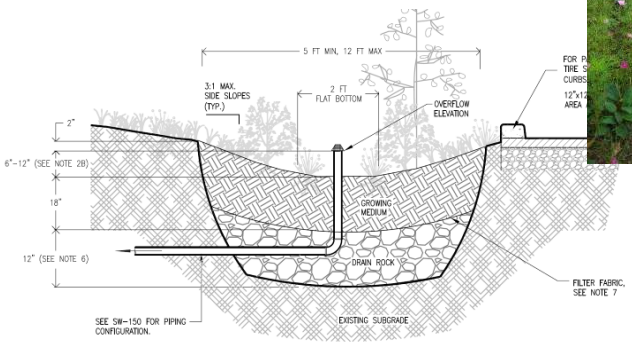
Assessing the Accuracy of Bioretention Installation in North Carolina (2011) B. Wardynski and W. Hunt.

BIORETENTION PROFILE

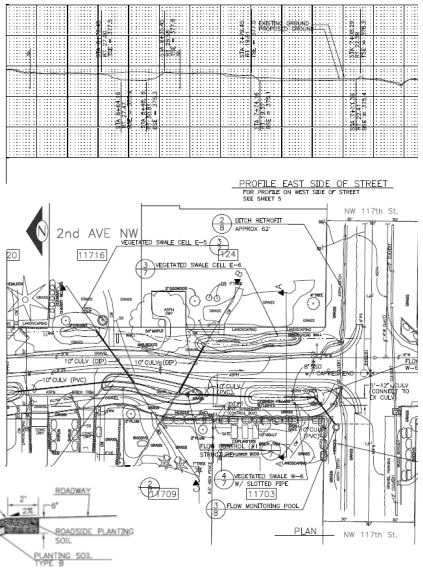
Let's take a quick sidetrack and look at the typical components of a bioretention system and example cross sections

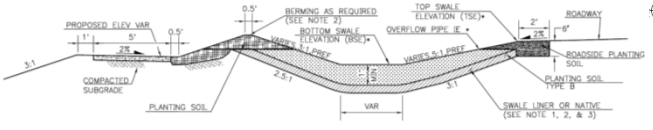
Bioretention

Swale - Small



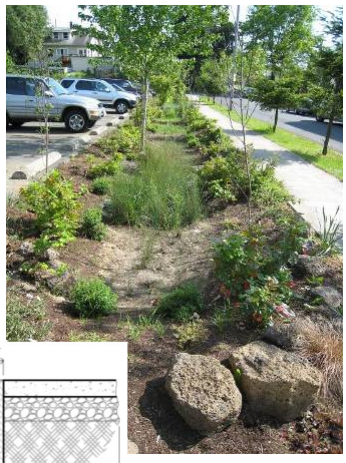
Swale - Large

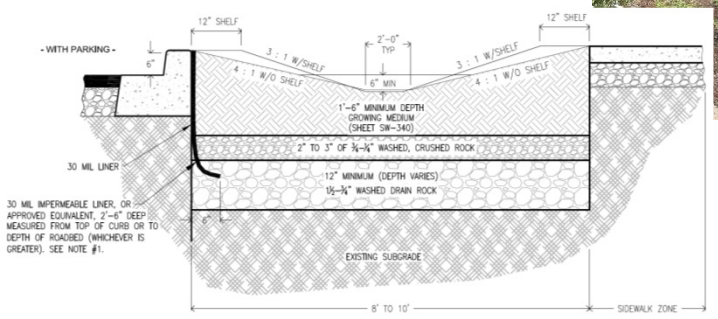




CROSS-SECTION VEGETATED SWALE (TYP) 3/3.4

Parking Lot Swale

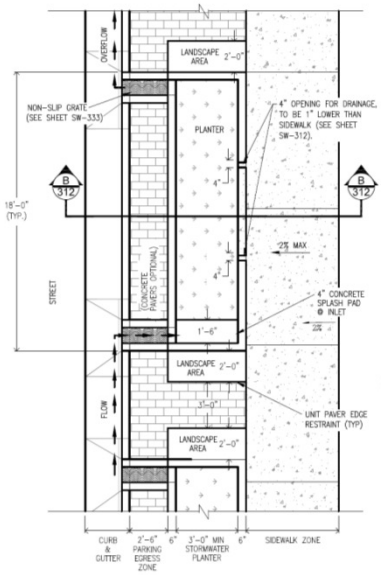


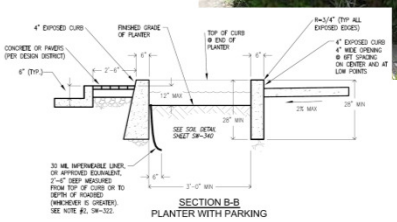


Bioretention Parking Lots

Bioretention at Building Sites

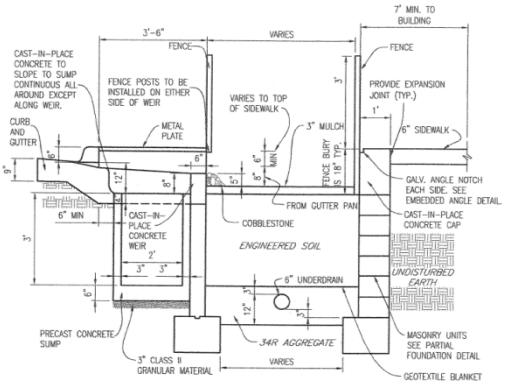
Linear Planter - Small



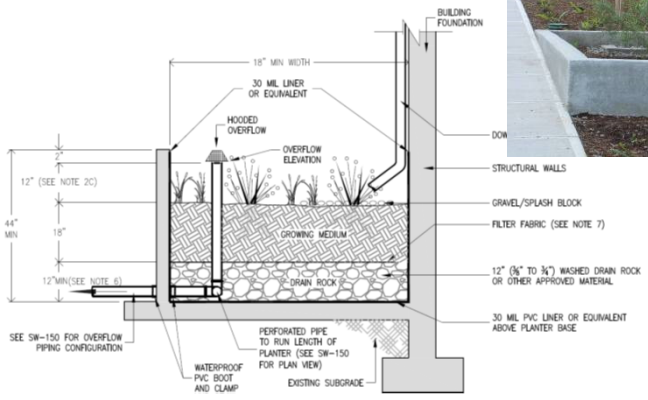


SECTION B-B
PLANTER WITH PARKING

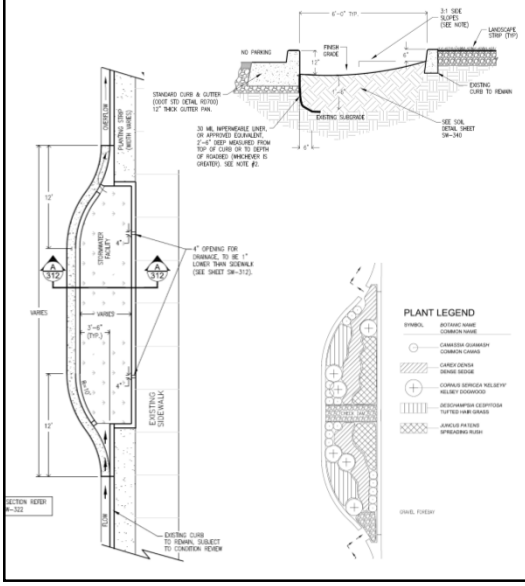
Linear Planter - Large



Planter Box Next to Building



Curb Extension

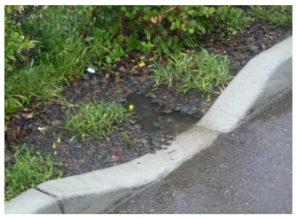


BIORETENTION DETAILS

Now let's look a little closer at the component details

Inlet

- Sized to capture design flow
- **Location** and **elevation**
- Prevent clogging and sediment accumulation
- Guard against excessive inlet velocities



Pretreatment

- Capture large sediment (*sometimes trash and debris*)
- Prevent erosion
- Level weir wall
- Options
  - Filter strips
  - Grass channels
  - Sumps
  - Hydrodynamic devices
  - Screens and baskets
- Design based on dynamic settling and Stokes Law

Primary Storage Area

- Level soil surface
- Encourage even infiltration and reduce erosion

Vegetation

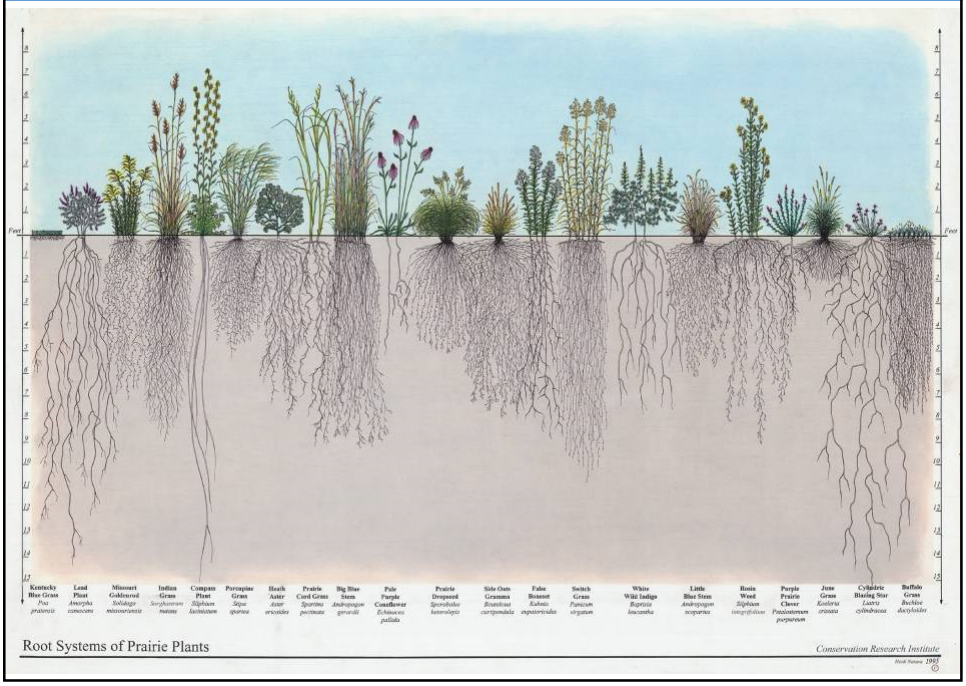
- Water Uptake
- Stabilization
- Impeding Flow
- Filtration
- Infiltration
- Nutrient Uptake
- Toxin Uptake
- Pollutant Breakdown

- *Plants for Stormwater Design : Species Selection for the Upper Midwest, by D. Shaw and R.Schmidt, 2003.*
- *Plants for Stormwater Design: Species Selection for the Upper Midwest, Volume II. By D. Shaw, T. Randazzo, H. Johnson, R. Schmidt, B. Ashman, 2007.*

Transpiration Rates of Various Plants

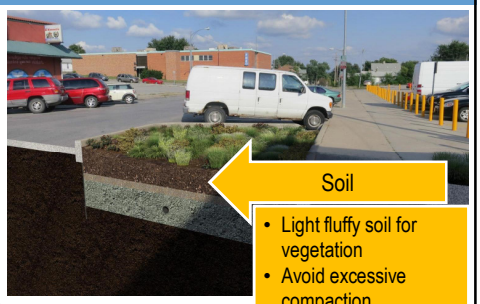
Plant Name	Plant Type	Transpiration Rate
Perennial rye	Lawn grass	0.27 in/day
Alfalfa	Agriculture crop	0.41 in/day
Common reed	Wetland species	0.44 in/day
Great bulrush	Wetland species	0.86 in/day
Sedge	Wetland/prairie species	1.9 in/day
Prairie cordgrass	Prairie species	0.48 in/day
Cottonwood	Tree (2 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)



Soil

- A special or engineered soil specified by the particular practice
- Chosen for specific porosity – infiltration of stormwater
- May have special characteristics to treat or absorb nutrients and other pollutants

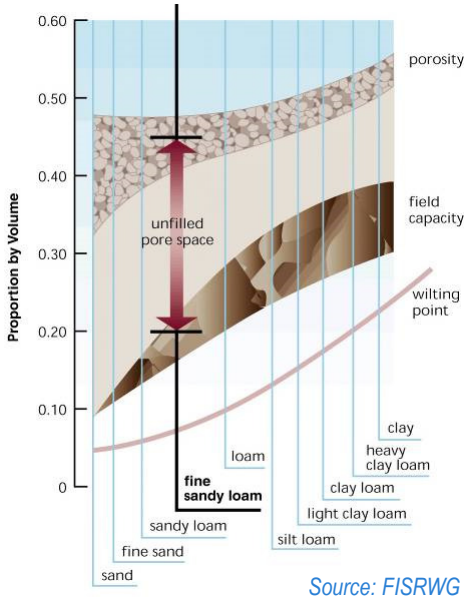


Example Mixes

- *Prince Georges Co. MD: 50-60% sand; 20-30% compost; 20-30% topsoil*
- *Minnesota added <5% clay stipulation to PG County mix*
- *NCSU: 85% sand; 12% fines; 3-5% organics*
- *Portland OR: 60-70% sand; 30-40% compost (35-65% organic); particle gradation specified*
- *LID Center: 50% sand; 30% planting soil (50-85% sand, 0-50% silt, 10-20% clay, 1.5 -10% organic); 20% shredded hardwood mulch*

Soil Characteristics

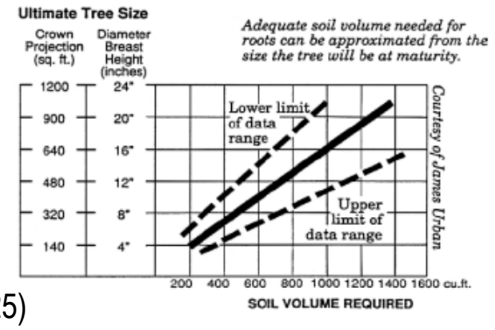
- Porosity: void space of soil (space for water)
- Infiltration: movement of water through soil
- Field Capacity: proportion of void space that stays wet due to surface tension (i.e. after water drains by gravity)
- Wilting Point: point at which plants can no longer withdraw water fast enough to keep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



Source: FISRWG

A Word About Trees

- 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)



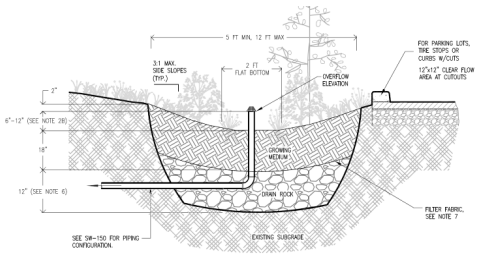
- Area of impervious surface needed to generate 250 cf of stormwater from a 1-inch of runoff = 3,000 sf
- Assuming drainage from ½ a 66-ft ROW equates to one tree box every 91-ft
- *Ignored evaporation, infiltration, water uptake by plants, and depression storage*

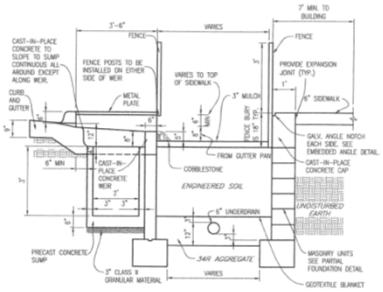
Outlet and Overflow

- Water needs a way to get out
- In-line versus off-line
- **Location** and **elevation**
- Mulch and topsoil should stay in

Supported Sides

- Compact materials under sidewalk and roads
- Light fluffy soil in bioretention





Filter or Choker Layer

- Challenges
  - Often specified wrong
  - Common failure point of system due to clogging
- Information Needed
  - Required drainage rates (permittivity of filter)
- Geotextiles
  - Filtration
  - Separation
  - Stabilization
  - Permanent Erosion Control
  - Silt Fence
- Aggregate Filter*
  - recommended

- Separation layer between soil and aggregate reservoir
- Material may be aggregate or geotextile

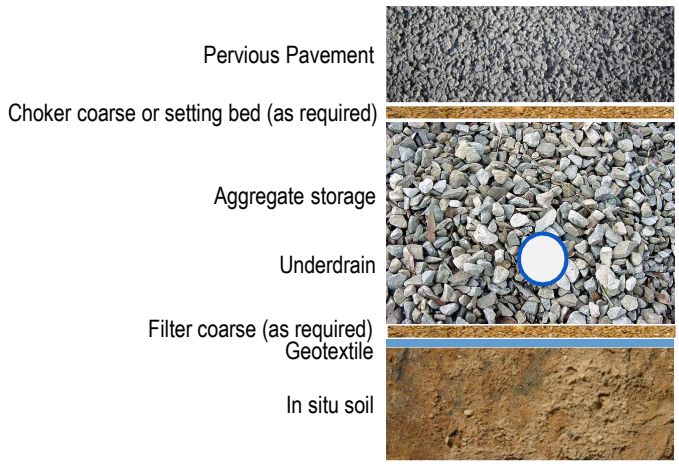
- *AASHTO Standard Specification for Geotextile Specification for Highway Application. M 288-06. 2011.*
- *Departments of the Army and the Air Force. Engineering Use of Geotextiles. TM 5-818-8, AFJMAN 32-130. 1995.*
- *Franks, C., A. Davis, and A. Aydilek. Geosynthetic Filters for Water Quality Improvement of Urban Storm Water Runoff. ASCE Journal of Environmental Engineering. 2012.*

Sloped Terrain

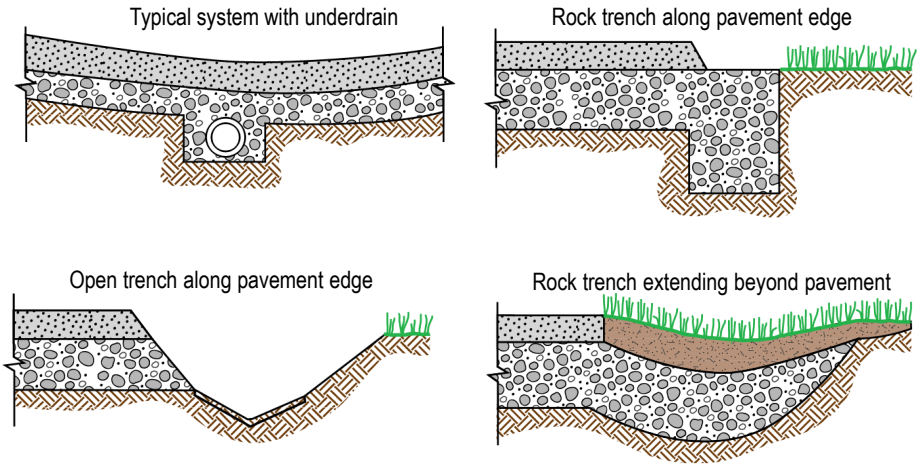
- Within each cell:
  - Soil and aggregate are level
  - Maximizes storage
  - Promotes infiltration
- Between cells:
  - Separating wall
  - Overflow from one cell cascades to next one downstream
- Can be constructed as continuous swale.
  - System used for conveyance, not just storage
  - Reduced storage volume.
  - Increased likelihood of surface flooding downstream.

POROUS PAVEMENTS

Porous Pavements



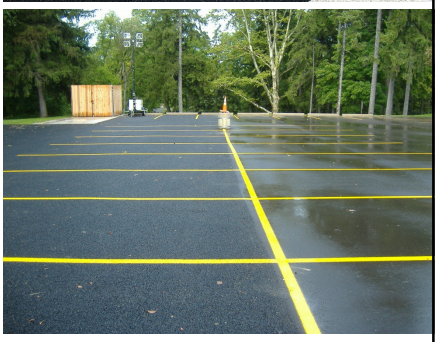
Porous Pavements



Source: American Concrete Pavement Association, 2006

Asphalt

- Installed with standard HMA paving equipment and no special training
- Mix Design is required
- Binder Content 5.0 - 6.5%
- Air Voids ≥ 18%
- Drain down ≤ 0.3%
- Evaluate for Moisture Susceptibility
- Typical cross-section
  - 2 to 4-inch asphalt layer
  - Choker course, 1 to 2 inches thick composed of 0.5-inch diameter stone
  - Aggregate subbase, thickness varies

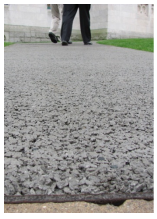


Porous Asphalt Pavements for Stormwater Management: Design, Construction and Maintenance Guide. Information Series 131. National Asphalt Pavement Association (NAPA). 2008.

Concrete

Illinois Ready Mixed Concrete Association, Pervious Concrete. http://www.irmca.org/site/page23.aspx
National Ready Mixed Concrete Association. Pervious Concrete. http://www.perviouspavement.org/
FHWA www.fhwa.dot.gov/pavement/concrete/pubs/hif13006/index.cfm

- Pervious designed as regular concrete pavement, but has lower strength
  - Ranges from 400 psi to 4000 psi
  - Strength decreases linearly as void ratio increases
  - 15% to 20% void ratio can result in 7-day compressive strengths of 2900 to 3300 psi
- ACPA PerviousPave software for design www.acpa.org/perviouspave/
- Most "car traffic only" pavements are 6 inches of pervious concrete
- Use certified professionals (list available on nrmca.org)
- Water content is critical to success
- Cover during curing



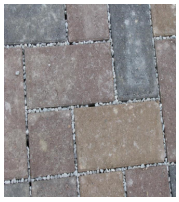
Other Aggregate Based Paving Systems

- Flexi®-Pave (kbius.com)
- Filterpave® (http://filterpave.com)
  - Glass (recycled) or aggregate
  - elastomeric binder
- PorousPave (www.porouspaveinc.com)
  - Recycled tires, aggregate and urethane binder
  - Sidewalks, driveways, play areas, parking lots
- Gravel Driveway
- *and many more…*

Open-Jointed Paving Blocks

- Water drains between pavers
- Concrete and clay materials
- Typical cross-section
  - Paver stone
  - Bedding course 1 to 2 inches thick, typically ASTM No. 8
  - Aggregate subbase, thickness varies, typically ASTM No. 57
- Edge restraints are required

Interlocking Concrete Pavement Institute
www.icpi.org
Brick Industry Association
www.gobrick.com

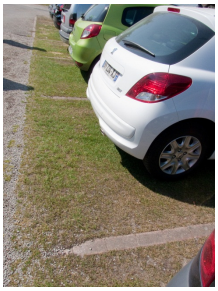


Open-Celled Paving Grids

- Similar design and installation as the open-jointed paving blocks
- Pavers contain large openings
- Voids filled with various materials
- Concrete blocks

Plastic Geocells and Porous Turf

- Various manufacturers
- Vertical load supported by honeycomb structure
- Void space typically filled with granular material
- May be vegetated



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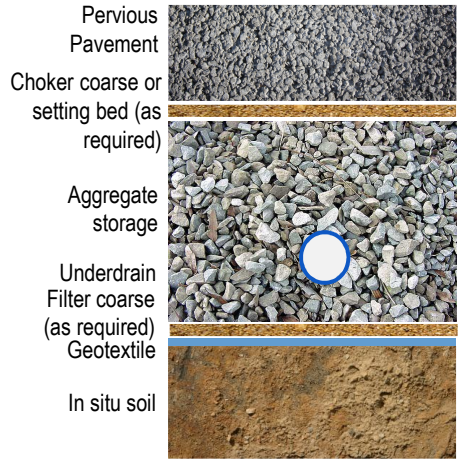
  - Common failure point of system due to clogging
- Information Needed
  - Grain size analysis of in situ soil
  - Required drainage rates (permittivity of filter)
- Geotextiles
  - Filtration
  - Separation
  - Stabilization
  - Permanent Erosion Control
  - Silt Fence
- Aggregate Filter



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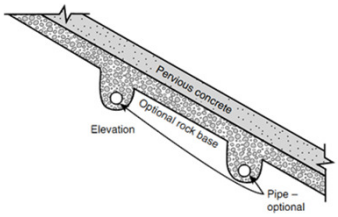
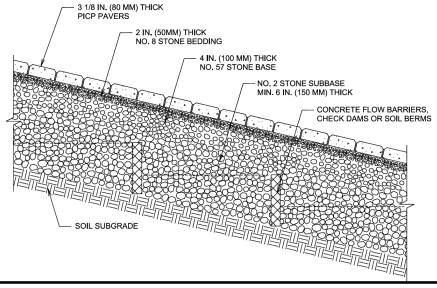
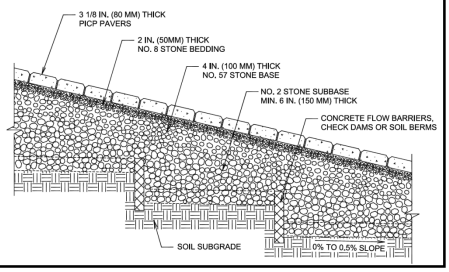
Working on slopes

- Pervious concrete successfully used on 16% slopes
- Asphalt surfaces <= 5% (NAPA recommended)
- Check Dams or Soil Berms
- Terrace the bottom







COMMON ELEMENTS

Used with both bioretention and porous pavements

Aggregate Storage

- Can be used to increase storage volume
- Open graded aggregate
- Load bearing
- Crushed concrete
  - increases pH for years
  - impedes vegetation growth
  - *Steffes R., Laboratory Study of the Leachate From Crushed Portland Cement Concrete Base Material, Iowa DOT. MLR-96-4. September 1999.*

Aggregate Porosity

Sample	Porosity	Bulk Density
AASHTO #4	37.4 - 46.1%	70.8 - 103.0 lbs/ft^3
AASHTO #57	38.7 – 52%	74.8 – 97.7 lbs/ft^3
1 ½ inch	35.3 – 41.9%	93.6 – 101.7 lbs/ft^3
¾ inch	38.5 – 38.9	97.9 – 100.3 lbs/ft^3

Source: LandSaver Stormwater Management System. Porosity of Structural Backfill. Tech Sheet #1, Rev. 1/16/2006

Other Types of Storage

- Manufactured devices
- Plastic and CMP arches
- Precast concrete boxes
- Etc.

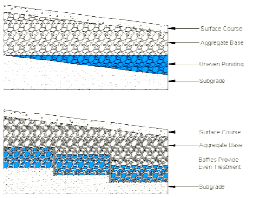
Underdrain

- Optional based on infiltration capacity of in situ soil
- Purpose to ensure drainage
- 4-inch diameter or larger
- Types
  - Rigid PVC
  - Flexible HDPE
  - SmartDrain (www.smartdrain.com)
- May be paired for redundancy
- Clean-out fittings

- Outlet is commonly used to control allowable discharge rate
  - Orifice end plate
  - Valve to allow for flow adjustments
- May include upturned elbow to enhance nutrient removal

The bottom

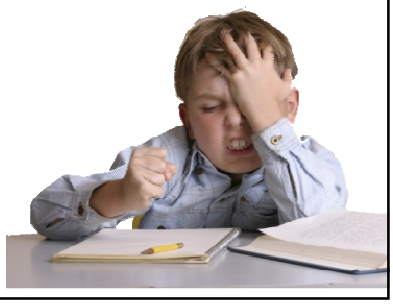
- Level bottom preferred
- On slopes terrace the bottom or use heck dams
- Compact
  - Infrastructure subgrades and bases = **Yes**
  - In situ soil below stormwater practices typically do not (should not) be compacted before placing aggregate and/or soil overtop
  - Aggregate reservoirs = **Yes**
  - Planting soil = **No**
- Loosen and scarify soils
  - Before planting
  - Before placing aggregate or soil layer



COMMON MISTAKES AND LESSONS LEARNED

Common Design Mistakes

- Not understanding the tributary area (size and surface coverage)
- Inadequate inlet
- Sloped surface resulting in reduced infiltration and erosive velocities
- Wrong mulch, floats away and clogs the outlet
- Lack of pretreatment
- No soil tests
- Poor plant selection
- Overly complex
- No maintenance plan
- Wrong geotextile specified



QUESTIONS AND DISCUSSIONS

TETRA TECH

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