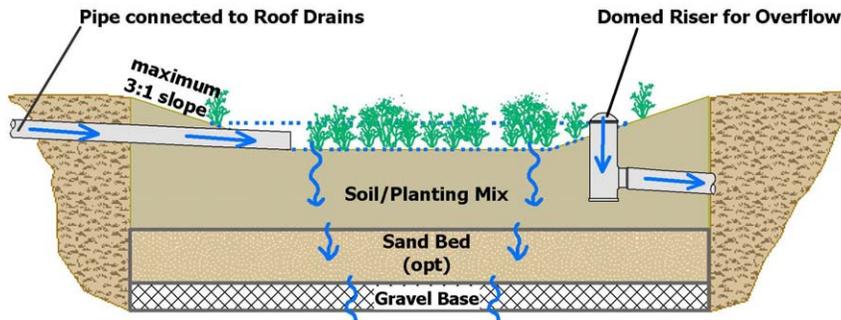


Structural BMP Criteria

BMP #: Recharge Garden/Rain Garden/Bioretention Garden



Geotextile fabric should line the bed.
Sand bed and/or gravel base are optional features based on existing soil conditions.

A Recharge Garden (also called a Rain Garden or a Bioretention Garden) is an excavated shallow surface depression planted with specially selected native vegetation to treat and capture runoff and typically underlain by a sand or gravel infiltration bed.

<p style="text-align: center;"><u>Key Design Elements</u></p> <ul style="list-style-type: none"> ● Infiltration volume sized for the 2-year storm or lesser volumes, with overflows ● Flexible in terms of size and infiltration ● Ponding depths restricted to 6 inches or less for rapid draw down ● Soil infiltration tests required ● Native hydrophytic vegetation that is tolerant of hydrologic variability and environmental stress ● Modify soil with compost ● Re-mulch every summer season 	<p style="text-align: center;"><u>Potential Applications</u></p> <p>Residential Subdivision: YES Commercial: YES Ultra Urban: YES Industrial: YES Retrofit: YES Highway/Road: YES</p> <hr/> <p style="text-align: center;"><u>Stormwater Functions</u></p> <p>Volume Reduction: Medium Recharge: High Peak Rate Control: Low/Med. Water Quality: Med./High</p> <hr/> <p style="text-align: center;"><u>Pollutant Removal</u></p> <p>Total Suspended Solids: x Nutrients: x Metals: x Pathogens: x</p>
---	---

Description

Bioretention is a method of treating stormwater by pooling water on the surface and allowing filtering and settling of suspended solids and sediment at the mulch layer, prior to entering the plant/soil/microbe complex media for infiltration and pollutant removal. Recharge gardens (also called Rain Gardens) utilize bioretention techniques to accomplish water quality improvement and water quantity reduction. Prince George's County, Maryland, and Alexandria, Virginia have used this BMP since 1992 with success in many urban and suburban settings.

Recharge Gardens can be integrated into a site with a high degree of flexibility and can balance nicely with other structural management systems, including porous asphalt parking lots, infiltration trenches, as well as non-structural stormwater BMP's described in Section 4.



Figure 1. Recharge Garden in State College, PA.

The Recharge Garden vegetation serves to filter (water quality) and transpire (water quantity) runoff, and the root systems can enhance infiltration. The plants take up pollutants; the soil medium filters out pollutants and allows storage and infiltration of stormwater runoff; and the infiltration bed provides additional volume control. Properly designed bioretention techniques mimic natural forest ecosystems through species diversity, density and distribution of vegetation, and the use of native species, resulting in a system that is resistant to insects, disease, pollution, and climatic stresses.

Bioretention with Recharge Gardens function to:

- Reduce runoff volume
- Filter pollutants, through both soil particles (which trap pollutants) and plant material (which take up pollutants)
- Recharge groundwater
- Reduce stormwater temperature impacts
- Enhanced aesthetics
- Provide habitat

Primary Components of a Recharge Garden/Bioretention System

The primary components (an subcomponents) of a recharge garden/bioretention system are:

Pretreatment (optional)

- Sheet flow through a **vegetated buffer strip** prior to entry into the Recharge Garden

Flow entrance

- Varies with site use (e.g., parking island versus residential lot applications)
- Water may enter via an **inlet** (e.g., flared end section)
- Sheet flow into the facility over grassed areas
- Curb cuts with grading for sheet flow entrance
- Roof leaders with direct surface connection
- Trench drain

Ponding area

- Provides temporary surface storage of runoff
- Provides evaporation for a portion of runoff
- Design depths allow sediment to settle
- Limited in depth to prevent mosquito/other problems

Plant material

- Evapotranspires stormwater
- Root development and rhizome community create pathways for infiltration
- Bacteria community resides within the root system creating healthy soil structure with water quality benefits
- Improves aesthetics for site
- Provides habitat for animals and insects
- Reinforces long-term performance of subsurface infiltration

Organic layer or mulch

- Acts as a filter for pollutants in runoff
- Protects underlying soil from drying and eroding
- Simulates leaf litter by providing environment for microorganisms to degrade organic material
- Provides a medium for biological growth, decomposition of organic material, adsorption and bonding of heavy metals

Planting soil and filter media

- Provides water/nutrients to plants
- Enhances biological activity and encourages root growth
- Provides storage of stormwater by the voids within the soil particles

Sand Bed / Gravel Base (Filter Fabric Wrapped)

- Sand Bed (optimal) and Gravel Base provide volume control
- Protect long-term infiltration performance of the BMP

Positive overflow

- Discharges runoff during large storm events when the sub-surface/surface storage capacity is exceeded.
- Examples include domed riser, inlet, weir structure, etc.

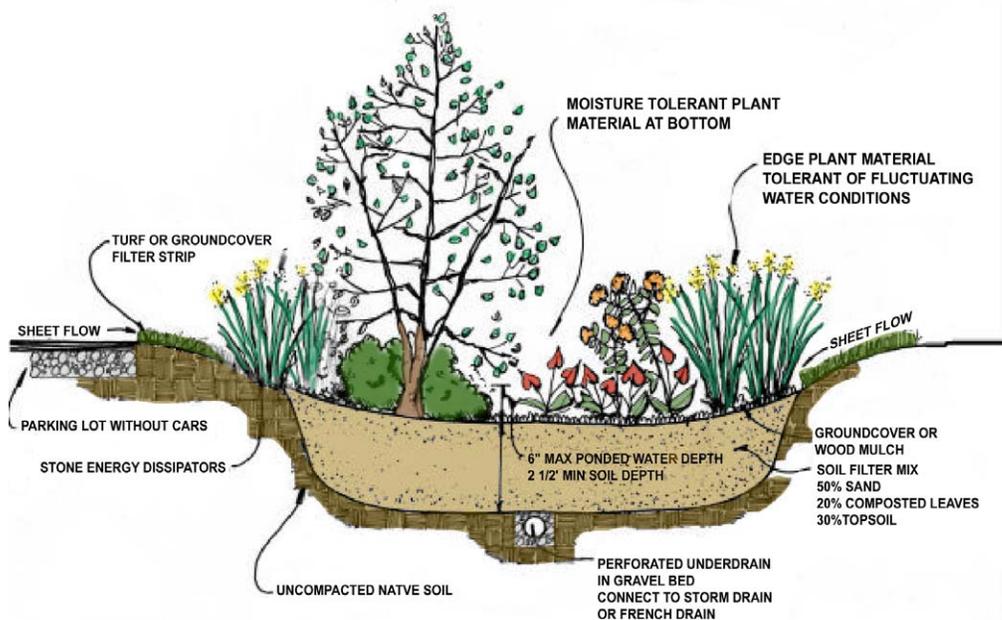


Figure 2. Components of a recharge garden (PGDER)

Variations

Generally, a Recharge Garden/Bioretention system is a vegetated surface depression that provides for the infiltration of relatively small volumes of stormwater runoff, often managing stormwater on a lot-by-lot basis (versus the total development site). If greater volumes of runoff need to be managed or stored, the system can be designed with an expanded subsurface infiltration bed or the Recharge Garden can be increased in size.

The design of a Recharge Garden can vary in complexity depending on the quantity of runoff volume to be managed, as well as the pollutant reduction objectives for the entire site. Variations exist both in the components of the systems, which are a function of the land use surrounding the Recharge Garden system. Recharge Gardens have been designed elsewhere without a Sand Bed or Gravel Base, making them a less desirable option (i.e., reduced volume control, reduced long-term infiltration performance).

Flow Entrance: Curbs and Curb Cuts



Figure 3. Curb cut inlet for a recharge garden in a parking island (PGDER, 2002)

Flow Entrance: Trench Drain



Figure 4. Trench drain inlet for recharge garden in parking lot (LIDC)

Filter Media: Subsurface Infiltration Bed (see BMP x for design information)

- Perforated pipe for distribution
- Geotextile liner
- Uniformly graded rock

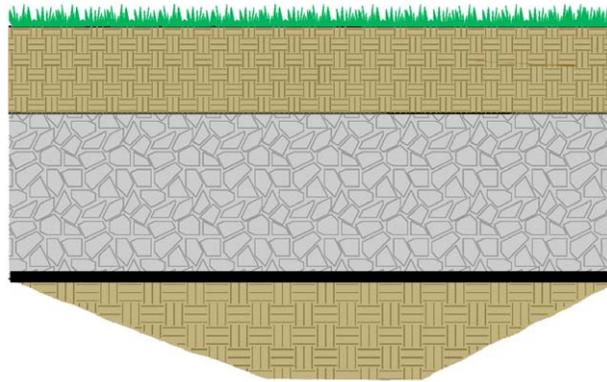


Figure 5. Subsurface Infiltration Bed

Positive Overflow: Domed Riser



Figure 6. Domed riser provides positive overflow during extreme storm events

Positive Overflow: Overflow weir

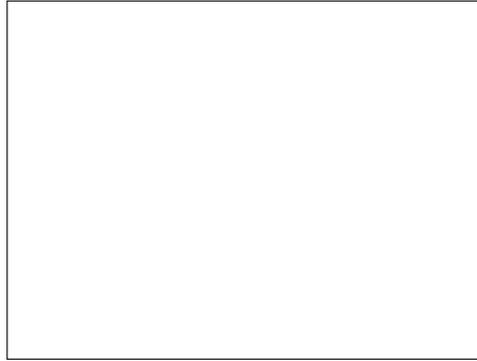


Figure 7. Overflow Weir

Positive Overflow: Inlet



Figure 8. The surface inlet shown in the lower left provides positive overflow during extreme storm events (LIDC)

Applications

Bioretention areas can be used in a variety of applications: from small areas in residential lawns to extensive systems in large parking lots (incorporated into parking islands and/or perimeter areas).

Residential On-lot

- **Landscaped Garden (PGC)**
 - Simple design that incorporates a planting bed in the low portion of the site



Figure 9. Example of residential on-lot rain garden (LIDC)

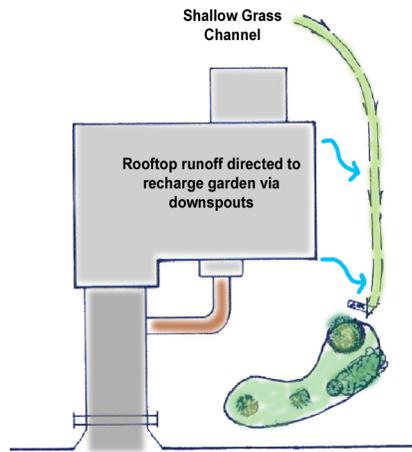


Figure 10. Recharge garden in residential application (Georgia Manual)

- **Tree and Shrub Pits**

- Stormwater management technique that intercepts runoff and provides shallow ponding in a dished mulched area around the tree or shrub.
- Extend the mulched area to the tree dripline

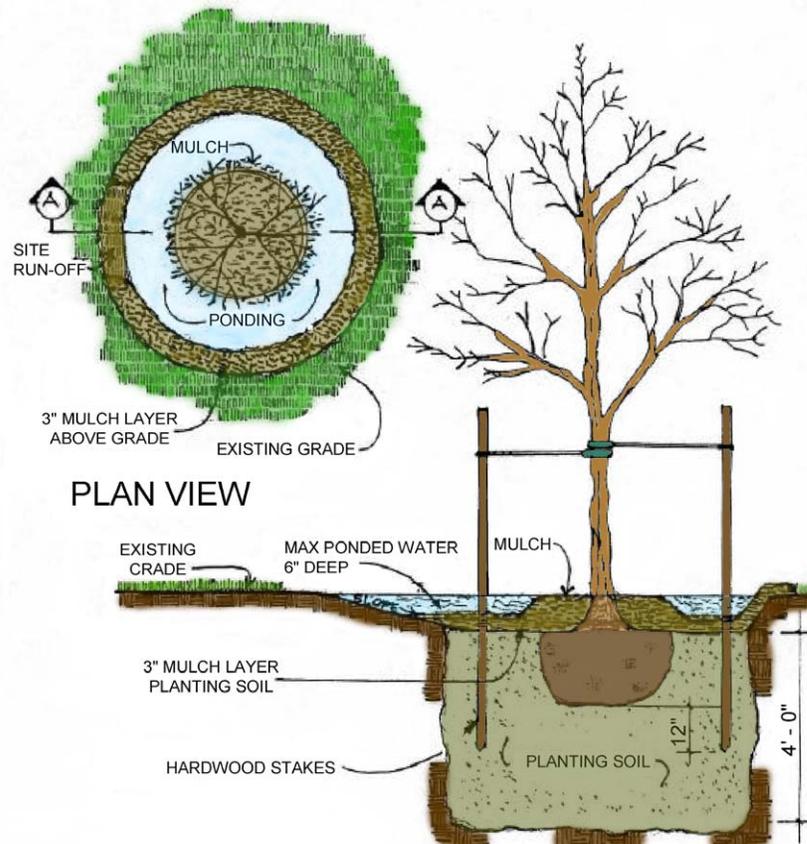


Figure 11. Tree Pit Bioretention (PGDER, 2002)

Roads and highways



Figure 12. Example of rain garden treating highway runoff (LIDC)

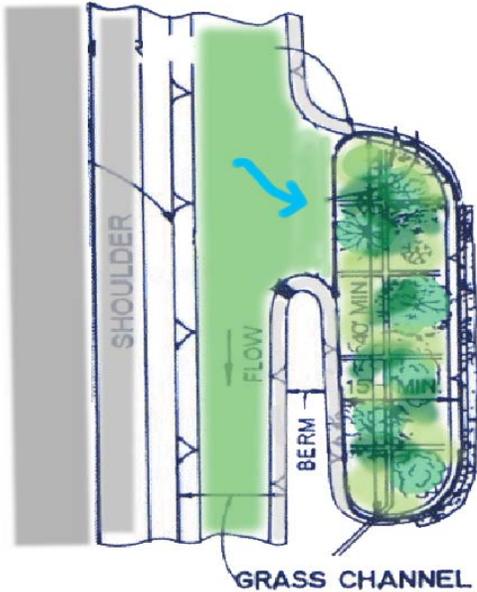


Figure 13. Schematic showing of highway drainage rain garden (modified figure, from Georgia Manual)

Parking Lots



Figure 14. Parking island rain garden (LIDC)

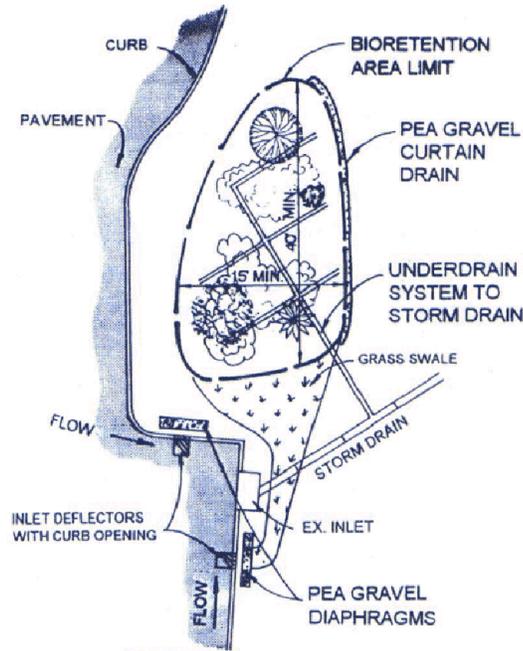


Figure 15. Schematic showing of parking lot rain garden (Georgia Manual TO BE EDITED)

Commercial/Industrial/Institutional

- In commercial, industrial, and institutional situations, stormwater management and greenspace areas are limited, and in these situations, Recharge Gardens for stormwater management and landscaping provide multi-functional options.
- **Curbless Parking Lot Perimeter Bioretention**
 - The Recharge Garden is located adjacent to a parking area with no curb, allowing stormwater to sheet flow over the parking lot directly into the Recharge Garden. Shallow grades must direct runoff at reasonable velocities; this design can be used in conjunction with depression storage for stormwater quantity control.

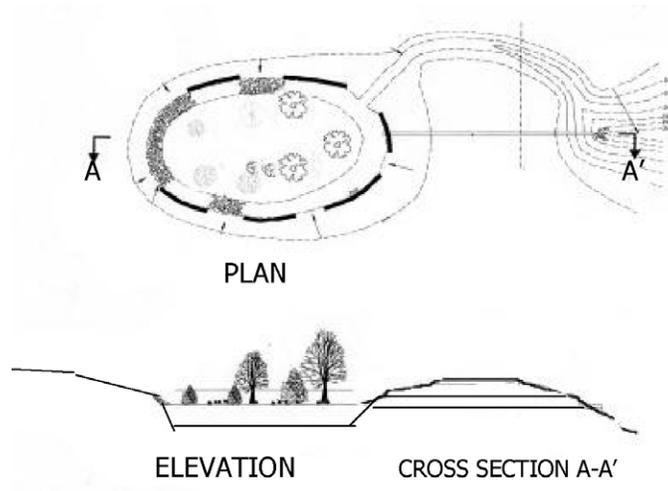


Figure 16. Curbless Bioretention Area (PGC, TO BE EDITED)

- **Curbed Parking Lot Perimeter Bioretention**



Figure 17. Curbed parking lot perimeter recharge garden (PGDER, 2002)

- **Parking Lot Island Bioretention**



Figure 18. Parking lot island with recharge bed (LIDC)

- **Roof leader connection from adjacent building**



Figure 19. Recharge garden along an office building in Alexandria, Virginia (LIDC)



Figure 20. Recharge garden that receives runoff from roof leaders in West Philadelphia, PA.

Design Considerations

Recharge Gardens are flexible in design and can vary in complexity according to water quality objectives and runoff volume requirements. Though Rain Gardens are a structural BMP, the initial siting of bioretention areas should respect the Comprehensive Stormwater Management Procedures described in Section 4 and integrated with the preventive non-structural BMP's to the maximum.

It is important to note that bioretention areas are not to be confused with constructed wetlands or other BMP's which pond water and store it to allow for infiltration and water quality benefits. Bioretention is best suited for areas with at least moderate permeability (more than $\frac{1}{4}$ inch per hour), and in extreme situations where permeability is less than $\frac{1}{4}$ inch per hour, special variants may apply, including underdrains, or even constructed wetlands.

Recharge Gardens are often very useful in retrofit projects and can be integrated into already developed lots and sites. An important concern for all Recharge Garden applications is their long-term protection and maintenance, especially if undertaken in multiple residential lots where individual homeowners provide maintenance. In such situations, it is important to provide some sort of management that insures their long-term functioning (deed restrictions, covenants, and so forth).

1. Sizing criteria

- a. **Surface area** is dependent upon storage volume requirements but should not exceed a maximum loading ratio of 5:1 (drainage area to infiltration area, where drainage area is assumed to be 100% impervious; to the extent that the drainage area is not 100% impervious, the loading ratio may be modified; see Site Guidelines for Infiltration Protocol for additional guidance or loading rates.)
- b. **Side slopes** should be gradual. For most areas, 3:1 side slopes are recommended, however where space is limited, 2:1 side slopes may be acceptable.
- c. **Surface Ponding depth** should not exceed 6 inches and should empty within 48 hours.
- d. **Ponding area** should provide sufficient surface area to meet required storage volume without exceeding the maximum surface ponding depth. The sub-surface storage/infiltration bed is used to supplement surface storage where feasible.
- e. **Planting soil depth** shall not be less than 24" where only herbaceous plant species will be utilized. If trees and woody shrubs will be used, soil media depth should be increased to a minimum of 48"-54", depending on plant species.

2. **Planting Soil** should be a loam, loam/sand mix, loamy sand or sandy loam capable of supporting a healthy vegetative cover. In-situ soils may be amended with a sand, organic material or a sand/organic mix. A typical sand/organic amended soil is combined with 20-30% organic material (compost), and 50% construction (coarse grained) sand. Planting soil should be approximately 4 inches deeper than the bottom of the largest root ball.

3. **Soils** should also have a pH of between 5.5 and 6.5 (better pollutant adsorption and microbial activity), a clay content less than 10% (a small amount of clay is beneficial to adsorb pollutants and retain water), be free of toxic substances and unwanted plant material.

4. Proper **plant selection** is essential for bioretention areas to be effective. Typically, native floodplain plant species are best suited to the extreme environmental conditions encountered in a

Recharge Garden. If shrubs and trees are included in a bioretention area (which is recommended), at least three species of shrub and tree should be planted at a rate of approximately 700 shrubs and 300 trees per acre (shrub to tree ratio should be 2:1 to 3:1). Plants should be placed at irregular intervals to replicate a natural forest. Appendix ___ provides recommended plant listings. Use local landscape architect to design native planting layout.

5. Planting periods will vary, but in general trees and shrubs should be planted from mid-March through the end of June, or mid-September through mid-November

6. A maximum of 2 to 3 inches of aged hardwood **mulch** or wood chips (or other comparable product) should be uniformly applied immediately after shrubs and trees are planted to prevent erosion, enhance metal removals, and simulate leaf litter in a natural forest system. Trees and shrubs should generally only be planted from early April through the end of June or from early September through late October. Mulch layer should not exceed 3" in depth so as not to restrict oxygen flow to roots.

7. Not recommended for areas with steep **slopes**

8. Underdrains should never be used except where in-situ soils fail to drain at a rate equal to or greater than 0.25" per hour.

Detailed Stormwater Functions

Infiltration Area:

The Infiltration Area is the bottom area of a Recharge Garden or the sub-surface infiltration bed Gravel Base, defined as:

Length of bed x Width of bed (or bottom area of irregularly shaped bed) = Infiltration Area (Bottom Area)

This is the area to be considered when evaluating the Loading Rate to the Recharge Garden.

Volume Reduction Calculations:

The storage volume of a Recharge Garden is defined as the sum total of the surface and subsurface void volumes beneath the level of the discharge invert. Inter-media void volumes may vary considerably based on design variations.

The Surface Storage Volume is defined as the volume of water stored on the Recharge Garden surface, below the discharge invert. This is equal to:

Surface Storage Volume = Average Recharge Garden Surface Area x Ponding Depth

where:

Average Recharge Garden Surface Area = (Bottom Area + Area at Discharge Invert) / 2

Ponding Depth = Depth to Discharge Invert (maximum 6 inches)

Subsurface Void Volume is defined as the volume of water stored within soil or aggregate media. The subsurface void volume is combined with the surface storage volume to provide additional storage capacity to meet volume/rate requirements. The void volume is equal to:

Subsurface Void Volume = (Surface Area of Soil/Planting Mix) x (Depth of Soil/Planting Mix) x (Void % of Soil/Planting Mix, as assumed or measured) + (Surface Area of Sand Bed, if included) x (Depth of Sand Bed) x (Void % of Sand Bed, as assumed or measured) + (Surface Area of Gravel Base) x (Depth of Gravel Base) x (Void % of Gravel Base)

Note: In most cases, the surface area for the Sand Bed will be equal to that for the Gravel Base. The surface area for the soil/planting mix may be slightly larger than these other areas if the side slopes, up to the discharge invert, are considered.

The void ratio is typically around 40% for recommended bed aggregate (AASHTO No 3) in the Gravel Base. If a conveyance pipe or perforated distribution pipe is proposed within the gravel base, the volume of the pipe may also be included, thereby increasing volume capacity of the system. Void percentages for both the Sand Bed (if included) and the soil/planting mix will vary by application. All Infiltration beds should be designed to infiltrate or empty within 48 hours.

Peak Rate Mitigation:

See Section z/z in Section 8 for Peak Rate Mitigation methodology which addresses link between volume reduction and peak rate control.

Water Quality Improvement:

See Section a/a in Section 8 for Water Quality Improvement methodology which addresses pollutant removal effectiveness of this BMP.

Construction Sequence

The following is a typical construction sequence; however, alterations will be necessary depending on design variations.

1. Install temporary sediment control BMP's as shown on the plans.
2. Complete site grading. If applicable, construct curb cuts or other inflow entrance but provide protection so that drainage is prohibited from entering construction area.
3. Stabilize grading within the limit of disturbance except within the Recharge Garden area. Recharge garden beds may be used as sediment traps provided that the proposed finish elevation of the bed is 1 foot lower than the bottom elevation of the sediment trap.
4. Excavate Recharge Garden to proposed invert depth and scarify the existing soil surfaces. Do not compact in-situ soils.
5. Install subsurface infiltration/storage bed, distribution pipes and stormwater structures, as specified.
6. Backfill Recharge Garden with planting soil as shown on plans and specifications. Overfilling is recommended to account for settlement. Light tamping is acceptable if necessary.
7. Presoak the planting soil prior to planting vegetation to aid in settlement.
8. Complete final grading to achieve proposed design elevations, leaving space for upper layer of compost, mulch or topsoil as specified on plans.

9. Plant vegetation according to planting plan.
10. Mulch and install erosion protect at surface flow entrances where necessary.



Figure 21. Newly constructed rain garden at Pennsylvania State University, State College, PA.

Maintenance Issues

Properly designed and installed Recharge Gardens require little maintenance.

- While vegetation is being established, pruning and weeding may be required.
- Detritus may also need to be removed approximately twice per year. Perennial grasses can also be cut down or mowed at the end of the growing season.
- Mulch should be replaced when erosion is evident. Once every 2 to 3 years the entire area may require mulch replacement (remove old mulch first).
- Recharge Gardens should be inspected annually for sediment buildup, erosion, vegetative conditions, etc.
- During periods of extended drought, Recharge Gardens may require watering approximately every 10 days.
- Recharge Gardens should not be mowed on a regular basis.
- Trees and shrubs should be inspected twice per year to evaluate health.

Cost Issues

Although Recharge Gardens are relatively expensive to construct, they often replace areas that would have been landscaped and maintenance-intensive so that the net cost can be considerably less than the actual construction cost. In addition, the use of Recharge Gardens can decrease the cost for stormwater conveyance systems at a site. Recharge Gardens cost approximately \$5 to \$7 per cubic foot of storage to construct.

Specifications

A. Quality Assurance

1. All materials, methods of construction and workmanship shall conform to applicable requirements of PennDOT Standard Specifications and AASHTO Standards, unless otherwise specified.

B. Execution

1. Owner and Engineer shall be notified at least 24 hours prior to all work.
2. Subgrade preparation
 - a. Existing sub-grade in Recharge Gardens shall NOT be compacted or subject to excessive construction equipment traffic.
 - b. Initial excavation can be performed during rough site grading but shall not be carried to within two feet of the final bottom elevation. Final excavation should not take place until all disturbed areas in the drainage area have been stabilized.
 - c. Where erosion of sub-grade has caused accumulation of fine materials and/or surface ponding in the graded bottom, this material shall be removed with light equipment and the underlying soils scarified to a minimum depth of 6 inches with a York rake or equivalent by light tractor.
 - d. Bring sub-grade of bioretention area to line, grade, and elevations indicated. Fill and lightly re-grade any areas damaged by erosion, ponding, or traffic compaction. All bioretention areas shall be level grade on the bottom.
 - e. Halt excavation and notify engineer immediately if evidence of sinkhole activity or pinnacles of carbonate bedrock are encountered in the bioretention area.
3. Recharge Garden Installation
 - a. Upon completion of sub-grade work, the Engineer shall be notified and shall inspect at his/her discretion before proceeding with bioretention installation.
 - b. For the sub-surface storage/infiltration bed installation, geotextile shall be placed on the bottom and sides of excavated area with a minimum overlap of 12 inches and shall extend at least 4 feet beyond the bed area to protect bed from sedimentation.
 - c. Clean, washed, uniformly graded aggregate (AASHTO #3, #57 or approved substitute with at least 40% void space) shall be placed in the bed as per design depth. After placement of stone, geotextile should be folded over the top of the stone bed to prevent migration of fines into the stone bed.
 - d. Planting soil shall be placed immediately after approval of sub-grade preparation/stone bed installation. Any accumulation of debris or sediment that takes place after approval of sub-grade shall be removed prior to installation of planting soil at no extra cost to the Owner.
 - e. Install planting soil (exceeding all criteria) in 18-inch maximum lifts and lightly compact (tamp with backhoe bucket). Keep equipment movement over planting

soil to a minimum – **do not over compact**. Install planting soil to grades indicated on the drawings.

- f. Plant trees and shrubs according to supplier's recommendations and only from early April through the end of June or from early September through late October.
- g. Install 2-3" shredded hardwood mulch (minimum age 6 months) or compost mulch evenly as shown on plans. Do not apply mulch in areas where ground cover is to be grass or where cover will be established by seeding.
- h. Protect Recharge Gardens from sediment at all times during construction. Hay bales, diversion berms and/or other appropriate measures shall be used at the toe of slopes that are adjacent to Recharge Gardens to prevent sediment from washing into these areas during site development.
- i. When the site is fully vegetated and the soil mantle stabilized the Engineer shall be notified and shall inspect the Recharge Garden drainage area at his/her discretion before the area is brought online and sediment control devices removed.
- j. Water vegetation at the end of each day for two weeks after planting is completed.

Contractor shall provide a one-year 80% care and replacement warranty for all planting beginning after installation and inspection of all plants.

References and Additional Sources