TETRA TECH

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Maintenance of Green Infrastructure and Low Impact Development Practices

Jason Wright, PE

Maintenance Trigger: Dirty watershed

- Dirty/poorly maintained watersheds = clogged filtration/infiltration systems

General Maintenance

- Good Housekeeping: Keep the watershed clean

General Maintenance

- Bioretention/ Bioswale/Planters/Green Roofs
  - Landscaping O&M
- Permeable pavement
  - Vacuum sweeping
- Reinforced turf / Vegetated swales / Filter strips
  - Mowing
- Infiltration practices (trenches, dry wells)
  - Replacement of surficial layer
- Water Harvesting
  - Periodic inspection
  - Drainage

Pruning

- Maintain lines-of-sight
- Allow sunlight into bed to kill pathogens
- Facilitate trash pick-up
- Safety issues

Mowing regimen for grassed systems?

- As needed
- Consider safety
- Aesthetic appearance

Mulching

Bioretention Areas

- Bioretention areas
  - Mulch
  - Vegetation

Photos courtesy Watershed Management Group

Bioretention Areas
(Mulch)

- Bioretention areas
  - Mulch
    - Hardwood Mulch fades and breaks down in intense sunlight
    - Landscaping stone an alternative

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Bioretention Areas
(River Rock Mulch)

Photos courtesy Watershed Management Group

Bioretention Areas
(Inlets)

- Inlet Configuration

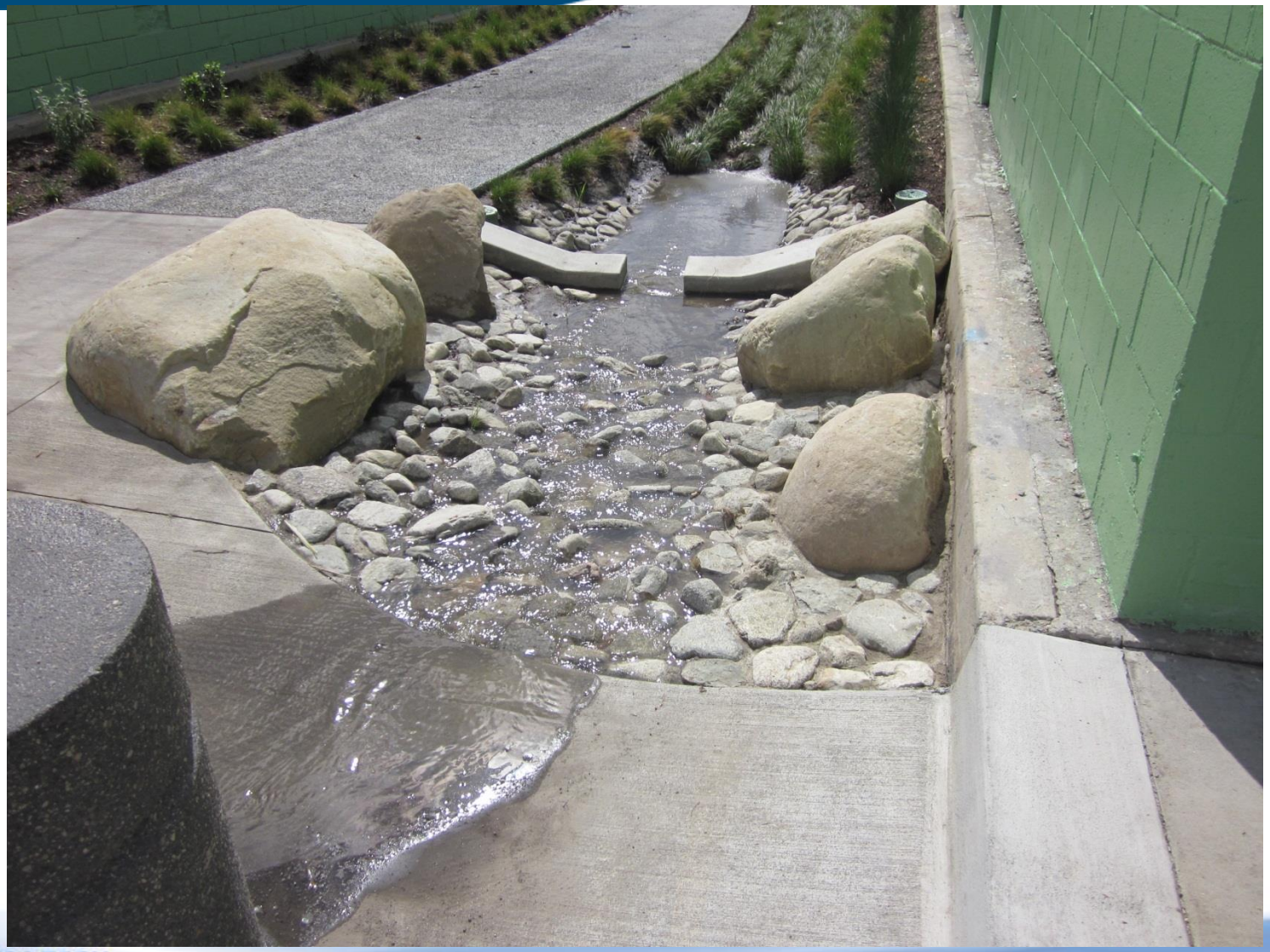
Bioretention Areas
(Inlets)

- Inlet Configuration

Bioretention Areas
(Inlets)

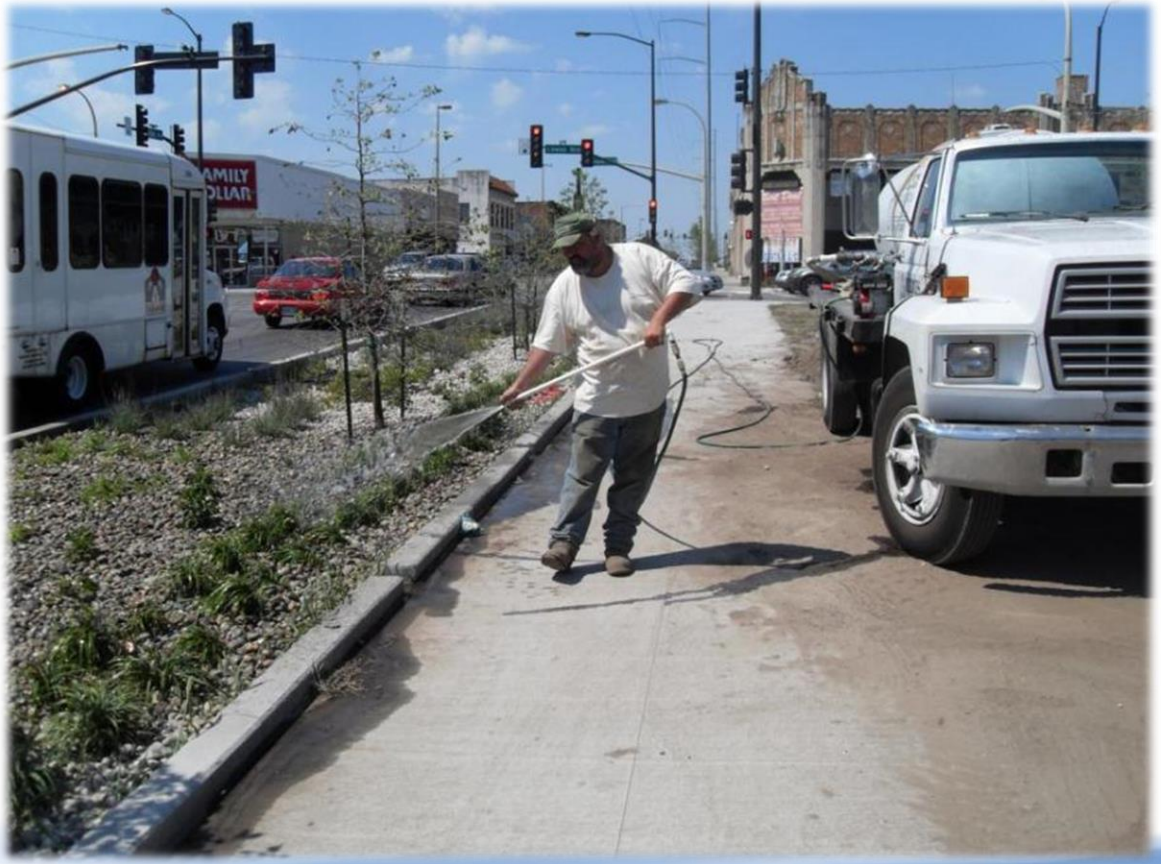
- Inlet Configuration
  - Armored inlet, forebay, diversion structure

Bioretention Areas
(Inlets)



If Vegetated….

- You may need to irrigate



Bioretention Areas
(Vegetation)

- Bioretention areas
  - Mulch
  - Vegetation
    - ½ water use in Utah and S. California is irrigation

      (Erickson et al 2002, Salt Lake City 2010)

Bioretention Areas (Vegetation)

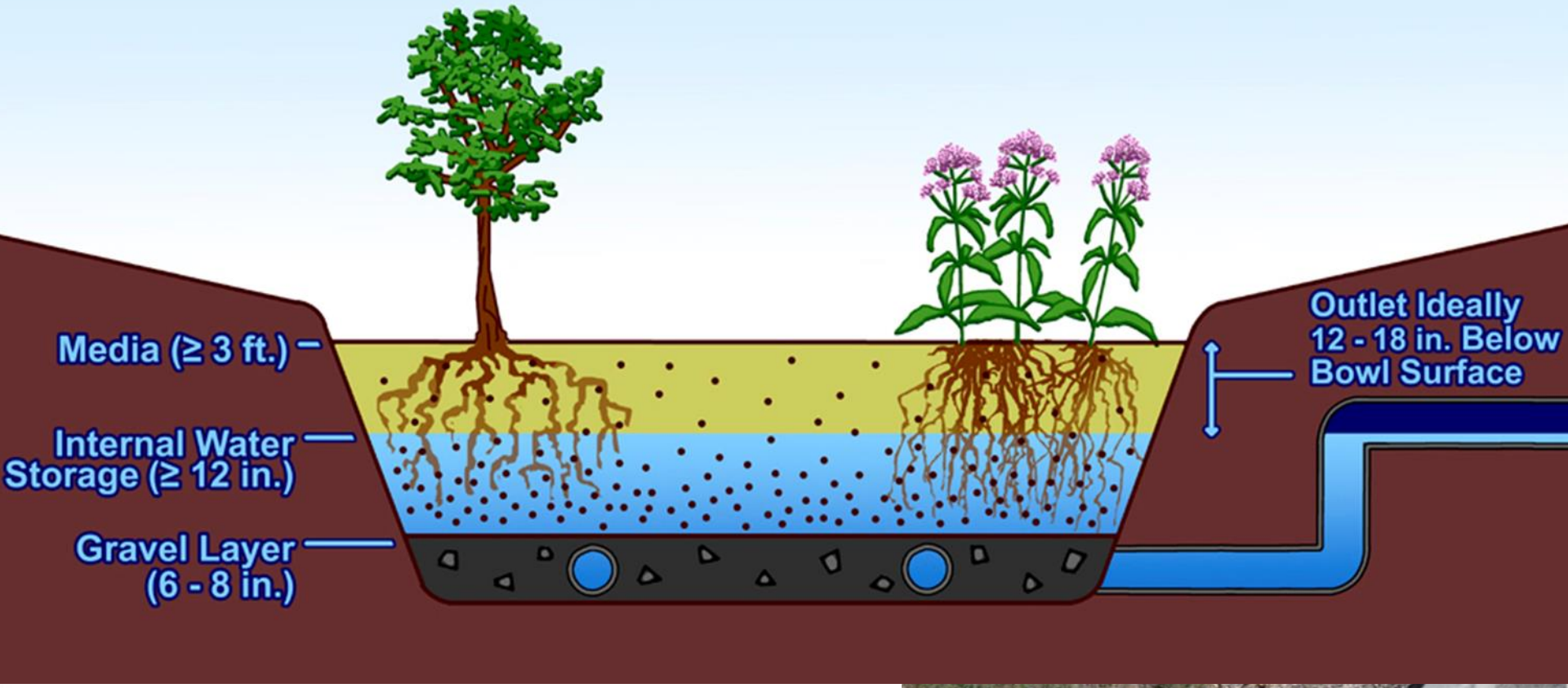
- Bioretention areas
  - Vegetation
    - Drought tolerant native vegetation
    - Phreatophytes
      - Large deep tap roots (> 100 ft)
      - Root system 4 to 9 times above ground biomass
        - » Scrub Oak and Mesquite

Adapted from Houdeshel et al. 2012

Photos courtesy Watershed Management Group

Bioretention Areas
(Vegetation)

- Bioretention areas



Source: NCSU BAE

Photos courtesy Watershed Management Group

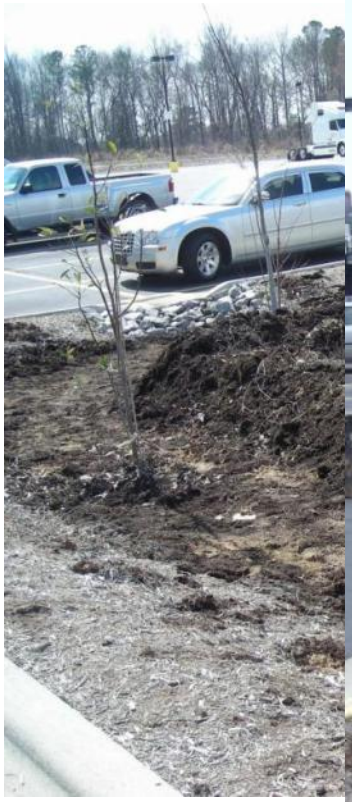
Bioretention Areas
(Vegetation)

- Bioretention areas
  - Vegetation
    - Drought tolerant native vegetation
    - Shallow Roots with Underdrains
      - Bunchgrasses and Shrubs

Photo courtesy Summer Waters,UA

Mulch removal/Bed Replacement

- Remove clogging layer & top 3 inches of media to increase surface ponding volume



Source: NCSU BAE

Maintenance Tasks and Schedule

TASK	SCHEDULE
Sedimentation prevention	Ass Needed: Observe adjacent parcels and parking lot use
Trash removal	Monthly/Semi-annual
Mowing	As needed; Maintain 3-4”
Pruning	Annual
Remove sediment	As needed or during mulch renewal; Annual
Mulch renewal	Annual
Plant replacement	As needed; Annual
Mulch removal/Bed Replacement	Every 3 years

Avoid Soil Compaction

Soil type/Compaction	Number of tests	Average infiltration rate (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

Infiltration Rates during Prior Tests of Disturbed Urban Soils (Pitt, Chen)

Permeable Pavement
(Concrete Transition Strip)

Permeable Pavement Problems

- Clogging
- Weeds and grass
- Oil and grease

Permeable Pavement

- Permeable Pavement
  - Dust and atmospheric deposition

Permeable Pavement

- Permeable Pavement
  - Dust and atmospheric deposition
    - Sweep after dust storms

Street Sweeping

Permeable Pavement Problems: Clogging

- Grass growth is a sign of Sediment Accumulation

- Don't pull large weeds – can pull up pavers and fill gravel
- Do control weeds when they are small – if killed when large, dead weed biomass can clog pavement
- Some permeable pavements are meant to be vegetated – be careful

Permeable Pavement Tasks and Schedule

TASK	SCHEDULE
Regular sweeping and vacuuming	Semi-annual to Quarterly
Gravel replacement	Post-Vacuuming
Oil and grease cleaning	As needed
Avoidance of landscape debris (grass clippings, leaves)	Each landscape maintenance
Spray Weeds and Moss with Herbicides	Monthly during growing season
Adjoining land and watershed stabilization	Keen observation

Know Your Watershed!

General Consideration for Most Practices

- Adjacent parcel erosion control (EC)
- Construction EC
- Internal and external flow velocities
- Pretreatment
- Inlets
- Media
- Outlets/underdrains

Facility Field Card

Siting and Suitability

The use of permeable pavement is encouraged for sites such as parking lots, driveways, pedestrian plazas, rights-of-way, and other lightly traveled areas. Numerous types and forms of permeable pavers exist and offer a range of utility, strength, and permeability. Permeable pavement must be designed to support the maximum anticipated traffic load but should not be used in highly trafficked areas. For designs that include infiltration, surrounding soils must allow for adequate infiltration. Precautions must be taken to protect soils from compaction during construction.

Aquifer Protection Zones and Karst: Permeable pavement can be used in sensitive geology if impermeable liners and a sand filter layer are used. In areas outside the Edwards Aquifer Recharge and Transition Zones, infiltration into native subsoils is encouraged.

Available Space: Permeable pavement is typically designed to treat storm water that falls on the pavement surface area and runon from other impervious surfaces. It is most commonly used at commercial, institutional, and residential locations in area that are traditionally impervious. Permeable pavement should not be used in high-traffic areas.

Underground Utilities: Complete a utilities inventory to ensure that site development will not interfere with or affect utilities.

Existing Buildings: Assess building effects on the site. Permeable pavement must be set away from building foundations at least 10 feet and 50 feet from steep slopes.

Water Table and Bedrock: Permeable pavement is applicable where depth from subgrade to seasonal high water table, bedrock, or other restrictive feature is 3 feet or greater.

Soil Type: Examine site compaction and soil characteristics. Minimize compaction during construction; do not place the bed bottom on compacted fill. Determine site-specific permeability; it is ideal to have well-drained soils.

Areas of Concern: Permeable pavement that includes infiltration in design is not recommended for sites with known soil contamination or *hot spots* such as gas stations. Impermeable membrane can be used to contain flow within areas of concern.

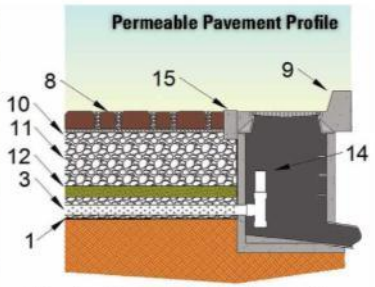
Design Considerations & Specifications *(see Appendix B for details)*

		Design Component	General Specification
BMP Function	1	Impermeable liner	If non-infiltrating (per geotechnical investigation), use clay liner, geomembrane liner, or concrete.
	2	Lateral hydraulic restriction barriers	May use concrete or geomembrane to restrict lateral seepage to adjacent subgrades, foundations, or utilities.
	3	Underdrain/ Infiltration	Underdrain required if subsoil infiltration < 0.5 in/hr. Schedule 40 PVC pipe with perforations (slots or holes) every 6 inches. 4-inch diameter lateral pipes should join a 6-inch collector pipe. If design is fully infiltrating, ensure that subgrade compaction is minimized.
	4	Observation Wells	Provide capped observation wells to monitor drawdown.
	5	Internal Water Storage (IWS)	If using underdrain in infiltrating systems, the underdrain outlet can be elevated to create a sump to enhance infiltration and treatment.
	6	Drawdown Time	If using fully-lined system, provide orifice at underdrain outlet sized to release water quality volume over 2–5 days.
	7	Subgrade Slope and Geotextile	Subgrade slope should be 0.5% or flatter. Baffles should be used to ensure water quality volume is retained. Geotextile should be used along perimeter of cut to prevent soil from entering the aggregate voids.
Profile	8	Surface Course	Pervious concrete, porous asphalt, and permeable interlocking concrete pavers (PICP) are the preferred types of permeable pavement because detailed industry standards and certified installers are available.
	9	Temporary Ponding Depth (in Edwards Aquifer Zones)	Surface ponding should be provided (by curb and gutter) to capture the design storm in the event that the permeable pavement surface clogs.
	10	Bedding Course (for PICP)	Use a 2-inch bedding course of ASTM No. 8 stone.
	11	Reservoir Layer	Base layer should be washed ASTM No. 57 stone (washed ASTM No. 2 may be used as a subbase layer for additional storage).
	12	Soil/Sand Filter Layer	With underdrains or when subsoils are not suitable for filtration (per geotechnical investigation): min. 4-inch layer of ASTM C-33 washed sand above gravel of underdrain drainage layer. No underdrains: min. 12-inch of native subsoil as subgrade.
	13	Structural Design	A pavement structural analysis should be completed by a qualified and licensed professional.
Routing	14	Large Storm Routing	For poured in place systems (pervious concrete or porous asphalt): system can overflow internally or on the surface. For modular/paver-type systems (PICP): internal bypass is required to prevent upflow and transport of bedding course.
Other	15	Edge Restraints and Dividers	Provide a concrete divider strip between any permeable and impermeable surfaces and around the perimeter of PICP installations.
	16	Signage	Signage should prohibit activities that cause premature clogging and indicate to pedestrians and maintenance staff that the surface is intended to be permeable.
	17	Multi-Use Benefits	Provide educational signage, enhanced pavement colors, or stormwater reuse systems.

Permeable Pavement Cross Section

Pervious concrete captures runoff from the Alamo Heights Fire Station. An impermeable concrete transition strip delineates the pervious concrete for maintenance personnel and functions as a hydraulic restriction barrier to protect adjacent pavement and infrastructure from lateral seepage.

Permeable Pavement Profile



This schematic represents a typical permeable pavement profile with internal water storage to enhance capture and infiltration of the design storm volume. An orifice can be provided at the invert of the underdrain to slowly dewater captured runoff in non-infiltrating systems.

Maintenance Considerations *(see Appendix F for detailed checklist)*

Task	Frequency	Indicator Maintenance is Needed	Maintenance Notes
Catchment inspection	Weekly or biweekly during routine property maintenance	Sediment accumulation on adjacent impervious surfaces or in voids/joints of permeable pavement	Stabilize any exposed soil and remove any accumulated sediment. Adjacent pervious areas may need to be graded to drain away from permeable pavement.
Miscellaneous upkeep	Weekly or biweekly during routine property maintenance	Trash, leaves, weeds, or other debris accumulated on permeable pavement surface	Immediately remove debris to prevent migration into permeable pavement voids. Identify source of debris and remedy problem to avoid future deposition.
Preventative vacuum/ regenerative air street sweeping	Twice a year in higher sediment areas	N/A	Pavement should be swept with a vacuum power or regenerative air street sweeper at least twice per year to maintain infiltration rates.
Replace fill materials	As needed	For paver systems, whenever void space between joints becomes apparent or after vacuum sweeping	Replace bedding fill material to keep fill level with the paver surface.
Restorative vacuum/ regenerative air street sweeping	As needed	Surface infiltration test indicates poor performance or water is ponding on pavement surface during rainfall	Pavement should be swept with a vacuum power or regenerative air street sweeper to restore infiltration rates.

BEXAR REGIONAL WATERSHED MANAGEMENT

Description

Permeable pavement allows for percolation of stormwater through subsurface aggregate and offers an alternative to conventional concrete and asphalt paving. Typically, stormwater that drains through the permeable surface is allowed to infiltrate underlying soils and excess runoff drains through perforated underdrain pipes.

Treatment Efficiency	
Runoff Volume	High (unlined)/Low (lined)
Sediment	High
Nutrients	Low
Pathogens	Medium
Metals	Medium
Oil & Grease	Medium
Organics	Low

Permeable Pavement

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SAN ANTONIO RIVER AUTHORITY
Leaders in Watershed Solutions

Maintenance Checklist

Inspection and Maintenance Checklist

BIORETENTION

Property Address _____

Property Owner _____

Treatment Measure No. _____ Inspection Date _____

Inspector(s) _____

Type of Inspection:

☐ Monthly ☐ Pre-wet season ☐ Post-wet season ____ ☐ After heavy runoff

☐ Other: _____

Defect	Conditions when maintenance is needed	Maintenance needed?	Comments[a]	Results expected when maintenance is performed
1. Standing water	Water stands in the bioretention area between storms and does not drain within 24 hours after rainfall.			There should be no areas of standing water once inflow has ceased. Any of the following could apply: sediment or trash blockages removed, grade from head to foot of bioretention area improved, media surface scarified, underdrains flushed.
2. Trash and debris	Trash and debris accumulated in the bioretention area and around the inlet and outlet.			Trash and debris removed from the bioretention area and disposed of properly.
3. Sediment	Evidence of accumulated sediment in the bioretention area.			Material removed so that there is no clogging or blockage. Material is disposed of properly.
4. Erosion	Channels have formed around inlets, there are areas of bare soil, or there is other evidence of erosion.			Obstructions and sediment removed so that water flows freely and disperses over a wide area. Obstructions and sediment are disposed of properly.
5. Vegetation	Vegetation is dead, diseased or overgrown.			Vegetation is healthy and attractive. Grass is maintained at least 3 inches in height.
6. Mulch	Mulch is missing or patchy. Areas of bare earth are exposed or mulch layer is less than 3 inches deep.			All bare earth is covered, except mulch is kept 6 inches away from trunks of trees and shrubs. Mulch is even at a depth of 3 inches.
7. Inlet/outlet	Sediment accumulations.			Inlet/outlet is clear of sediment and debris and allows water to flow freely.
8. Miscellaneous	Any condition not covered above that needs attention for the bioretention area to function as designed.			The design specifications are met.

Maintenance Timing

Photos courtesy Dr. William Hunt

Maintenance Timing

Maintenance Timing

Photos courtesy City of San Diego

Maintenance Timing

Task	Frequency	Maintenance notes
Pruning	1–2 times/year	Nutrients in runoff often cause bioretention vegetation to flourish.
Mowing	2–12 times/year	Frequency depends on location and desired aesthetic appeal.
Mulching	1–2 times/year	
Mulch removal	1 time/2–3 years	Mulch accumulation reduces available water storage volume. Removal of mulch also increases surface infiltration rate of fill soil.
Watering	1 time/2–3 days for first 1–2 months. Sporadically after establishment	If droughty, watering after the initial year might be required.
Fertilization	1 time initially	One-time spot fertilization for *first year* vegetation.
Remove and replace dead plants	1 time/year	Within the first year, 10 percent of plants can die. Survival rates increase with time.
Inlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for sediment accumulation to ensure that flow into the bioretention is as designed. Remove any accumulated sediment.
Outlet inspection	Once after first rain of the season, then monthly during the rainy season	Check for erosion at the outlet and remove any accumulated mulch or sediment.
Miscellaneous upkeep	12 times/year	Tasks include trash collection, plant health, spot weeding, removing invasive species, and removing mulch from the overflow device.

Maintenance Timing

Maintenance Timing

Maintenance Timing

Maintenance Costs

Best Management Practices and LID Whole Life Cost Models
www.werf.org/bmpcost
Water Environment Research Foundation and EPA developed a set of spreadsheet tools to estimate life cycle costs for stormwater management

BMP-REALCOST
www.udfcd.org/downloads/software/BMP-REALCOST_v1.0.zip
Spreadsheet-based tool, developed by the Urban Drainage and Flood Control District in Denver, Colorado, analyzes the life cycle costs of BMPs for planning purposes..

Maintenance Costs

Operation and maintenance activities	LID practice type						
	Bioretention	Permeable Pavement	Infiltration trench	Planter boxes	Vegetated (Green) Roof	Sand filter	Cisterns / rain barrels
Routine Maintenance (maintenance required monthly to every 2 years)							
Routine (small)	$6.35/ft^2	$1.62/ft^2	$3.13/ft^2	$4.73/ft^2	$3.95/ft^2	$3.42/ft^2	$2.85/ft^2
Routine (medium)	$2.04/ft^2	$0.60/ft^2	$1.21/ft^2	$1.44/ft^2	$1.13/ft^2	$1.19/ft^2	$0.92/ft^2
Routine (large)	$1.47/ft^2	$0.48/ft^2	$1.01/ft^2	$0.95/ft^2	$0.79/ft^2	$0.86/ft^2	$0.57/ft^2
Intermediate Maintenance (once or perhaps twice during the service life; every 6-10 years)							
Intermediate (small)	$8.02/ft^2	$3.23/ft^2	$4.52/ft^2	$6.40/ft^2		$4.81/ft^2	
Intermediate (medium)	$3.71/ft^2	$1.21/ft^2	$2.60/ft^2	$3.11/ft^2		$2.58/ft^2	
Intermediate (large)	$3.14/ft^2	$0.96/ft^2	$2.40/ft^2	$2.61/ft^2		$2.25/ft^2	
Replacement (end of service live; 20 years)							
Replacement (small)	$14.68/ft^2	$13.17/ft^2	$11.46/ft^2	$13.07/ft^2	$6.69/ft^2	$8.98/ft^2	0.6-2.25/gal
Replacement (medium)	$10.37/ft^2	$8.57/ft^2	$9.54/ft^2	$9.77/ft^2	$3.87/ft^2	$6.74/ft^2	0.6-2.25/gal
Replacement (large)	$9.80/ft^2	$2.02/ft^2	$9.34/ft^2	$9.28/ft^2	$3.53/ft^2	$6.42/ft^2	0.6-2.25/gal

Large LID BMP systems = 4000 ft^2

Medium LID BMP system = 2000 ft^2

Small LID BMP system = 500 ft^2

Questions??