2E-4 Bioretention Cells

BENEFITS Low = <30% Medium = 30-65% High = 65-100%			
	Low	Med	High
Suspended Solids		■	
Nitrogen		■	
Phosphorous	■		
Metals		■	■
Bacteriological			■
Hydrocarbons		■	

Description: Bioretention systems incorporate shallow landscaped level depressions that temporarily store and readily infiltrate runoff. They include both rain gardens and bioretention cells. A rain garden relies solely on soils with good percolation rates. Rain garden design details are provided in the Iowa Rain Garden Design and Installation Manual. Bioretention cells typically include a rock chamber, subdrain, and modified soil mix. In bioretention cells stormwater runoff collected in the upper layer of the system is filtered through the surface vegetation, mulch layer, pervious soil layer, and then stored temporarily in a stone aggregate base layer. The WQv is drained from the aggregate base by infiltration into the underlying soils and/or to an outlet through a perforated pipe subdrain. Systems can operate either off-line or online. They are designed with a combination of plants that may include grasses, flowering perennials, shrubs, or trees. Integrated upstream treatment is provided by a perimeter grass filter strip or grass swale for initial capture of sediment.

Typical uses:

- Manages water quality runoff volume from residential, commercial, and institutional sites.
- Drainage area for each cell is typically 0.5-2 acres. Larger drainage areas should be divided into smaller sub-areas with individual bioretention cells distributed throughout the site.
- Suitable for landscaped depressional areas such as parking lot islands, road medians, and street rights-of-way.

Advantages/benefits:

- Reduce runoff rate and volume from impervious areas; provide opportunity for infiltration and filtration processes. Good for highly-impervious areas, such as parking lots.
- Removes fine sediments, heavy metals, nutrients, bacteria, and organics. Reduces thermal pollution from runoff across pavement surfaces.
- Flexible design options for varying site conditions; subdrain system allows use on sites with limiting soils. Good retrofit opportunities.
- Flexible landscaping options can provide an aesthetic feature.

Disadvantages/limitations:

- High entrance velocities and concentrated flows may need special design considerations.
- High sediment loads can cause premature failure; upstream practice is needed.
- High water table may require special design considerations.

Maintenance requirements:

- Routine landscape maintenance - removal of undesirable and dead vegetation.
- Replenish mulch layer.
- Removal of accumulated sediment in pretreatment areas.

A. Overview

1. Description

Bioretention cells are structural stormwater controls. They capture and temporarily store the water quality volume using soils and vegetation in shallow basins or landscaped areas to remove pollutants from stormwater runoff.

Bioretention cells use vegetation and engineered soils in a treatment area to accept runoff from impervious surfaces. Stormwater flows into the bioretention cell, temporarily ponds on the surface, and gradually infiltrates into the modified soil layer. Examples of bioretention cells are shown in **Figure 1**. Components of a bioretention cell are illustrated in **Figures 2 and 3**. Bioretention cells are intended to replicate the stable hydrologic functions of a native ecosystem. Bioretention functions as a soil and plant-based filtration system for stormwater runoff, and removes pollutants through a variety of physical, chemical, and biological processes in the upper engineered soil layer and the underlying native soils. The design can impact the processes and their function. Some of the major processes that occur through bioretention include: interception, infiltration, settling, evapo-transportation, filtration, absorption, thermal attenuation, and biological degradation/decomposition.

The filtered runoff can be allowed to either percolate into the underlying soils or be temporarily stored in the aggregate subdrain system and discharged at a controlled rate to the storm sewer system or a downstream open channel. Runoff can be controlled closer to where it is generated by the uniform distribution of bioretention cells to break up the area in manageable sub-watersheds. Higher flow events ($> Q_2$), and runoff volume that exceeds the infiltration capacity of these systems can be returned to the conveyance system or safely bypassed.

Plants in bioretention cells enhance infiltration and provide an evapotranspiration component. Native species provide resistance to moisture changes, insects, and disease and provide uptake of runoff water and pollutants. Deep-rooted native plants (grasses and forbs) are recommended to maintain high organic matter content in the soil matrix, provide high infiltration rates, and provide uptake of runoff water. The mulch layer and organic matter component of the soil matrix provide filtration and a place for beneficial microbial activity. Aerobic conditions are necessary to maintain microbial activity for processing pollutants.

There are many ways to incorporate bioretention cells into new construction projects or to retrofit existing urban areas. Bioretention can be used in residential yards, as interior or perimeter structures in parking lots, for rooftop drainage at residential and commercial building sites, along highways and roads, within larger landscaped pervious areas, and as landscaped islands in impervious or high-density environments.

A complementary upstream practice is provided to reduce the sediment loading to the bioretention cell. Bioretention cells are often built with grass filter strips around the bioretention area. These filter strips remove particulates and reduce runoff velocity. Filter strips also prevent crusting of pore spaces with fines and reduce maintenance. A freeboard storage area (temporary ponding) creates temporary storage for runoff prior to infiltration, evaporation, and uptake.

Each component of the bioretention cell is important. The engineered soil layer provides filtration and holds water and nutrients for the plants, enhances biological activity, encourages root growth, and provides storage of stormwater through the voids within the soil particles. The plant material evapo-transpires stormwater, creates pathways for percolation through the soil, improves soil structure, improves aesthetics, and reinforces long-term performance of subsurface percolation. Native plant material is recommended because of its deep root structure and ability to improve soil quality. The mulch layer acts as a filter for pollutants in runoff, protects underlying soil from drying and eroding, and provides an environment for microorganisms to degrade organic pollutants. It also provides a medium for biological growth, decomposition of organic material, and adsorption and bonding of heavy metals.

Mosquitoes are not a problem because bioretention cells do not retain standing water long enough for mosquito reproduction (4 to 10 days). Properly designed bioretention cells will infiltrate standing water within 4 to 12 hours.

Figure 1: Example bioretention applications.

(a) Cascading feature in two-stage bioretention cell at the Coralville Fire Station.

(b) The grassed pretreatment area provides a long flow path to this bioretention cell in Ankeny. Curb cuts were installed after the young plants became established.

(c) Newly planted bioretention area in Ames with native grasses.

(d) Terraced bioretention cells in Ames under construction.

2. Applications for Stormwater Management (Stormwater management suitability)

Bioretention cells are designed primarily for stormwater quality in the removal of pollutants. Bioretention can provide limited runoff quantity control, particularly for smaller storm events. These facilities may sometimes be used to partially or completely meet channel protection requirements on smaller sites. However, bioretention cells will typically need to be used in conjunction with another structural control to provide channel protection as well as overbank flood protection. It is important to ensure that a bioretention cell safely bypasses higher flows.

Figure 2: Bioretention cell schematic.

Bioretention cell schematic key

1. 3" Hardwood mulch
2. Curb cut
3. 18-30" Modified soil
4. Stone aggregate choker layer
5. Stone aggregate base layer
6. Subdrain
7. Undisturbed soil
8. Overflow/Cleanout
9. Plantings

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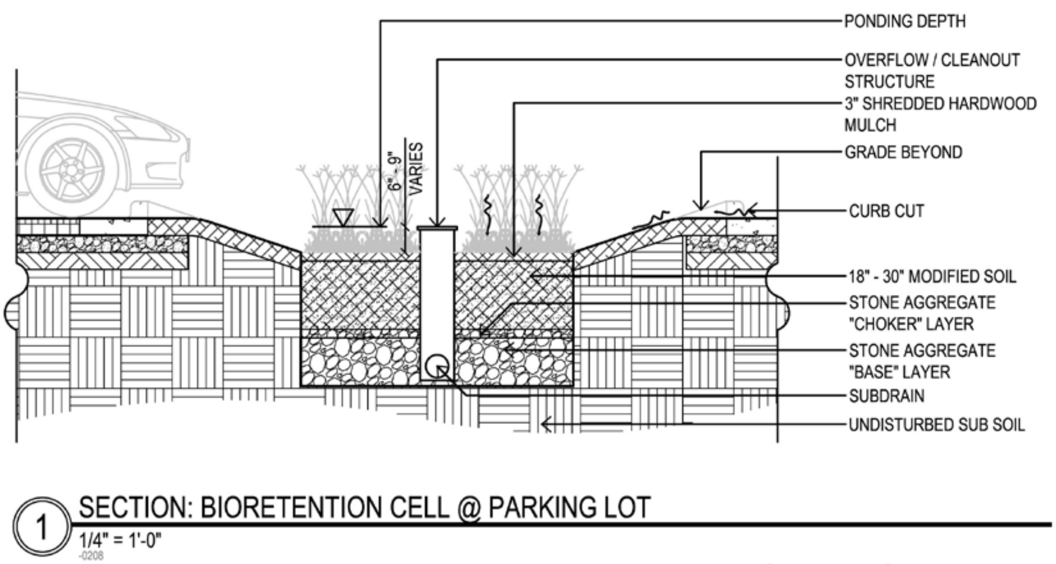
Figure 3: Cross section and plan views of a bioretention cell.



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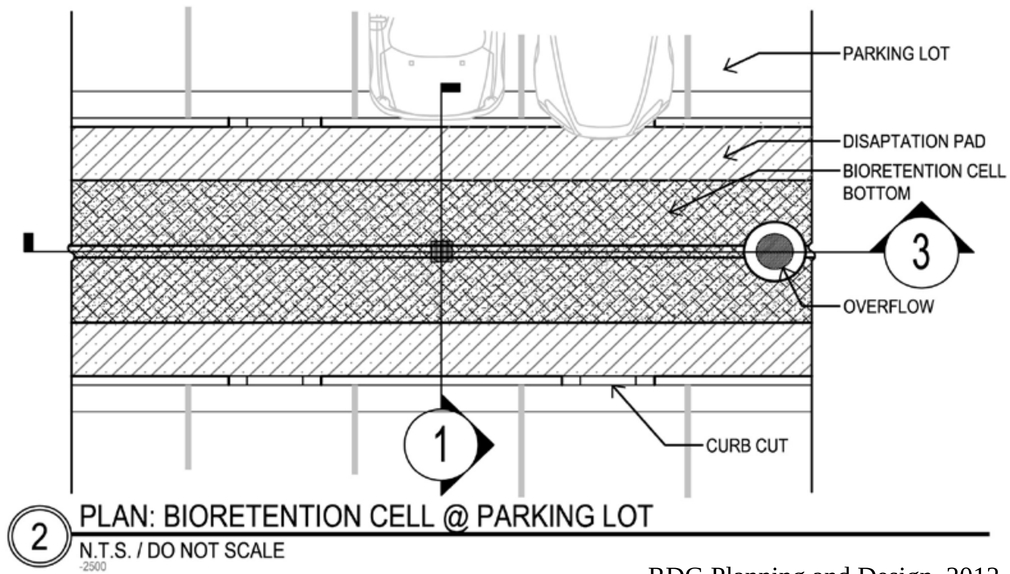

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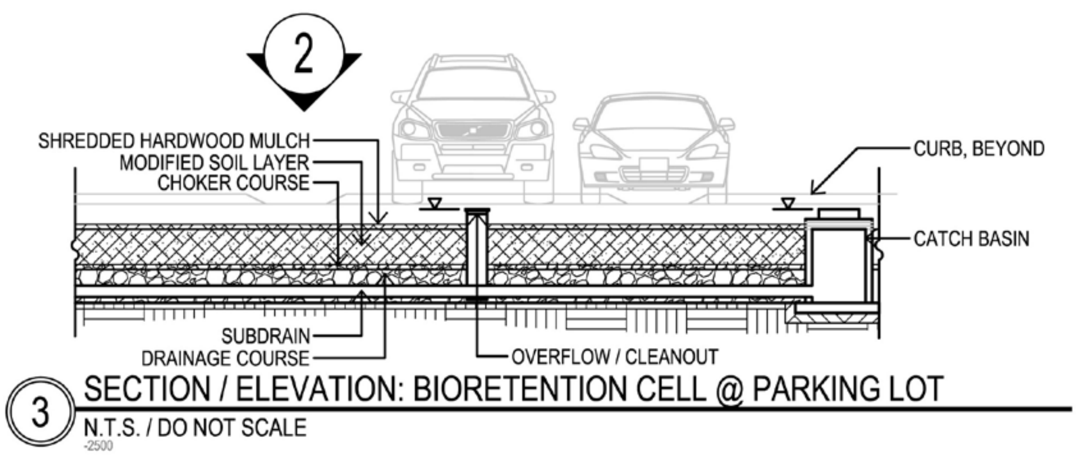

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a. **Water quality.** Bioretention is an excellent stormwater treatment practice due to the variety of pollutant removal mechanisms. Each of the components of the bioretention cell is designed to perform a specific function (**see Figure 3**).
   1) Pretreatment practices reduce incoming runoff velocity and filter particulates from the runoff.
   2) The ponding area provides for temporary storage of stormwater runoff prior to its evaporation, infiltration, or uptake and provides additional pollutant settling capacity.

3) The organic or mulch layer provides filtration, as well as an environment conducive to the growth of microorganisms that degrade hydrocarbons and organic material.
4) The modified soil in the bioretention cell acts as a filtration system, and clay organic matter in the soil provides adsorption sites for hydrocarbons, heavy metals, nutrients, and other pollutants.
5) Herbaceous and woody plants in the ponding area provide vegetative uptake of runoff and pollutants, and also serve to stabilize the surrounding soils, but will require maintenance such as trimming, pruning and selective removal of volunteer species.
6) Finally, an aggregate layer provides for positive drainage and aerobic conditions in the modified soil, and provides a final polishing treatment media.

b. **Channel protection.** For smaller sites, a bioretention cell may be designed to capture the entire channel protection volume in either an off-line or on-line configuration. The requirement of extended detention of the 1-year, 24-hour storm runoff volume can be achieved by increasing the footprint of the practice, or combining additional storage above the WQv ponding depth, with a slow release stage of an intake or other surface outlet structure. For off-line systems on larger sites, where only the WQv is diverted to the bioretention cell, another structural control must be used to provide CPv extended detention.
c. **Overbank flood protection*.** Typically, another structural control must be used in conjunction with a bioretention cell to reduce the post-development peak flow of storms greater than the 5-year storm (Qp) to pre-development levels (detention).
d. **Extreme flood protection*.** Bioretention cells must provide flow diversion and/or be designed to safely pass extreme storm flows and protect the ponding area, mulch layer, and vegetation.

* Refer to design procedures included in this section for more discussion on on- and off-line systems as well as detention or attenuation of larger storm events.

(See Section 2B-1 and Section 2C-6 for more details on the Unified Sizing Criteria and Small Storm Hydrology)

Pollutant removal capabilities

In landscaped and residential areas, the major pollutants of concern are fertilizers such as nitrogen and phosphorus. The following design pollutant removal rates are conservative average pollutant reduction percentages for design purposes, derived from sampling data, modeling, and professional judgment (**Table 1**). In a situation where a removal rate is not deemed sufficient, additional controls may be put in place at the given site in a series or treatment train approach. For additional information on monitoring BMP performance, see ASCE/EPA "Urban Stormwater BMP Performance Monitoring: A Guidance Manual for Meeting the National Stormwater BMP Database Requirements."

Table 1. Pollutant removal efficiency of bioretention cell.	
Parameter	**Removal Efficiency (%) Median values (N=10)**
Total suspended solids	59
Total phosphorous	5
Total nitrogen	46
Nitrogen NO2-NO3	43
Copper	81
Zinc	79

Source: CWP National Pollutant Performance Database, v3, Sept., 2007

More information on pollutant removal capabilities for bioretention BMPs can be found in the National Pollutant Removal Performance Database (www.cwp.org), the National Stormwater Best Management Practices Database (www.bmpdatabase.org), and the ASCE/EPA database.

The University of Maryland Engineering Department, completed an evaluation "Optimization of Bioretention," of the effectiveness of pollutant removal. The experiment yielded valuable data on pollutant removal efficiency rates and processes for bioretention. This manual incorporates those findings into the design criteria. **Table 2** summarizes the efficiency removal rates for various pollutants.

Table 2. Cumulative percent removal of pollutants by depth in bioretention cells.								
Laboratory/Field Summary (%)								
Depth	**Cu**	**Pb**	**Zn**	**P**	**TKN**	**NH_4**	**NO_3**	**TN**
1 ft	90	93	87	0	37	54	-97	-29
2 ft	93	99	98	73	60	86	-194	0
3 ft	93	99	99	81	68	79	23	43

Source: Davis, A.P. et al, University of Maryland, 1998

3. Application and feasibility

Bioretention is suitable for a wide variety of development options, including commercial, high-density urban, and single-family residential areas. They can be used for new construction and also to retrofit urban landscapes. Their capacity to be used as a landscaped feature allows them to fit into many types of urban design. Bioretention cells are ideally suited to many ultra-urban areas, such as landscaped parking lot islands and along streets and boulevards. Ultra-urban areas are densely-developed urban areas in which little pervious surface exists. While they consume a fairly large amount of space (approximately 5-10 percent of the impervious area that drains to them), they can fit into existing parking lot islands or other landscaped areas, when used as a stand alone practice. They can also treat runoff from intensively managed areas that have the potential for pollutants, such as golf courses. **Figure 3** includes an example site configuration.

The following criteria should be evaluated to ensure the suitability of a bioretention cell for meeting stormwater management objectives on a site or development. **Table 3** provides a list of considerations when planning for a bioretention cell.

a. General feasibility:

- Suitable for use in developed or developing areas, provided that heavy sediment loads are not expected in post-construction conditions (i.e. may not be suitable in watersheds with on-going site construction, routinely disturbed areas, agricultural lands without conservation practices, etc.). Suitable for use in brownfield projects and areas with pollutant hotspots. Special considerations are needed in areas with karst topography, loess soils, or high water tables.

- Bioretention practices should be located where they are accessible to be maintained and where maintenance is assured by a designated responsible party.

- Bioretention practices are not recommended to be used as a single large BMP (regional stormwater control). Flow velocities may be too high near the entrance to the practice and/or the required area for treatment would likely be too large to be expected to be constructed with a level bottom. Divide larger watersheds into multiple, smaller sub-areas for treatment or review other water quality BMPs that are better at managing larger drainage areas.

b. Physical feasibility – physical constraints at project site:

- Drainage area: 0.5 to 2 acres of impervious area are preferred. Larger areas of imperviousness can be broken into smaller catchments.
- Space required: Approximately 3-7% of the tributary <u>impervious</u> area is required
- Site slope: Special design considerations for sites with steep slopes
- Minimum head: Need sufficient elevation to allow subdrain system to daylight downstream, or connect to available storm sewer system.
- Minimum depth to water table: A separation distance of 2 feet is recommended between the bottom of the bioretention cell and the elevation of the seasonally high water table.
- Soils: No restrictions; engineered media required. Since modified soils and a subdrain system are included in bioretention cells, cells do not need to rely on the percolation rates of subsoil layers to function. However, locating cells in areas with higher percolation rates, allows opportunities to reduce the volume of surface runoff from a site and provide groundwater recharge.

Table 3. Planning criteria for bioretention cells.	
Site Conditions	The bottom of the aggregate layer should have 2 feet of vertical separation from expected high groundwater elevations or bedrock layers.
Source of Runoff	Bioretention cells can be placed close to the source of runoff generation.
Distributed Placement and Location	It is preferred to consider stormwater management during initial site design. Several, smaller bioretention cells can treat more manageable amounts of runoff closer to its source. Use site grading to divert runoff to smaller depressions in open spaces such as parking islands, landscaped areas, etc.
Site Integration	Stormwater management site integration is a preferred alternative to end-of-pipe BMP design, where feasible.
Location	Bioretention cell locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design. Elevations must be carefully worked out to ensure that the desired runoff flow enters the facility with no more than the maximum design depth.
Drainage Area	Potential bioretention cells should be applied where impervious surfaces within subdrainage areas to each cell are limited to less than 2 acres.
On-line or Off-line	Off-line systems employ some type of diversion structure which typically diverts the first flush of flow to the treatment practice, but allows flows from larger events to bypass the practice. This can prevent erosion within the practice and re-suspension of captured sediments. A cell is considered on-line if all runoff from the upstream area enters the practice.
Flow Diversion for Off-line cells	When used in an off-line configuration, the WQv (and perhaps CPv) is diverted to the bioretention area through the use of a flow splitter, diversion structure, and/or overflow outlet. Larger stormwater flows are diverted to other controls downstream (see Section 2F-1, part F [page 10]) for more discussion of off-line systems and design guidance for diversion structures and flow splitters).
Intermittent Flow	Bioretention cells are designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, heavy irrigation, sump pumps, or other sources.
Storm Events	Typically bioretention cells are used to manage small storm events (this may include events smaller than the Water Quality event (WQv) or the Channel Protection event (CPv – 1-year event). Refer to **Section 2C-6** for additional information about small storms. On-line systems may offer the possibility to attenuate or detain flows from larger storm events, with caution needs to prevent: • Erosive flow velocities near inlets/outlets • Deep ponding could compact soil layers • Extended drawdown periods that could affect desired plants

B. Design Methods

1. Initial Design Consideration and Preliminary Investigation

For new development sites, it is urged that consideration is given to how post-construction water quality will be addressed early in the design process. Bioretention practices are most effective when they are located in numerous, well distributed locations to be used for stormwater treatment as close as possible to the source of runoff. Distributed practices allow for the creation of a chain of smaller treatment practices, reducing the impact on downstream areas if a single practice should fail. Sites with fewer, larger practices are generally less effective at achieving pollutant and runoff reductions, as each practice has a larger amount of runoff to treat; and should practices fail, a greater proportion of runoff would be mismanaged. Redevelopment sites may have less flexibility, but smaller distributed practices are still preferable to a single, larger practice.

Before choosing to employ a bioretention practice, review the feasibility information included earlier in this section. If feasible, proceed with designing a bioretention practice, starting with a review of the initial design considerations listed in **Table 4**, as well as the preliminary investigation information in **Table 5**.

Table 4. Initial design considerations.	
Limiting Factors	Determine the depth to bedrock or typical groundwater elevation. Verify with geotechnical explorations or other methods.
Watershed Concerns	Check with local officials and other agencies to determine if there are any additional restrictions and/or surface water or watershed requirements that may apply.
Separation Distances	Ensure that room is available for installation including any setback and/or separation requirements. Recommended setbacks include: 25 feet from the foundation of a building; 5 feet from a property line; 50 feet from a private well; 20 feet from a geothermal well field; 100 feet from a municipal well.
Intermittent Flows	Bioretention cells are designed for intermittent flow and must be allowed to drain and re-aerate between rainfall events. They should not be used on sites with a continuous flow from groundwater, sump pumps, heavy irrigation or other sources.
Local Requirements	What are the local requirements for water quality and quantity control?
Character of Runoff Generator	What is the land use that will generate runoff directed to the cell? What is the expected watershed area, and how much of that is expected to be impervious?
Pollutants	What pollutants are expected to be present in runoff?
Multiple Practices	Will the bioretention cell be used independently of other BMPs, or will it be installed along with other practices? If part of a series of practices, what portion of the treatment required will be dedicated to each practice?
On-Line or Off-Line	Will the practice be an on-line or off-line configuration? (See Part 2D for more discussion of off-line systems and design guidance for diversion structures and flow splitters).
Quality Control	What design storm is required to meet stormwater water quality management criteria?
Quantity Control	For an on-line system is the cell being used for quantity control (or attenuation / detention) of a portion of larger storm events?
Aesthetics and Site Plans	Bioretention cell locations should be integrated into the site planning process, and aesthetic considerations should be taken into account in their siting and design.
Plant materials	Native species are recommended that are tolerant of expected moisture conditions, as their deep root structures can help preserve percolation rates. Consider salt tolerance where its use in ice removal is expected.
Maintenance	Review a typical maintenance plan, and determine the parties responsible for carrying it out. Consider access paths for equipment required for maintenance. See **Table 9** of this Section.

The following table includes the information required to complete the design procedure for a bioretention cell included within this section. Determine the values for each variable as accurately as possible. Assumed values may need to be used in preliminary design, then revised later as site design proceeds and more accurate values can be determined.

Table 5. Preliminary investigations.	
Properties of the Drainage Area Tributary to the Bioretention Cell	Determine the expected drainage area to be routed to the bioretention cell, and the projected amount of impervious surfaces. It is recommended that the **impervious** area to each cell not exceed 2 acres. Multiple cells can be designed to treat runoff from larger areas. Surface properties required to determine time of concentration will be needed for final design (refer to **Section 2A-4**).
Space Required	The required temporary ponding area will be approximately 3-7% of the tributary **impervious** area. Most of the ponding area must be level, so remember that additional space will be needed for slope grading to establish the overflow elevation and match surrounding grades.
Slope	Cells are easier to construct away from steep slopes, but special elements such as retaining walls can be included for sites with steep slopes. Care must be taken to not compact the soils within the bioretention area during installation of any structural feautures around the cell.
Minimum Head	Make sure that there is sufficient elevation difference to pond water as needed and drain the soil and aggregate layers through a subdrain and/or outlet works to a finished surface, swale or storm sewer system.
Water Table	A separation distance of 2 feet is recommended between the bottom of the bioretention cell and expected high groundwater levels..
Existing Site Soils	No restrictions when modified soils are used. However, soils with higher infiltration rates can be used to promote infiltration and groundwater recharge, reducing post-development surface runoff volumes.

2. Typical Components of a Bioretention Cell

Before proceeding with final design, it is important to understand the function and purpose of the elements that make up this type of practice. Table 6 provides a summary of a bioretention cell components and their function.

Table 6. Bioretention cell design components.	
Inlet structures	Storm water may be routed to a bioretention cells in many ways, such as sheet flow off hard surfaces, or as concentrated flow from curb openings, downspouts and pipe outlets. Inlet structures may also include features which divert only a portion of stormwater runoff to the cell (known as an off-line configuration). Level spreaders can be used to disperse concentrated flows to sheet flows reducing flow depths and velocities, enhancing pre-treatment possibilities.
Pre-treatment area	These areas are used to reduce velocities and capture heavier sediment and debris. They are needed to reduce the potential of clogging the porous soils desired in the bioretention cell. Features such as grass filter strips and swales can remove sediment and debris through filtration. Mechanical treatment systems, sediment traps, ditch checks can be used to pond water in areas where heavier sediment particles can settle out. If designed and functioning properly, all of these pretreatment practices will capture sediment and debris, so provisions for regular maintenance and removal of collected materials is required.
Temporary Ponding area	Provides for temporary surface storage of the runoff before it infiltrates into the soil bed. Typically limited to a depth of 6-9 inches. Additional freeboard depth can be provided for larger storm events in on-line systems. The ponding area is intended to drain dry within 4-12 hours after typical storm events, and should never have standing water longer than 24 hours after very rare events.
Organic mulch layer	The mulch layer should consist of 3 inches of fine shredded hardwood mulch.

	This layer protects the soil bed from erosion, retains moisture in the plant root zone, provides a medium for biological growth and decomposition of organic matter, provides some filtration of larger sediment particles and controls weeds.
Modified soil layer	The modified soil layer filters stormwater. Pollutants are removed through filtration, plant uptake, adsorption, and bacteriological decomposition. It also provides water and nutrients to support plant life in the bioretention cell.
Stone aggregate sub-base layer	The aggregate layer at the bottom of the structure provides additional temporary storage capacity for the captured runoff after filtration. The layer consists of an open-graded, clean, durable aggregate of 1-2 inches diameter with a porosity of 35-40%.
Subdrain	Perforated pipe underdrains are recommended. They provide the outlet for filtered water in areas with soils with poor percolation rates and act as a secondary outlet where soil percolation rates are better.
Outlet Structures	To avoid excessive ponding depths and drawdown times, outlet controls are needed to manage runoff from larger storm events. An overflow spillway set above the ponding depth can release flows in a non-erosive manner (velocities less than 3 feet per second). For on-line configurations, riser pipes, intakes, or weirs may be used to release runoff from larger storms more rapidly than it could infiltrate through the soil layers.
Hydrologic design	The primary goal of the practice is to capture and treat runoff from the WQv event. For off-line configurations, the majority of flows larger than those generated by the WQv will bypass the bioretention cell. For on-line configurations, where all runoff passes through the cell, some level of "detention" or temporary storage of larger flows may be possible, with caution to avoid excessive storage depths or drawdown periods which could compact the soil layers within the bioretention cell.

3. Bioretention Cell Sizing and Design Calculations

The following design procedure, assumes that the designer has completed preliminary investigations, and understands the design components of a bioretention cell, as outlined in Tables 5-7. It is recommended that these calculations be completed as early as possible in the design process, so that adequate room is reserved for stormwater management as site design development continues. Calculations can be adjusted as final site design is completed.

Step 1: Compute the required WQv treatment volume

Refer to Section 2C-6 for additional details on Small Storm Hydrology.

Use the following information:

(DA) = Drainage area to be treated, in **acres**
(I) = Impervious cover of drainage area, in **%**
(P) = WQ event rainfall depth, in **inches** (recommend using 1.25" for Iowa)

Step 1a: Compute (Rv) = 0.05 + 0.009(I)
i.e. 75% impervious => (I) = 75

Step 1b: Compute WQv = (Rv) x (P) x (DA) x 43,560 SF/ac x (1 ft/12in)
WQv is calculated in **cubic feet**

Step 2: Compute the peak runoff rates for other key rainfall events:

Refer to: Sections 2C-1 General Information for Stormwater Hydrology
Sections 2C-2 Rainfall and Runoff Analysis
Sections 2C-3 Time of Concentration
Sections 2C-5 NRCS TR-55 Methodology
Sections 2C-7 Runoff Hydrograph Determination

The peak rates of flow and volumes of runoff will need to be determined for the following events:

Use method outlined in Section 2C-6, part C [page 3], to compute the peak rate of flow (in **cubic feet per second**) and volume of storm water runoff (in **cubic feet**) for the Channel Protection Volume (CPv).

Use methods such as the NRCS TR-20, TR-55 (Section 2C-7) or other acceptable methods to generate hydrographs to determine peak rates of flow (in **cubic feet per second**) and runoff volumes (in **cubic feet**) for the following events:

Overbank Flood Protection Volume Requirements (Qp); Section 2B-1, part F [page 10]
2-year (50% annual recurrence or AR), 5-year (20% AR)
10-year (10% AR) – only if applicable to local storm sewer design

Extreme Flood Volume Requirements (Qf); Section 2B-1, part F [page 10]
10-year (10% AR) –if not applicable to local storm sewer design
25-year (4% AR), 50-year (2% AR), 100-year (1% AR)

Note: The annual recurrence (AR) is the likelihood of a certain rainfall event of a given depth and duration occurring once during any given calendar year.

Step 3: Identify if the bioretention system is intended to be an on-line or off-line system.

If planning for an on-line system, there is no need to design a flow diversion structure; proceed to ***Step 4***.

If planning for an off-line system; a diversion weir, flow splitter or other practice needs to be designed to route flows from the WQ event to the bioretention cell, while allowing most of the flows from larger events to bypass the system (via parallel storm sewer system or other conveyance). Refer to Section 2F-1, part F [page 10] for additional design information. Include calculation details for the diversion structure with this design procedure.

Step 4: Select, Locate, and Size Pretreatment Practice(s).

Forebays, grass filter strips, grass swales and mechanical separators are some of the options that can be used as pretreatment. Bioretention practices can fail if too much debris or sediment is allowed to enter the cell, reducing the ability of the modified soil layer to infiltrate stormwater. Pretreatment is needed to filter or capture larger sediment particles, trash and debris before it can enter the ponding area. Collected materials will need to be removed over time, so consider how the facility is expected to be maintained when evaluating methods of pretreatment.

For grass swales, refer to Section 2I-2, part E [page 4] for general sizing requirements. The target flow velocity for water quality treatment is 1 fps during the WQv event. Section 2I-2 includes methods on how to modify the value of "n" for Manning's equation to evaluate shallow flow in grass swales, beginning on page 10 of that section.

For filter strips, refer to Section 2I -4, part C.4 [page 7] for sizing requirements.

Forebays should have a storage volume of 0.1 inches per impervious acre drained (Section 2C-11). Sediment will need to be mechanically removed from the forebay over time, so a depth marker and durable, solid materials are recommended for the bottom (to be certain when excavation is complete). The volume of WQv to be used to size the ponding area of the bioretention cell can be reduced by the amount addressed in the pretreatment area(s) (typically no more than 10% of WQv).

Step 5: Review Entrance Designs

To reduce the potential for surface erosion or displacement of mulch and planting materials, it is recommended that flow velocities entering the ponding area should not exceed 3 feet per second (for all storm events reviewed). For on-line systems, the peak velocity of flow entering the cell during the largest Qf event (1% AR) should be checked. Redesign the cross-section of the entrance as needed. Provide stabilization at pipe outlets and areas of rapid expansion as necessary (USDOT FHA HEC-14 is a recommended resource for energy dissipater design).

Step 6: Select Desired WQ Event Ponding Depth

A WQv ponding depth of 6-9 inches (0.50-0.75 feet) should be planned over the level bottom of the bioretention cell. The bioretention cell will need an overflow spillway, or staged outlet structure (set above the WQv ponding depth) to avoid excessive ponding during larger storms. More detail is included in ***Step 11***.

Step 7: Design Cross-Sectional Elements

A 3 inch (0.25 feet) depth layer of fine shredded hardwood mulch is recommended to prevent erosion, retain moisture for plants and control weeds.

The modified soil layer should be 18-30 inches (1.5-2.5 feet) deep and consist of a uniform mixture of 80% concrete sand and 20% approved organic compost material that meets specifications.

The greater depths of modified soil (24-30 inches) are usually considered when trees or shrubs are planned within the bioretention cell or extended filtration time is required to remove certain types of pollutants are determined to be necessary. This would be determined by a known pollutant source or watershed based removal goal.

The stone aggregate layer is recommended to be at least 12 inches (1.0 feet) deep. Material should be 1-2” clean stone aggregate (0.08-0.16 foot typical diameter). The stone layer should have a porosity of 35-40%.

> The depth of the stone layer can be increased to provide for additional storage, or to enhance infiltration to subsoil layers. However, it is desired that the stone layer should drain out within 48 hours (2 days) after a storm event. Percolation rates of virgin subsoils or the capacity of the subdrain system may limit the depth of storage that can be provided below a subdrain outlet. For example, subsoils with percolation rates of 0.50 inch/hour (1.0 feet/day) may be able to drain down 24 inches (2.0 feet) of water stored in the aggregate layer below the subdrain over the 48 hour drawdown period.

Step 8: Calculate the Recommended Footprint of WQ Ponding Area

The footprint area for temporary ponding of the WQv can be determined by the following equation:

$$A_f = \frac{WQv \times df}{[k \times (hf + df) \times tf]}$$

Solve for (Af) = Required ponding area to treat WQv, in **<u>square feet</u>**

Variables:
(WQv) = Water Quality Volume, in **<u>cubic feet</u>** (from ***Step 1***)
(df) = filter bed layer depth, in **<u>feet</u>** (from ***Step 7***, includes mulch, soil and aggregate)
(hf) = average WQv ponding depth, in **<u>feet</u>** (value from ***Step 6***, <u>divided by 2</u>)
(tf) = desired time to drain modified soil layer, in **<u>days</u>** (recommend to use 1 day)
(k) = coefficient of permeability, in **<u>feet/day</u>**
If the modified soil mix described in ***Step 7*** is used, use a value of 2 feet/day

> After solving for the required ponded area, check to see if it falls in the range of 3-7% of the <u>impervious</u> area that drains to it.
> If existing soils have permeability rates of greater than 1 inch/hour (2 feet/day), and the cell can be constructed in a manner to prevent compaction of such soils, the modified soil layer may not be needed. In this case the permeability rate of site soils can be used for the value of (k). However, this is only usually the case for Hydrologic Group A soils and designers are cautioned to not over-estimate the permeability of existing soils.

Step 9: Design Surface Geometry of WQv Ponding Area

The bottom of the ponding area should be level, typically ranging from 10-30 feet in width. The cell should typically be at least 2x longer than it is wide, as measured along the direction of flow (longer flowpaths through the system increase filtration and percolation). Length to width ratios may not be applicable when runoff enters the cell along the side via sheet flow through a pre-treatment vegetative strip, or if multiple concentrated entry points are used to distribute flow entry across the cell. [For concentrated inflow points, refer back to step 4 and 5 to provide proper pretreatment at entry points and to reduce the potential of local erosion within the ponding area.] Non-uniform shapes fitted into the contours of the finished landscape may be more aesthetically pleasing, where possible.

> Minimum widths are established to ensure that side slopes don't encroach into the level bottom. Minimum widths do not need to apply near the extreme ends of the ponding area. Maximum widths are required to allow the cell to be constructed from the edges (no heavy equipment placed on excavated subsoils), and a true level bottom is maintained. Cells that are too large may be not be truly level, leading to low points where runoff collects, minimizing the real area dedicated to infiltration.
>
> If you can't reach the required ponding area (Af) from Step 8 using the dimensions above, it is recommended to use multiple bioretention cells or use other water quality BMPs to treat the remaining volume. Bioretention cells can be used in series or parallel.

Grades around the perimeter of the cell are recommended to be 6:1 or flatter; however slopes may be steeped to 3:1 where space is limited. Review the need for adequate sediment and erosion controls on steeper slopes to prevent side slope erosion into the modified soil layer (turf reinforcement mats, wattles or sod are examples of practices that could be employed for surface stabilization).

> After preparing a preliminary grading plan for the bioretention area, double check to make sure that the area ponded to the desired depth is greater than or equal to (Af).

Step 10: Subdrain System Design

For a bioretention cell, the subdrain system is needed to drain the aggregate layer over a 24 hour (1 day) period. The design flow rate can be determined from the following equation:

$$Q = (k) \times (Af) \times (1 \text{ day} / 24 \text{ hours}) \times (1 \text{ hour} / 3600 \text{ seconds})$$

Solve for (Q) = Average subdrain flow rate (in **cubic feet per second**)

Variables:
(Af) = Required ponding area to treat WQv, in **<u>square feet</u>** (from ***Step 8***)
(k) = coefficient of permeability, in **<u>feet/day</u>** (from ***Step 8***, based on modified soil **–** minimum k)

After solving for Q, use typical engineering methods to size pipe diameter.

> Subdrain materials should comply with requirements for Type 1 Subdrains under SUDAS 4040. A minimum size of 8" is recommended for cleaning and inspection.
>
> The length of pipe should be determined, so that the area within 1 foot either side of the subdrain is at least 10% of the required ponding area (Af). (i.e. A cell with a ponding area of 1,000 SF would need (1,000 SF) x 10% / (1 feet x 2) = 50 feet of subdrain.)

Subdrains should be installed at least 3 inches above the bottom of the aggregate layer. Note that the portion of the aggregate layer below the invert of the subdrain can only be drained through infiltration into the native soils below, refer to notes within ***Step 7***.

Step 11: Staged Outlet Design for On-line Systems

Off-line systems may not need a staged outlet structure, as flows to the bioretention cell are limited at the inlet of the system. Review the rest of this step, then proceed to ***Step 12*** if warranted.

On-line systems will receive flows from larger storms which will pond water to depths greater than those selected in ***Step 6***. Without other means of release, all water diverted to the bioretention cell would need to filter through the soil and aggregate layers. To prevent excessive ponding depths and long drawdown periods, a staged outlet is necessary to release larger storms more quickly.
Inlet structures, riser pipes, weirs or stabilized spillways are options for features that can be used as a second stage for controlled release of storm water runoff. It is recommended to set an opening for the second stage at or just above the desired maximum WQv ponding depth. Refer to Section 2C-12 on how to correctly size the selected type of control structure.

For on-line systems, it is recommended to complete a stage-storage model of the basin created above the bioretention cell with inflow hydrographs generated in ***Step 2*** to determine storage volumes, depths and release rates for all relevant storm events. To prevent compaction of the modified soil layer, excessive storage depths and drawdown times should be avoided. For the CPv, check that ponding depths above the soil layer do not exceed 24 inches (2 feet) and surface drawdown does not exceed 24 hours (1.0 days). For the Qp-Qf events, check that ponding depths above the soil layer do not exceed 48 inches (4 feet) and surface drawdown does not exceed 30 hours (1.25 day).

Step 12: System Outlet and Overland Spillway Design Considerations

Check peak flow velocities near pipe outlets and spillways expected to be overtopped during large storms. For all storm events reviewed, velocities at any pipe outlets should be less than 5 feet per second, and stabilization provided (refer to HEC-14). Overflow spillways should be designed with sufficient width to keep velocities less than 5 feet per second, and be properly stabilized or reinforced to withstand such velocities. Refer to Section 2C-12, part H [page 28] for additional information.

Calculation Example

Figure 4: Recreation Center, Marshould County, Iowa.

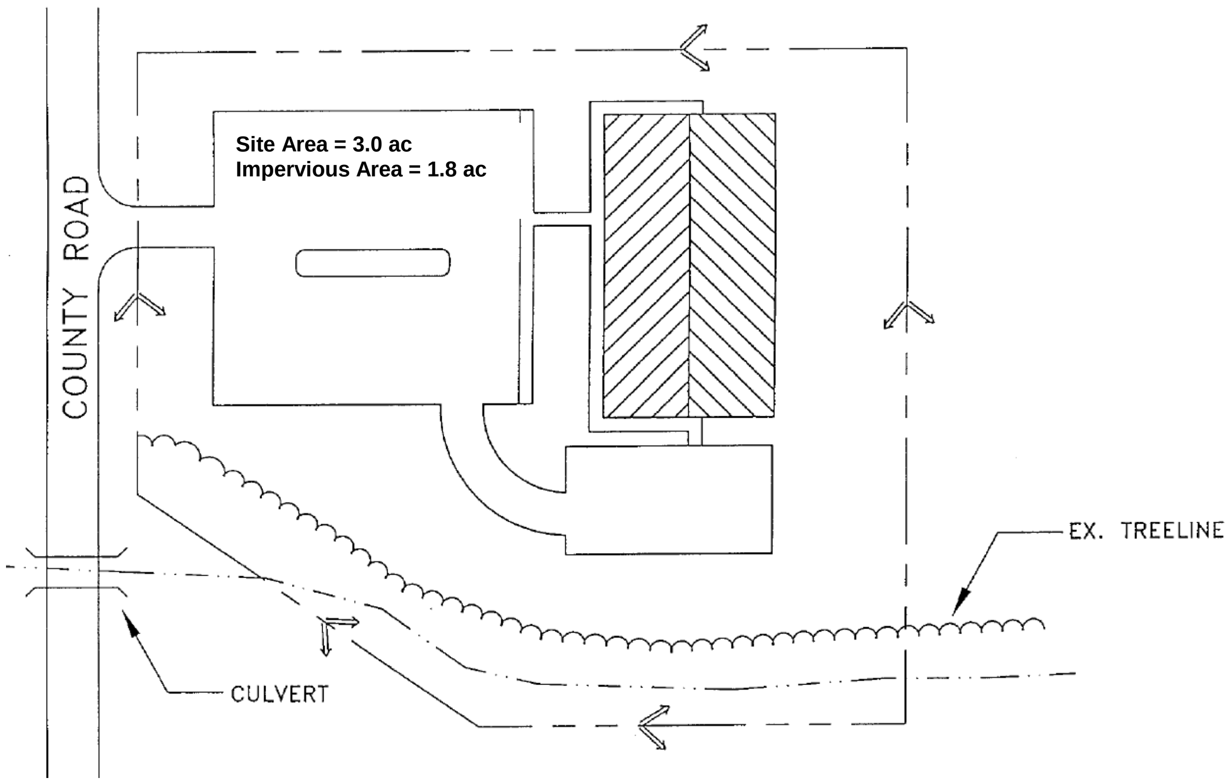

Table 7: Site data.

Base Site Data	Hydrologic Data		
Total site drainage area (A) = 3 ac		Pre-	Post-
Impervious area = 1.80 ac; I = 1.80 / 3.0 = 60%	CN	58	88
Soils: pre-developed HSG B (loam) developed use HSG C for compaction	t_c	25 min 0.42 hr	10 min 0.17 hr

Step 1: Compute the required WQv treatment volume

(DA) = 3 **acres**
(I) = 60 **%**
(P) = 1.25 **inches**

Step 1a: Compute (Rv) = 0.05 + 0.009(I)
= 0.05 + 0.009 (60) = 0.59

Step 1b: Compute WQv = (Rv) x (P) x (DA) x 43,560 SF/ac x (1 ft/12in)
= (0.59) x (1.25") x (3 ac.) x 43,560 SF/ac x (1'/12")
= 8,031 cubic feet

Step 2: Compute the peak runoff rates for other key rainfall events:

Use method outlined in Section 2C-6, part C [page 3], to compute the peak rate of flow (in **cubic feet per second**) and volume of storm water runoff (in **cubic feet**) for the Channel Protection Volume (CPv).

For this example, TR-55 software was used, with results as follows:

1-year, 24-hour storm; For Central Iowa = 2.91" rainfall depth
Type II rainfall distribution, shape factor 484 (default values)

Condition	CN	Tc **minutes**	Peak rate **cfs**	Volume **watershed inches**	Volume **cubic feet**
Pre-developed	58	25	0.06	0.10	1,100
Post-developed	88	10	5.5	1.3	14,400

Use methods such as the NRCS TR-20, TR-55 (Section 2C-7) or other acceptable methods to generate hydrographs to determine peak rates of flow (in **cubic feet per second**) and runoff volumes (in **cubic feet**) for the following events:

	Storm Event	Rainfall	Pre-developed		Post-developed	
		Depth **inches**	Peak Rate **cfs**	Volume **cubic feet**	Peak Rate **cfs**	Volume **cubic feet**
Qp	2-year	2.91	0.29	2,600	7.5	20,000
	5-year	3.64	0.96	5,500	10.2	27,000
	10-year	4.27	1.8	8,500	13	33,000
Qf	25-year	5.15	3.1	13,000	16	43,000
	50-year	5.87	4.5	18,000	19	51,000
	100-year	6.61	5.9	23,000	21	59,000

Step 3: Identify if the bioretention system is intended to be an on-line or off-line system.

This facility is planned to be an off-line system. To size the diversion structure, we need to calculate peak rates of flow (in **cubic feet per second**) and runoff volumes (in **cubic feet**) for the WQv event. For this example, we will complete TR-55 calculations, using adjusted curve numbers (CNs) for this small event. Refer to Section 2C-6 for additional information.

Storm Event	Curve Number	Rainfall	Post-developed	
	NRCS Adjusted	Depth **inches**	Peak Rate **cfs**	Volume **cubic feet**
WQv	94	1.25	3.1	8,035

Using an adjusted CN value, the volume of runoff from this calculation should be close to the value of WQv calculated in ***Step 1***. (8,031 CF ≈ 8,035 CF **OK**)

Assume for this example that runoff is directed from the site through a pipe to a manhole where the diversion weir will be placed. Refer to Section 2F-1, part F for additional design information.

Step 3a: Size outlet pipe to bioretention practice

To reduce the potential for erosion, it is recommended to have outlet velocities of less than 10 fps at the pipe outlet. Try a 10 inch outlet pipe (Area of pipe = 0.545 square feet).

Rearranged continuity equation: V = Q / A = 3.1 cfs / 0.545 SF = 5.7 fps < 10 fps **OK**

Step 3b: Set diversion weir elevation

Determine the head required to divert all flow from the WQv event toward the practice. Use the orifice equation: $Q = CA(2gh)^{0.5}$ where C = 0.60 and g = 32.2 ft/s^2

Rearranged: $h = (Q/CA)^2 / (2g)$
$h = [3.1 \text{ cfs} / (0.60 \times 0.545 \text{ SF})]^2 / (2 \times 32.2 \text{ ft/s}^2)$
$h = 1.40$ feet

The top elevation of the weir should be set 1.40 feet above the center of the 10 inch outlet pipe (or 1.82 feet above the flowline of the 10 inch outlet pipe).

Step 3c: Set diversion weir width

The width of the weir needs to fit within diversion structure, allowing most of the flows that exceed WQv to bypass the system. Best to check this using the largest storm that the pipe is expected to handle. In many cases, this may be a 5- to 10-year event. In this example, we will use the 10-year event, and assume that larger storms surcharge the storm system and flow overland on a path that will bypass the bioretention practice. If surcharge flows are directed toward the practice, then the system should be designed as an on-line system as a diversion structure will fail to route large storms around the practice.

Use the weir equation: $Q = CLh^{3/2}$ where C = 3.33
Assume L = 4 feet (weir is to fit within a standard manhole diameter)

Use Q = peak runoff from 10-year event from ***Step 2*** – WQv event peak flow
= 13 cfs – 3.1 cfs = 9.9 cfs

Rearranged: $h = (Q/CL)^{2/3}$
$h = [(9.9 \text{ cfs} / (3.33 \times 4 \text{ feet})]^{2/3}$
$h = 0.82$ feet

This is the expected high water level above the top of the weir crest, inside the 4 foot diameter manhole during a 10-year storm event.

Step 3d: Double check flow through the diversion pipe to the practice during the maximum storm event, to avoid overloading the practice.

It is best to double check the flow through the outlet pipe to the bioretention area, to calculate the maximum expected peak flow to the practice.

$Q = CA(2gh)^{0.5}$
$Q = 0.60 \times 0.545 \text{ SF} \times \{[2 \times 32.2 \text{ ft/s}^2 \times (0.82 \text{ feet} + 1.40 \text{ feet})]\}^{0.5}$
$Q = 3.90 \text{ cfs}$

During the 10-year event (4.27” in 24-hour, Central Iowa) flow to the practice only increases about 0.8 cfs (25%) over the WQv design flow, meaning at least 9.1 cfs would bypass the practice (70% of the peak flow). This appears to be acceptable.

Step 4: Select, Locate, and Size Pretreatment Practice(s).

Alternatives to evaluate for pre-treatment are:

For grass swales, refer to Section 2I-2, part E [page 4] for sizing requirements.
Using a site imperviousness of 60%, and a slope of less than 2%; a 45 foot long, 2 foot wide swale is needed to meet pre-treatment requirements.

If the 10 inch discharge pipe is connected to a level spreader to convert concentrated flow to sheet flow, a filter strip could be used. For filter strips, refer to Section 2I -4, part C.4 for sizing requirements. The chart uses a maximum inflow approach length for impervious areas of 75 feet. To have an equivalent impervious approach length maximum of 75 feet, the 1.8 acres (78,408 square feet) of impervious surfaces in this example needs to be spread over a width of 1,045 feet (= 78,408 SF / 75 feet). Providing this length does not seem feasible. A filter strip might be a better option with a level spreader in a smaller watershed area, or as an on-line system receiving sheet flow runoff from paved areas that are less than 75 feet in length.
A forebay with a storage volume of 0.1 inches per impervious acre drained is an option.

Storage required = (DA) x (I/100) x (0.1 inches) x (1 foot / 12 inches) x (43,560 SF / acre)
= (3 acres) x (60/100) x (0.1 in.) x (1 ft. / 12 in.) x (43,560 SF / acre)
= 653 CF (or 8% of WQv)

A 15 foot wide x 15 foot long x 3 foot deep wet forebay would meet this requirement (675 CF).

A combination of practices could also be considered to meet pre-treatment requirements, with each practice meeting a certain portion of the requirement. For this example, it is assumed that only the grass swale option will be chosen.

Assume a 4 foot wide swale is used (larger than required, but easier to construct) that is 45 feet long and has a longitudinal slope of 1.5% and side slopes of 4:1.

It is recommended to double check that the maximum flow velocity for water quality treatment of 1 fps is met during the WQv event. The methods described in Section 2I-2 (beginning on page 10) can be used modify Manning’s equation to evaluate shallow flow in grass swales.

An iterative procedure, spreadsheets or analysis software may be used.

For the channel section selected and an estimated depth of flow of 7 inches (0.583 feet):

Manning's coefficient (n) = 0.105 Area = 3.67 SF Wetted Perimeter = 8.78 feet
Velocity = 0.97 fps (< 1.0 fps) **OK** Q = 3.5 cfs (> WQv = 3.1 cfs) **OK**

If WQv velocity > 1.0 fps, try widening the swale, or decrease the longitudinal slope.

Step 5: Review Entrance Designs

For larger events, solve the Manning's equation at the end of the pre-treatment swale selected in ***Step 4***. Again, an iterative procedure, spreadsheets or analysis software may be used.

For the channel section selected in ***Step 4***, and at a depth of flow of 7.5 inches (0.625 feet):

Manning's coefficient (n) = 0.098 Area = 4.06 SF Wetted Perimeter = 9.15 feet
Velocity = 1.08 fps (< 3.0 fps) **OK** Q = 4.4 cfs (> WQv = 3.9 cfs) **OK**

Step 6: Select Desired WQ Event Ponding Depth

A WQv ponding depth of 6 inches (0.50 feet) has been selected for this example.

Step 7: Design Cross-Sectional Elements

Use the following:

- A 3 inch (0.25 feet) depth layer of <u>fine</u> shredded hardwood mulch.
- A modified soil layer should of 18 inches (1.5 feet) deep.
- A stone aggregate layer is recommended of 12 inches (1.0 feet) deep.
- Total depth = 0.25 + 1.50 + 1.00 = 2.75 feet

Step 8: Calculate the Recommended Footprint of WQ Ponding Area

The footprint area for temporary ponding of the WQv can be determined by the following equation:

$$A_f = \frac{WQv \times df}{[k \times (hf + df) \times tf]}$$

Solve for (Af) = Required ponding area to treat WQv, in **<u>square feet</u>**

Variables:
(WQv) = 8,031 **<u>cubic feet</u>** (from ***Step 1***) **!** Option to reduce this value by pre-treatment volume.
(df) = 2.75 **<u>feet</u>** (from ***Step 7***)
(hf) = 0.50 feet / 2 = 0.25 **<u>feet</u>** (value from ***Step 6***, <u>divided by 2</u>)
(tf) = 1 **<u>day</u>** (recommended drain time of soil layer for WQv event)
(k) = 2 **<u>feet/day</u>** (used recommended modified soil mix)

Af =	[8,031 CF x 2.75 feet]	/	[2 feet/day x (0.25 feet + 2.75 feet) x 1 day]
Af =	22,085 CF x feet	/	6.00 square feet
Af =	3,681 square feet (4.7% of impervious area)		

Recommend to round up to 3,700 square feet

Step 9: Design Surface Geometry of WQv Ponding Area

The bottom of the ponding area should be level, typically ranging from 10-30 feet in width. The cell should typically be at least 2x longer than it is wide, as measured along the direction of flow (longer flowpaths through the system increase filtration and percolation).

Start with a cell twice as long as wide => L = 2 x W
W x L = 3,700 SF
W x 2 x W = 3,700 SF
W^2 = 1850 SF
W = 43.0 feet

Preliminary rough dimensions: Width = 43 feet, Length = 86 feet.
Check minimum and maximum widths, maybe adjust to: Width = 25 feet, Length = 148 feet.

Step 10: Subdrain System Design

For a bioretention cell, the subdrain system is needed to drain the aggregate layer over a 24 hour (1 day) period. The design flow rate can be determined from the following equation:

Q (**in cfs**) = (k) x (Af) x (1 day / 24 hours) x (1 hour / 3600 seconds)

Variables:
(Af) = 3,700 **square feet** (from Step 8)
(k) = 2 **feet/day** (from Step 8, based on modified soil – minimum k)

Q = (2 feet/day) x (3,700 SF) x (1 day / 24 hour) x (1 hour / 3600 sec)
Q = 0.09 cfs

The minimum recommended diameter of 8” will have sufficient capacity.

The length of pipe should be determined, so that the area within 1 foot either side of the subdrain is at least 10% of the required ponding area (Af).

Length of subdrain = Af x 10% / (1 feet x 2)
3,700 SF x 10% / (1 feet x 2) = 185.0 feet

Use at least 185 feet of 8” subdrain, set 3 inches above the bottom of the aggregate layer. Either the cell dimensions will need to be changed to be at least 185 feet long (i.e. 20’ x 185’ = 3,700 CF) and a single run of subdrain used, or parallel / perpendicular runs of subdrain will be needed to get to 185 feet of subdrain length (i.e. two parallel runs of 93 feet each). The upstream end of each subdrain should have a cleanout, extended to the surface for maintenance.

For this example, adjust ponding area size to 20 feet wide x 185 feet long, with a single 185 foot long subdrain and cleanout.

Step 11: Staged Outlet Design for On-line Systems

This calculation is an example of an off-line system. A staged outlet structure would not be needed in this case. However, an overflow spillway should be provided to prevent ponding deeper than the desired ponding depths. Referring to Section 2C-12, design an earthen spillway to crest 9 inches (0.75 feet) above the level surface of the mulch layer. The spillway should have a minimum bottom width of 10 feet, a section depth of 2 feet, side slopes of 3:1 or flatter and longitudinal slopes ranging from 1-10%. Steeper slopes may require additional stabilization measures.

Step 12: System Outlet and Overland Spillway Design Considerations

This example is an off-line system, with the subdrain discharging to a storm sewer system. If the subdrain did daylight, flows of 0.09 cfs would likely require minimal erosion protection.

For an on-line system, check exit velocities at pipe outlets and overflow spillways.

Figure 5: Site plan for the bioretention cell.

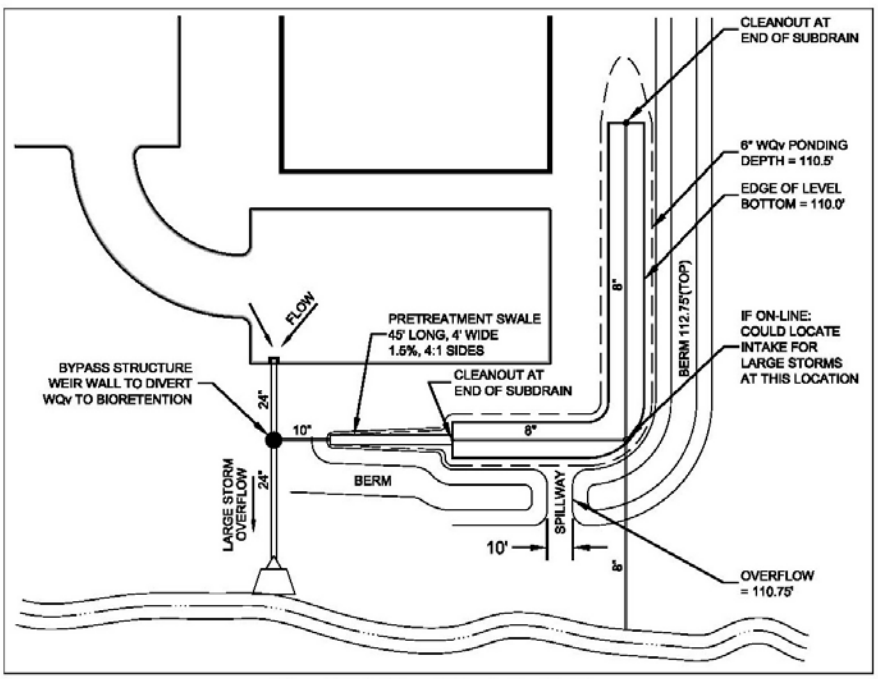

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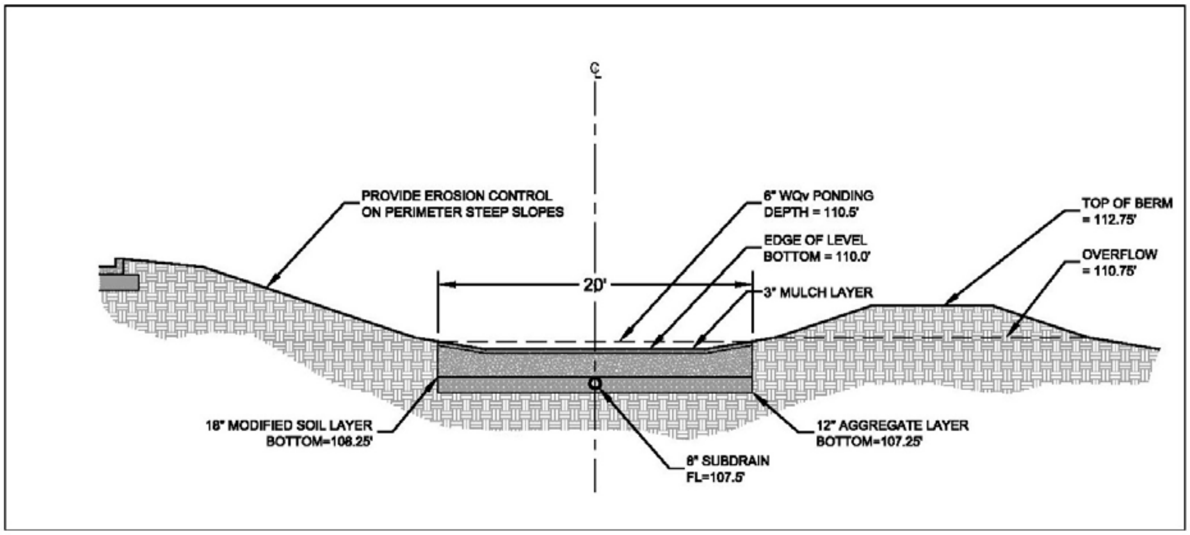
Figure 6: Section view of bioretention cell



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C. Construction

1. Preconstruction Meeting

Design and installation staff shall meet prior to any on-site construction to discuss the placement of all permanent stormwater management practices. This discussion should focus on minimizing soil compaction, identifying areas where infiltration practices will be placed, staging of construction to ensure site stabilization prior to the installation of bioretention cells and a discussion of the design details associated with the installation of the bioretention cell.

2. Staging

The construction project shall be staged so that the bioretention cell is installed during the final construction stage. Prior to bioretention cell installation, all soils within the area that will drain to the bioretention cell must be stabilized with permanent vegetation and/or other erosion, sediment and velocity controls. If the bioretention facility is to be used as a sediment basin prior to use as a bioretention facility, it shall be excavated to the dimensions, side slopes, and 1 foot above the bottom of the modified soil layer elevations shown on the drawings.

3. Construction Considerations

a. Staking.

The bioretention cell area shall be staked prior to any site construction to minimize traffic and compaction. This would not apply to situations where a sediment basin is converted to a bioretention cell.

b. Construction Site Stabilization

Bioretention cells shall not be constructed until all contributing drainage areas are permanently stabilized against erosion and sedimentation.

c. Weather

Construction of the bioretention cell shall not begin or be conducted during rainy weather resulting in saturated soil conditions.

d. Excavation

Any sediment from construction activities deposited in the bioretention cell shall be completely removed from the practice after all vegetation, including landscaping within the drainage area of the bioretention cell has been established.

The excavation limits shall be final graded to the dimensions, side slopes, and final elevations shown on the drawings.

Excavators and backhoes, operating on the ground adjacent to the bioretention cell, shall be used to excavate the cell area to the greatest extent possible. Otherwise, excavation shall be performed using low ground-contact pressure equipment.

Any discharge of sediment that affects the performance of the bioretention cell will require reconstruction of the bioretention cell as originally specified to restore its defined performance.

e. Compaction Avoidance and Remediation

No heavy equipment shall be used within the perimeter of the bioretention cell before, during, or after placement of the modified soil layer.

After placement of the under drain system and before the modified soil layer is placed, the bottom of the excavation shall be roto-tilled to a minimum depth of 6 inches to alleviate compaction. Should the soils be severely compacted, ripping or deep tillage equipment may be needed to break up the compacted layers prior to roto-tilling.

f. Placement of Modified Soil Layer

Any ponded water shall be removed from the bottom of the excavation and discharged to a vegetated area but not discharged directly to a storm sewer.

The modified soil layer shall be placed and graded using low ground-contact pressure equipment, or by excavators and/or backhoes operating on the ground adjacent to the bioretention facility. No heavy equipment shall be used within the perimeter of the bioretention facility before, during, or after placement the placement of this layer.

The modified soil layer shall be placed in horizontal layers not to exceed 12 inches for the entire area of the bioretention cell. It shall be saturated over the entire area of the cell after each lift of the modified soil layer is placed, until water flows from the underdrain, to lightly consolidate the mixture. Water for saturation shall be applied by spraying or sprinkling in a manner to avoid separation of the BSM components. An appropriate sediment control device shall be used to treat any sediment-laden water discharged from the underdrain during this process.

If the modified soil layer becomes contaminated with sediment or other deleterious material during, or after, construction of the cell, the contaminated material shall be removed and replaced with uncontaminated material.

Final grading of the modified soil layer shall be performed after a 24-hour settlement period. Upon completion of final grading, the surface of this layer shall be roto-tilled to a depth of 6 inches.

g. Planting, Mulch, Netting

Mulch should first be spread in cells prior to planting. When using wood mulch select fibrous, hardwood mulch. Netting may be needed to be placed on top of the surface of the mulch to minimize floating of the mulch.

Plants may require watering over several months to aid establishment, especially during drought periods.

Do not use pesticides, herbicides, or fertilizer during landscape construction, plant establishment, or maintenance.

When small plants are used delay curb cuts or place diversions in front of the cuts until plants are established.

4. Plant Selection and Arrangement

Refer to the following guidance.

5. Maintenance

Bioretention cells require seasonal maintenance. It is imperative that they be maintained to function properly and provide continuous visual aesthetics.

Table 8. Bioretention cell maintenance requirements.	
Activity	**Schedule**
• Prune and thin out plants when needed. Remove weeds throughout the growing season, preferably by pulling or trimming. Replace plants when needed. • Replace mulch when erosion is evident and/or weed growth is excessive. • Remove trash and debris from pretreatment area and bioretention cell.	Fall, spring, as needed
• Inspect inflow points for clogging (off-line systems). Remove any sediment. • Inspect filter strip/grass channel for erosion or gullying. Re-seed or sod as necessary. • Trees and shrubs should be inspected to evaluate their health and remove any dead or severely diseased vegetation.	Semi-annually
• Look for evidence of standing water in the observation port. This may be a sign of hydraulic failure.	Annually
• Replace pea gravel diaphragm when necessary • Replace modified soil layer when ponding greatly exceeds the design drainage time.	As necessary

Acknowledgements:

- Detailed technical review provided by Greg Pierce, Nilles Associates.
- Figures provided by RDG Planning and Design and Nilles Associates.
- Update provided by the ISWMM Technical Committee:
  Doug Adamson, Darice Baxter, Jolee Belzung, Jeff Berckes, Brian Boelk, Amy Bouska, Steve Jones, Rebecca Kauten, Mark Masteller, Wayne Petersen, Ryan Peterson, Greg Pierce, Aaron Putnam, Pat Sauer, Jennifer Welch