Post Construction Best Management Practices (BMPs)

Tool-Kit

Summary of Nebraska communities' procedures, definitions and strategies on <u>how</u> to incorporate responsible and low impact development for the protection of downstream surface water quality and infrastructure.

Statutes mandating the implementation of storm water management plans include The Clean Water Act **(applicable to water bodies with a State listed beneficial use such as primary contact recreation or aquatic life)**, and the National Pollutant Discharge Elimination System (NPDES) regulations **(applicable to all MS4 communities)**.

With respect to largely developed areas it is the ***<u>local land-use and watershed management authorities</u>*** that must effectively mandate more stringent storm water management planning and practices.

- NDOR, "Drainage and Erosion Control Manual – Chapter 3: Stormwater Treatment within MS4 Communities"
- Mile High Flood District (formerly Urban Drainage and Flood Control District), "Urban Storm Drainage Criteria Manual, Volume 3: Best Management Practices"

The designer is encouraged to adopt one design guide/manual for use on a project to the extent practicable. Other approved design guides and manuals may be used if design criteria for the desired BMP are not provided in the primary design guide/manual. Any variances from these manuals will require approval of the City. The City may evaluate the suitability of other types of BMPs not referenced in the approved design guides and manuals on a case-by-case basis.

The designer shall discuss the use of the alternative design guidance manuals before starting design along with any variance in BMP design. The designer shall also discuss other requirements for stormwater management within the City including the potential need for stormwater detention. Where one manual conflicts with another, the Engineer shall use sound, cost-effective design practices to resolve the issue. The following minimum design standards are provided to help resolve some identified conflicts.

9.6.1 *BMP Selection*

Each design guidance manual includes a unique selection of BMPs and what is included in one may not be included in another. Furthermore, two manuals may use different names for BMPs with the same or similar function. The function, criteria, and considerations of a specific BMP is what shall be used to determine its use by a design engineer. Table 9-3 provides a general comparison of the types of BMPs included in the approved design guidance manuals.

Table 9-3. BMP Design Guidance for Various Regulatory Agencies

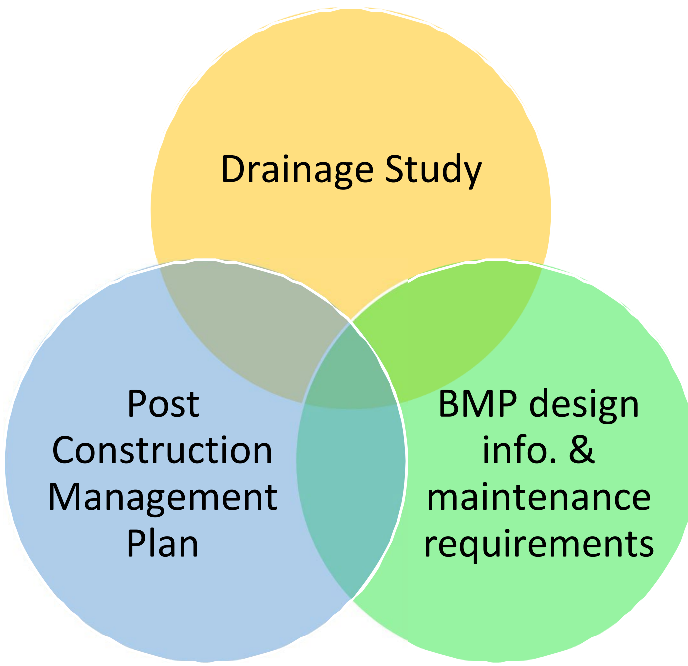
BMP Type	Omaha	Lincoln	NDOR	UDFCD
Vegetated Filter Strip	X		X	X
Grass Swale	X		X	X
Infiltration Trench			X	
Infiltration Basin			X	
Bioretention Basin	X	X	X	X
Media Filter			X	
Sand Filter				X
Extended Dry Detention	X	X	X	X
Wet Detention Ponds	X	X	X	X
Stormwater Wetland	X	X	X	X
Underground Detention		X		X
Pervious Pavement	X	X	X	X
Proprietary Structural Treatment Controls	X		X	X
Green Roofs	X	X		X
Soil Conditioning	X			

NOTE: All BMPs must be sized using WQCV or Qwq design criteria provided in Section 9.4 of this Chapter.

From: [National Menu of Best Management Practices (BMPs) for Stormwater-Post-Construction | US EPA]

All three (3) items are required when development of more than one (1) acre occurs in a Phase II (small) MS4 community. Phase II MS4's are required to address post-construction stormwater runoff from new development and redevelopments that disturb one or more acres. This primarily involves:

1. Strategies to implement a combination of structural and non-structural BMPs
2. An ordinance to address post-construction runoff
3. A Program to ensure adequate long-term operation and maintenance of BMPs.



Code/Regulatory

Statutes mandating the implementation of storm water management plans include: The Clean Water Act (Wetlands, Section 404; Storm water, Section 402), the National Pollutant Discharge Elimination System (NPDES) regulations, and in some cases, State Pollutant Discharge Elimination Systems (SPDES). State, local, or subdivision codes and zoning requirements may dictate designs or systems which are sometimes not consistent with current LID strategies. Especially in largely developed areas, however, the trend is for land-use or water-basin management authorities to mandate more stringent storm water management planning and practices.

1.3 BMP Applications

Alternative BMPs include a variety of methods that are simple and practical in design yet provide effective stormwater management as well as aesthetic enhancements for urban, suburban, and rural landscapes. These methods can be cost effective to build while providing long-term sustainability for City infrastructure and conservation of Lincoln's water resources. This manual presents information on the following alternative BMP types:

- Bioretention
- Retention Pond
- Extended Detention Basin
- Vegetated Buffer
- Grassed Swale
- Green Roof
- Infiltration Basin
- Infiltration Planter
- Infiltration Trench
- Native Vegetation
- Permeable Pavement
- Rain Barrels and Cisterns
- Rain Garden
- Soil Conditioning
- Stormwater Treatment Train
- Underground BMPs
- Urban Forest
- Vegetated Bioswale
- Constructed Wetland
- Hydrodynamic Separators

1.4 Examples of BMP Applications

In relatively small areas, alternative BMPs can effectively ameliorate stormwater runoff, slowing down and reducing stormwater runoff, allowing infiltration, soil storage, and available water for vegetative uptake. The following descriptions show how BMPs can be used in a variety of applications, from small-scale BMPs located within individual parcels to large-scale BMPs potentially spanning a large number of parcels and zoning classes.

1.4.1 Parcel-Level Applications

A variety of BMP types are well suited to implementation in residential parcels (i.e. on the scale of a single homeowner). BMPs at this scale are relatively inexpensive and easy to install and maintain. Taking advantage of these dispersed watershed management opportunities can greatly reduce the need for expensive, large scale infrastructure construction, expansion, and maintenance. Implementation of BMPs within residential parcels not only facilitates stormwater management for a watershed, it also involves citizens in the management process. The installation of rain gardens, vegetated swales, and various other small-scale BMPs provides homeowners with opportunities to mitigate stormwater runoff from their property while also adding to the aesthetic value of their homes (Figure 1). Alternative BMPs typically can be retro-fitted into existing landscaping or integrated into new landscaping layouts.

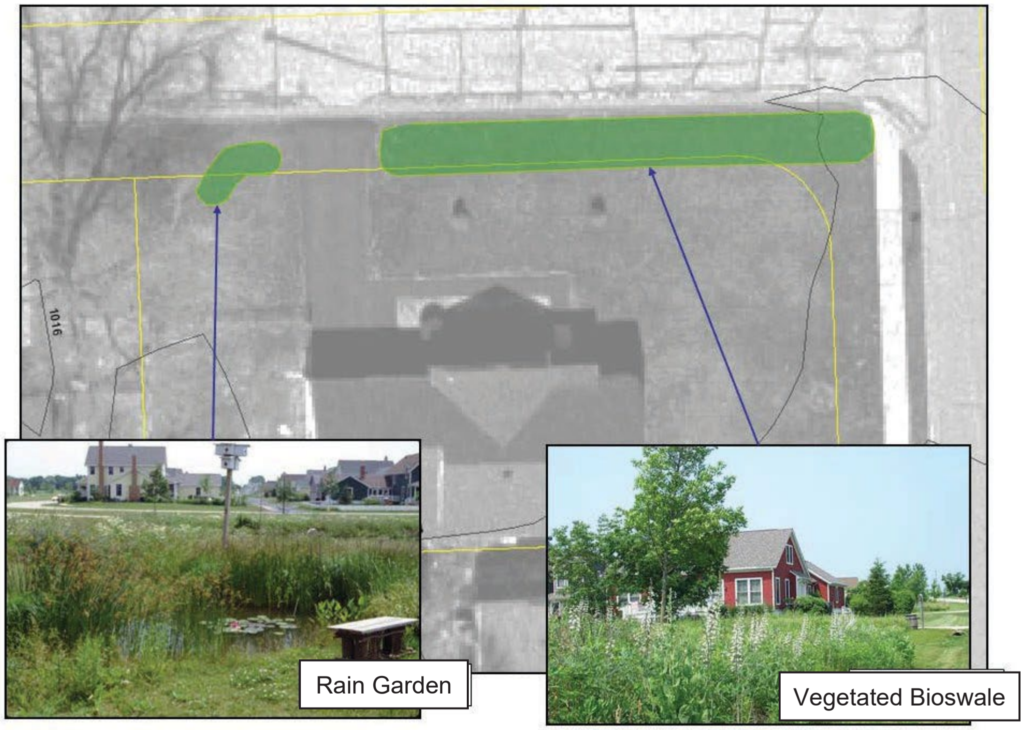
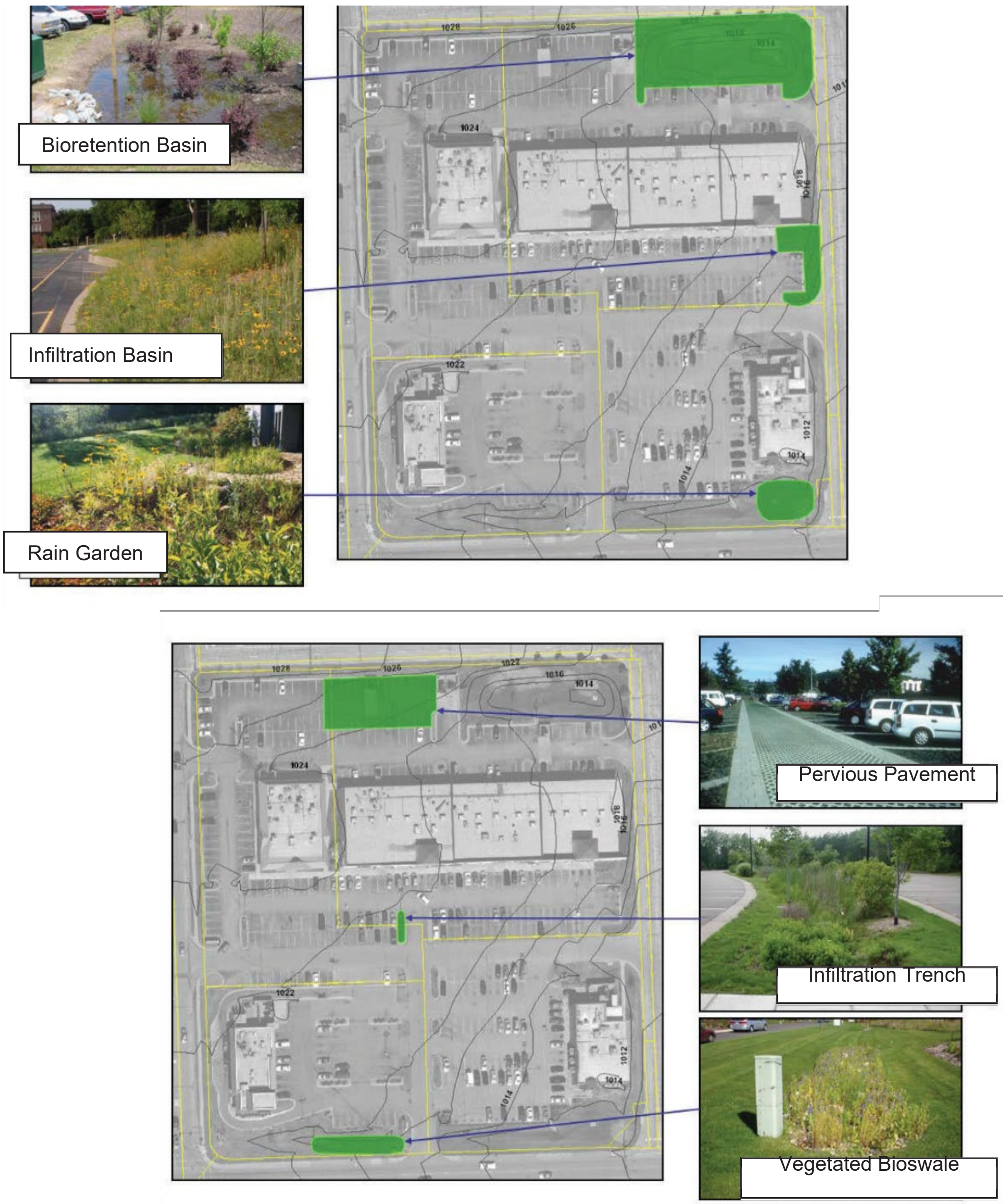


Figure 1: BMP applications at the residential level

Commercial properties by their nature feature extensive areas of impervious surfaces, resulting in large volumes of stormwater runoff. The increased runoff caused by these extensive impervious surfaces can overwhelm the City's stormwater systems and drainageways and rapidly erode and degrade streams. Parking lots are the primary features responsible for creating these increased runoff rates and volumes. They also impair water quality, since water flowing across their surfaces is more likely to pick up sediments and pollutants present there. Though large parking lots are sometimes required to accommodate customers, a variety of BMP types can mitigate these impacts (Figures 2 and 3).

Figure 2: Examples of potential BMP applications in a commercial parking lot



1.4.2 Block and Neighborhood-Level Applications

At the block- and neighborhood levels, BMPs can be coordinated between landowners and installed across several properties to optimize their impact for controlling stormwater runoff. Neighborhoods may consider installation of rear-yard and road right-of-way interconnected rain gardens and bioswales, pocket parks, and restored wetlands and prairie patches. At the block- and neighborhood-level, BMPs take advantage of open spaces overlapping numerous residential parcels. Sometimes, these open spaces occur in areas held as utility or rights-of-way easements, and they may simply represent management issues for homeowners who must maintain them but are not able to place improvements on them.

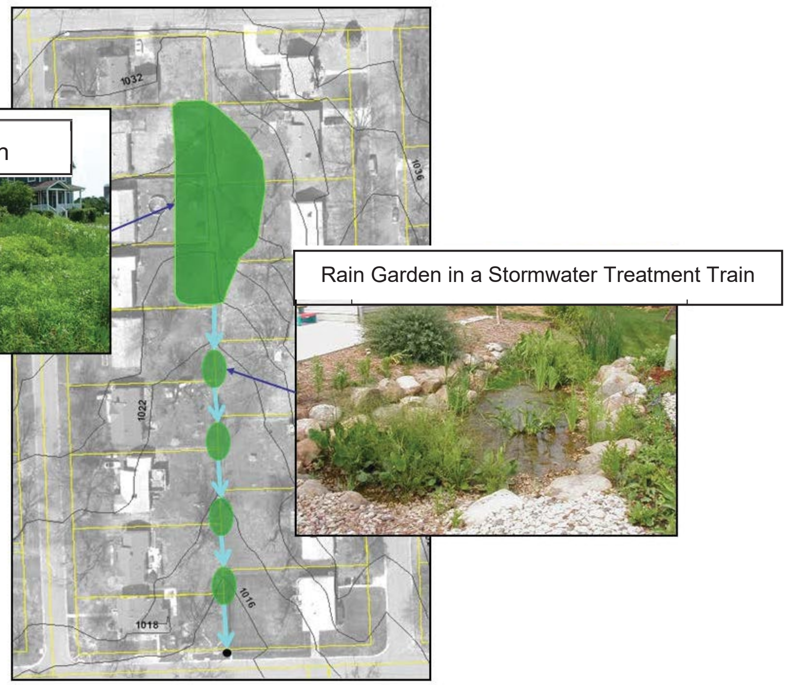
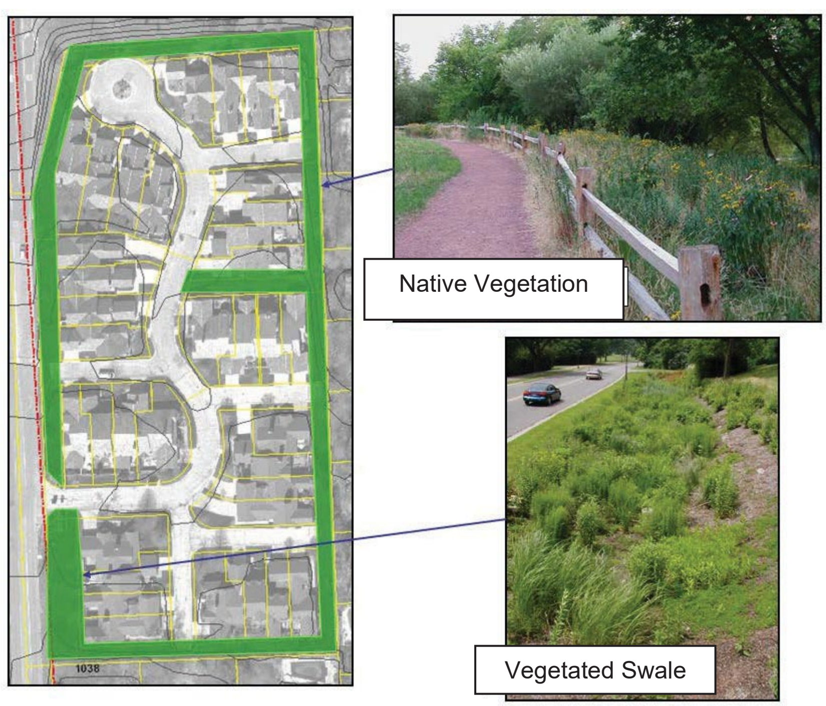


Figure 4: Applications of BMPs at the Block or Neighborhood Level



1.4.3 District-Level Applications

The implementation of bioretention areas, bio-detention basins, infiltration basins, corridor and pocket parks, stream, prairie and wetlands restoration BMPs can be completed for more wide-scale stormwater management.

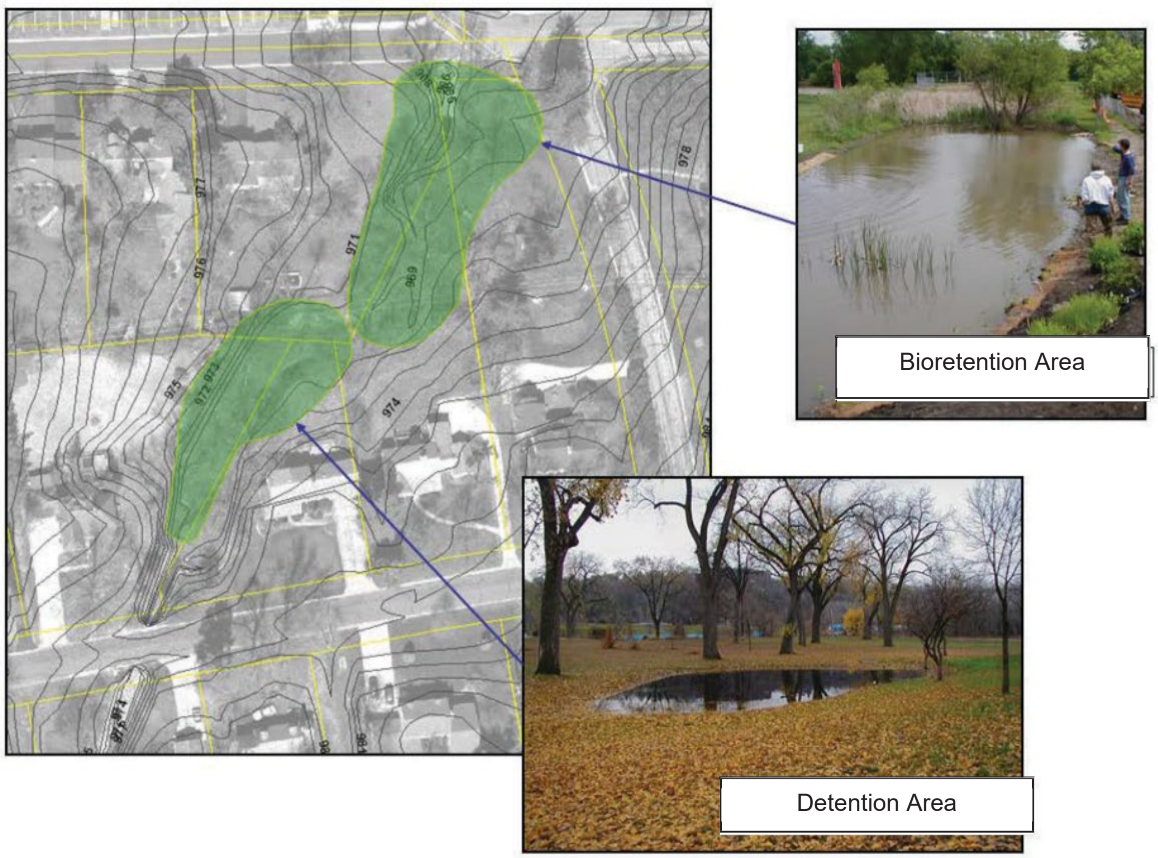


Figure 5: District-level implementations include large-scale BMPs such as bioretention areas and detention areas.

4. LOW IMPACT DEVELOPMENT

The following readings provide published information about the benefits and economics of low impact development (LID). LID commonly incorporates nearly all of the BMPs described in this guidance manual as a standard of practice and measurement, achieving not only environmental benefits, but economic benefits for developers and builders, for residents and commercial property owners, and municipal governments as well.

4.1 Seven Benefits of Low Impact Development

Effective. Research has demonstrated LID to be a simple, practical, and universally applicable approach for treating urban runoff. By reproducing predevelopment hydrology, LID effectively reduces runoff and pollutant loads. Researchers have shown the practices to be successful at removing common urban pollutants including nutrients, metals, and sediment. Furthermore, since many LID practices infiltrate runoff into groundwater, they help to maintain lower surface water temperatures. LID improves environmental quality, protects public health, and provides a multitude of benefits to the community.

Economical. Because of its emphasis on natural processes and micro-scale management practices, LID is often less costly than conventional stormwater controls. LID practices can be cheaper to construct and maintain and have a longer life cycle cost than centralized stormwater strategies. The need to build and maintain stormwater ponds and other conventional treatment practices will be reduced and, in some cases, eliminated. Developers benefit by spending less on pavement, curbs, gutters, piping, and inlet structures. LID creates a desirable product that often sells faster and at a higher price than equivalent conventional developments.

Flexible. Working at a small scale allows volume and water quality control to be tailored to specific site characteristics. Since pollutants vary across land uses and from site to site, the ability to customize stormwater management techniques and degree of treatment is a significant advantage over conventional management methods. Almost every site and every building can apply some level of LID and integrated management practices that contribute to the improvement of urban and suburban water quality.[3]

Adds value to the landscape. It makes efficient use of land for stormwater management and therefore interferes less than conventional techniques with other uses of the site. It promotes less disturbance of the landscape and conservation of natural features, thereby enhancing the aesthetic value of a property and thus its desirability to home buyers, property users, and commercial customers. Developers may even realize greater lot yields when applying LID techniques.[4] Other benefits include habitat enhancement, flood control, improved recreational opportunities, drought impact prevention, and urban heat island effect reduction.

Achieves multiple objectives. Practitioners can integrate LID into other urban infrastructure components and save money. Lot level LID applications and integrated stormwater management practices combine to provide substantial reductions in peak flows and improvements in water quality.

Follows a systems approach. LID integrates numerous strategies, each performing different stormwater management functions, to maximize effectiveness and save money. By emulating natural systems and functions, LID offers a simple and effective approach to watershed sensitive development.

Makes sense. New environmental regulations geared toward protecting water quality and stabilizing our now degraded streams, rivers, lakes, and estuaries are encouraging a broader thinking than centralized stormwater management. Developers and local governments continue to find that LID saves them money, contributes to public relations and marketing benefits, and improves regulatory expediencies. LID connects people, ecological systems, and economic interests in a desirable way.

4.2 Low Impact Development (LID) Practices for Stormwater Management

Water quality concerns have intensified, and storm water management practices have come under scrutiny, as development occurs on an increasing percentage of the available land area in the United States. With more stringent design requirements, costs for traditional collection and conveyance systems have risen sharply. Organizations from community groups, regional watershed authorities, and state and federal agencies have become involved in this issue. Subsequent changes in storm water regulations could strongly impact builders and communities as more new regulations and practices are implemented. Low Impact Development (LID) techniques can offer developers a more cost effective way to address storm water management through site design modifications and "Best Management Practices" (BMPs). These strategies allow land to be developed in an environmentally responsible manner, and create a more "Hydrologically Functional" landscape.

Low Impact Development (LID)

Low Impact Development is an ecologically friendly approach to site development and storm water management that aims to mitigate development impacts to land, water, and air. The approach emphasizes the integration of site design and planning techniques that conserve the natural systems and hydrologic functions of a site.

Low Impact Development (LID) strategies strive to allow natural infiltration to occur as close as possible to the original area of rainfall. By engineering terrain, vegetation, and soil features to perform this function, costly conveyance systems can be avoided, and the landscape can retain more of its natural hydrological function. Low Impact Development practices dovetail with "green" building practices that incorporate environmental considerations into all phases of the development process. Builders can often use green building and LID to lower actual development costs. (Although most effective when implemented on a community-wide basis, using LID practices on a smaller scale, i.e., on individual lots, can also have an impact).

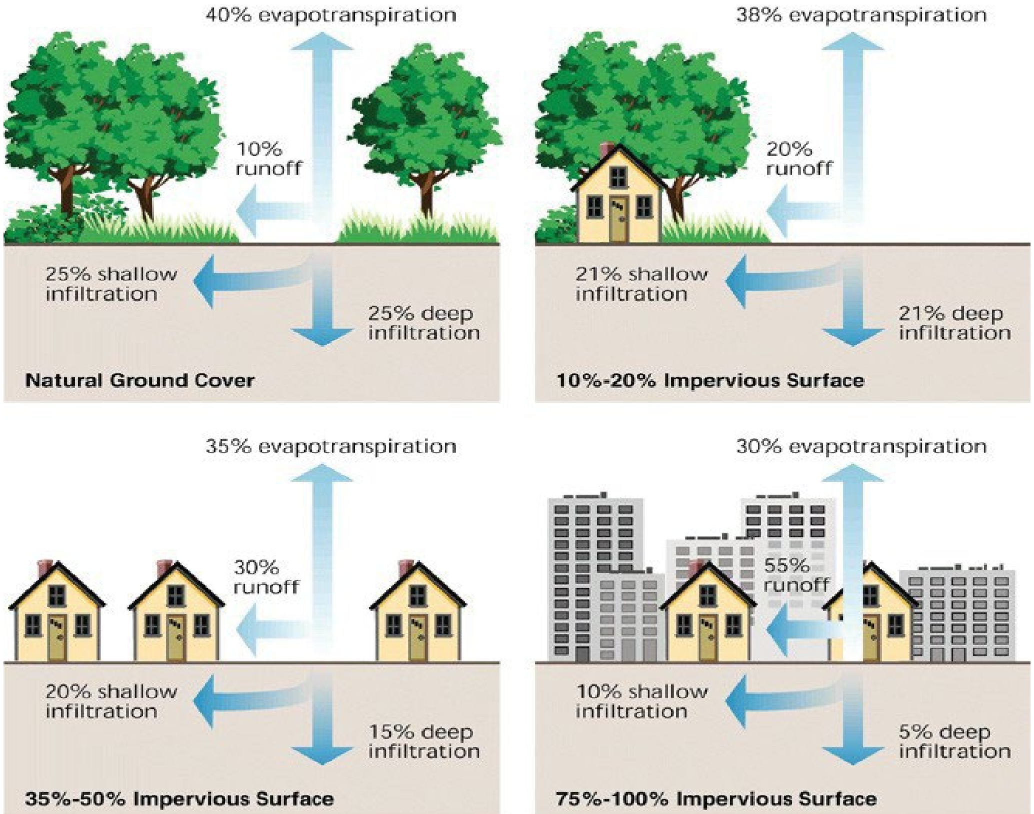
Pollution from stormwater runoff can also be a major concern, especially in urban areas. Rainwater washing across streets and sidewalks can pick up spilled oil, detergents, solvents, de-icing salt, pesticides, fertilizer, and bacteria from pet waste. Storm water drains do not typically channel water to treatment facilities, but carry runoff directly into streams, rivers, and lakes. Most surface pollutants are collected during the first one-half inch of rainfall in any "storm event". This is the period when the majority of pathogens, sediment, waste and debris are picked up by flow across lawns and roadways. Carried untreated into streams and waterways, these materials become "non-point source pollutants" which can increase algae content, reduce aquatic life, and require additional costly treatment to make the water potable for downstream water systems.

LID design principles can be used as buffers to filter these pollutants before they reach aquifers. For traditional conveyance systems, specially designed catch basins may be designed to perform a "first flush" filtering function using various technologies for collection of sediment and contaminants. Some units are designed to retrofit existing storm water inlets. Manufacturers include AquaShield, Stormtreat Systems, Inc, Stormceptor, and Stormwater Management Co.

Effects of Runoff

In 1998, a report on Stream Corridor Restoration was produced by the Federal Interagency Stream Restoration Working Group (FISRWG) documenting the impact of human activities on the stream systems forming the backbone of watersheds throughout the United States. This group represents 15 Federal agencies from the Departments of Agriculture, Commerce, Interior, Defense, Housing and Urban Development (HUD), Environmental Protection Agency (EPA), Federal Emergency Management Agency (FEMA), and Tennessee Valley Authority (TVA).

The following illustration from the report shows how development affects water infiltration into soils and runoff:



Less developed land areas allow a larger portion of storm water to seep gradually into soils, remove contaminants, replenish soil moisture, and recharge groundwater aquifers. As areas become developed, a much larger percentage of rainwater hits impervious surfaces including roofs, sidewalks, parking lots, driveways, and streets, and must be controlled through storm water management techniques. Traditional approaches have focused on collection and conveyance to prevent property damage. Local building code requirements often require developers to take an "end of pipe" approach, using gutters and piping systems to carry rainwater into ponds or detention basins. As new requirements have attempted to address water quality, erosion, flow volume, and other problems created by common conveyance methods, the cost and complexity of these engineered systems has increased.

History

On September 21-23, 2004 the first national Low Impact Development (LID) Conference, called *Putting the LID on Stormwater Management*, took place in College Park, Maryland. It highlighted innovative LID techniques designed to minimize the effect of development on watersheds. Presenters of over 85 papers provided insight into a variety of Low Impact Development projects conducted nationwide.

During the Conference's closing session, *Future Vision of LID and Storm Water Management*, a panel of experts reflected upon the current state of LID and the direction in which LID is headed. One common theme was that LID is a concept where residential developers, local public planners, engineers, citizens, and environmental groups all can support the idea of using water as a resource, reducing stream erosion, and pretreating storm water before it enters waterways and recharges groundwater aquifers.

LID should be more than just new storm water technologies for single lots. LID should be about looking at water resources in a holistic, watershed-based manner, and effectively managing such resources. Such an approach involves conserving water inside and outside a house, using decentralized storm water management BMPs for single lots and larger-scale developments, and identifying the best ways to handle wastewater.

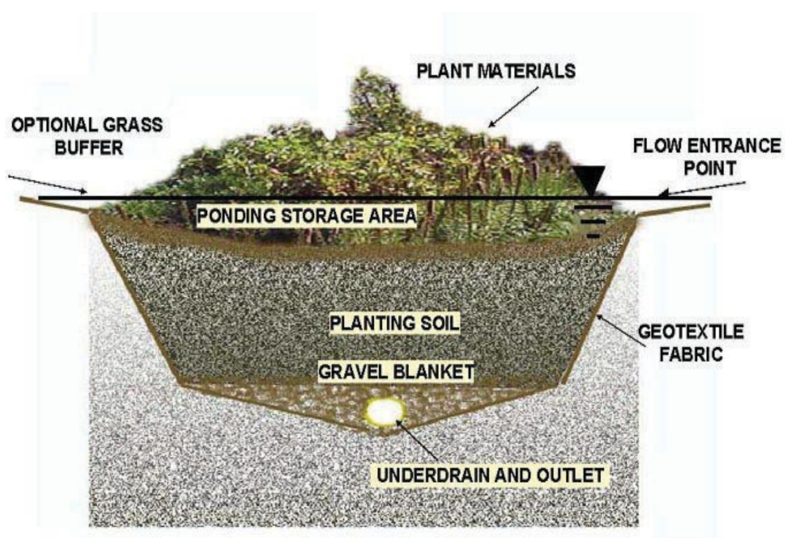
Details

Strategies fall under the two broad categories of ***practices*** and ***site design***. The most common concepts are summarized below:

Practices:

Basic LID strategy for handling runoff is to: 1) reduce the volume of runoff and 2) decentralize flows. This is usually best accomplished by creating a series of smaller retention/detention areas that allow localized filtration rather than carrying runoff to a remote collection area. For the practices noted below, special attention should be paid to the composition of existing soils, as well as new soils or amended soils used, and underlying topography. For instance, a locale with karst topography may react differently to introduction of LID practices than a site that does not have underground channels. Common methods include:

- **Bio-retention cells** typically consist of grass buffers, sand beds, a ponding area for excess runoff storage, organic layers, planting soil and vegetation. Their purpose is to provide a storage area, away from buildings and roadways, where storm water collects and filters into the soil. Permanent ponds can be incorporated into the cell design as landscaping features.



Temporary storage areas without ponds may be called **detention cells**. Bioretention areas have also been called **rain gardens** since they are typically landscaped with native plants and grasses, selected according to their moisture requirements and ability to tolerate pollutants. Annual maintenance of bioretention cells must be planned in order to replace mulching materials, remove accumulated silt, or revitalize soils as required.

- **Grass swales** function as alternatives to curb and gutter systems, usually along residential streets or highways. They use grasses or other vegetation to reduce runoff velocity and allow filtration, while high volume flows are channeled away safely. Features like plantings and check dams may be incorporated to further reduce water velocity and encourage filtration. Walkways are either separated from roadways by swales or relocated to other areas. In areas where salts are commonly used for winter de-icing, careful attention must be paid to selecting plant species which are salt tolerant.
- **Filter strips** can be designed as landscape features within parking lots or other areas, to collect flow from large impervious surfaces. They may direct water into vegetated detention areas or special sand filters that capture pollutants and gradually discharge water over a period of time.
- **Disconnected impervious areas** direct water flows collected from structures, driveways, or street sections, into separate localized detention cells instead of combining it in drainpipes with other runoff. Disconnecting the flow limits the velocity and overall amount of conveyed water that must be handled by end-of-pipe facilities.
- **Cistern collection systems** can be designed to store rainwater for dry-period irrigation rather than channeling it to streams. Smaller tanks that collect residential roof drainage are often called "**rain barrels**" and may be installed by individual homeowners. Some collection systems are designed to be installed directly under permeable pavement areas, allowing maximum water storage capacity while eliminating the need for gravel beds.

Site Design:

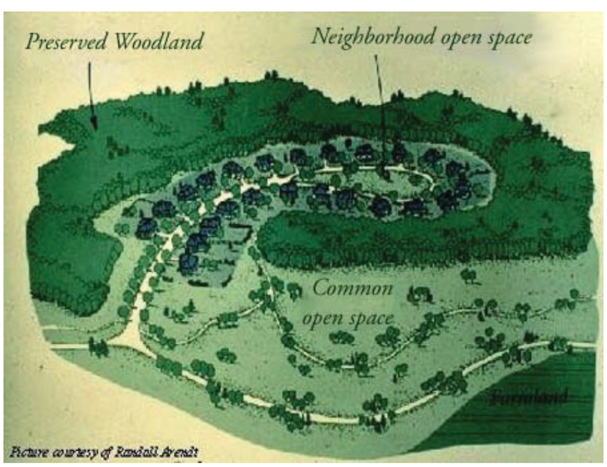
Decreasing Impervious Surfaces can be a simple strategy to avoid problems from storm water runoff and water table depletion, by reducing surfaces that prevent natural filtration. Methods may include:

- **Reducing Roadway Surfaces** can retain more permeable land area. In some cases, planners have reduced pavement needs by up to 40% by using longer, undulating roads that create more available lot frontage, instead of wide shorter streets with more intersections. Other options may include shared driveways, "flag" lots with reduced street frontage, landscaped detention islands within cul-de-sacs, or alternate designs for turn-around areas.

- **Permeable Pavement Surfaces** can be constructed from a variety of materials, including traditional asphalt and concrete, gravel or pavers. Permeable roadway or parking areas allow water to flow through, replenishing soil areas directly beneath. However, the sub-base underneath permeable pavements must be engineered to accommodate temporary water storage and filtration. In many cases, permeable surfaces can reduce or eliminate the need for traditional storm water structures.
- **Vegetative Roof Systems** create a lightweight, permeable vegetative surface on an impervious roof area. Moss, grass, herbs, wildflowers, and native plants can be used, creating an aesthetically pleasing roof landscape. The systems start with a high strength rubber membrane placed over the base roof structure. Various layers above the rubber may contain insulation, filter and drainage media, separation fabrics, lightweight growth media, vegetation, and wind erosion fabric. Some systems even incorporate rain barrel runoff collection, pumping, and irrigation equipment. These systems are more costly than standard roofs, and have not been used on a large scale for residential development in the U.S.

Planning site layout and grading to natural land contours can minimize grading costs and retain a greater percentage of the land's natural hydrology. Contours which function as filtration basins can be retained or enhanced and incorporated into the landscaping design.

Natural Resource Preservation and Xeriscaping can be used to minimize the need for irrigation systems and enhance property values. Riparian, or stream bank, areas are particularly crucial to water quality, and in most areas, subject to Federal or State regulations. Preserving existing wooded areas, mature trees, and natural terrain, can give new developments a premium "mature landscape" appearance and provide residents with additional recreational amenities. Both of these features can improve marketability. Xeriscaping refers to landscaping with plants native to area climate and soil conditions. These plants thrive naturally, requiring less maintenance and irrigation than most hybrid or imported varieties.



Clustering Homes on slightly smaller lot areas can allow more preserved open space to be used for recreation, visual aesthetics, and wildlife habitat. Clustering can reduce infrastructure costs to the builder, since fewer feet of pipe, cable, and pavement are needed, and maintenance costs are reduced for homeowners. Builders in many areas have been able to charge a premium price for "view lots" facing undisturbed natural vistas, or pond areas that also function as bioretention cells.

Installation

Low Impact Development requires more precise engineering for soil characteristics, filtration rates, water tables, native vegetation, and other site features. Participation of environmental consultants and planners is critical from the earliest planning phases for residential development.

Benefits

In addition to the practice just making good sense, LID techniques can offer many benefits to a variety of stakeholders.

Developers:

- Reduce land clearing and grading costs
- Potentially reduce infrastructure costs (streets, curbs, gutters, sidewalks)
- Reduce storm water management costs
- Potentially reduce impact fees and increase lot yield
- Increase lot and community marketability

Municipalities:

- Protect regional flora and fauna
- Balance growth needs with environmental protection
- Reduces municipal infrastructure and utility maintenance costs (streets, curbs, gutters, sidewalks, storm sewer)
- Increase collaborative public/private partnerships

Environment

- Preserve integrity of ecological and biological systems
- Protect site and regional water quality by reducing sediment, nutrient, and toxic loads to water bodies
- Reduce impacts to local terrestrial and aquatic plants and animals
- Preserve trees and natural vegetation

Costs

Cost benefits to builders and developers utilizing LID strategies can be significant. According to the Center for Watershed Protection, traditional curbs, gutters, storm drain inlets, piping and detention basins can cost two to three times more than engineered grass swales and other techniques to handle roadway runoff. Other LID strategies can have similar impact. Choosing permeable pavement for a parking area may remove the need for a catch basin and conveyance piping. Small distributed filtration areas on individual lots can reduce site requirements for larger detention ponds that take up valuable land area.

Dissatisfied with a conventional land plan, a developer in central Arkansas contacted Tyne and Associates in North Little Rock AR, who specializes in environmentally sensitive land development. The resulting design for the Gap Creek community was showcased in the Spring/Summer 2000 issue of Land Development Magazine along with the following cost information:

A Comparison of Two Different Land Plans for Gap Creek Community

PROJECTED RESULTS FROM TOTAL DEVELOPMENT		
Total Site	**Conventional Plan**	**Revised Green Plan**
Lot Yield	358	375
Linear Feet - Street	21,770	21,125
Linear Feet - Collector Street	7,360	0
Linear Feet - Drainage Pipe	10,098	6,733
Drainage Sections (Inlets, Boxes, Headwalls)	103	79
Estimated Total Cost	$4.6 million	$3.9 million

ACTUAL RESULTS FROM PHASE ONE		
Total Site (engineer estimate)	**Conventional Plan**	**Revised Green Plan**
Lot Yield	63	72
Total Cost	$1,028,544	828,523
Cost Per Lot	$16,326	$11,507

BENEFITS FROM LOW-IMPACT DEVELOPMENT	
General Benefit	**Specific Benefit**
Higher Lot Yield	17 additional lots
Higher Lot Value	$3,000 more per lot than competition
Lower Cost per Lot	$4,800 less per lot
Enhanced Marketability	80% of lots sold in the first year
Added Amenities	23.5 acres of green space/parks
Recognition	National, state, and professional group recognition
TOTAL ECONOMIC BENEFIT	More than $2.2 million in savings

This development was also cited in an NAHB Research Center report, published in July 2001, called *Environmentally Green... Economically Green, Tools for a Green Land Development Program.* The report provides a wealth of information and sources on Low-Impact and Sustainable Development practices.

<u>Limitations</u>

Not all sites can effectively utilize LID techniques. Soil permeability, slope, and water table characteristics may limit the potential for local infiltration. Urban areas and locations with existing high contaminant levels may be precluded from using LID filtration techniques.

Many existing local codes, zoning regulations, parking requirements and street standards were developed prior to the emergence of water quality and storm water management concerns and may prohibit or inhibit implementing LID practices.

Established practices can be difficult to modify, although cost factors may help drive change. Additionally, there may be negative perceptions among homebuyers. Even though many buyers welcome naturalistic features proscribed by LID, others may prefer large flat lots with wide curbed streets. While traffic studies have not borne out the theory, some consumers perceive curbs to be a safety feature for pedestrians. Others fear that the lack of conventional storm water systems will result in basement flooding or structural damage.

8.4 Post-Construction Stormwater Management Plans

A Post-Construction Stormwater Management Plan (PCSMP) is required for submittal and approval by the City of Omaha Public Works Department. The paragraphs below discuss the requirements for submittal of a PCSMP, information to be included on the PCSMP application, and elements to consider during plan development.

The proc s for submitting a PCSMP begins with a pre-application meeting with City of Omaha Public Works Department to discuss a concept pl . Aft the pre-application meeting, the owner shall apply for PC SMP application through the City of Omaha' Permix websit e accessible at www.omahastormwater.org. The City will assign a number to the PCSMP and the PCSMP numb should be applied to the plat submittal and the final version of the PCSMP application should be submitted.

A PCSMP will be required with the submittal of (1) storm sewer construction plans for subdivisions that have an approved prelimina plat, (2) a Grading Perm Application for projects that do not require a pr eliminary plat and disturb 1 ac. or more of the site or (3) Building Permit Application for projects that add or eplace less than 1 ac. but more than 5,000 sq. ft. of impervious surface area.

P C SMPs shall be prepared by or under the supervision of a licensed professional civil engineer registered in h e State of Nebraska or other professional approved by the City of Omaha Public Works Department. The r p sible professional sh l be listed as the Designer on the Application and will be required to provide a seal on PCSMP sheets and calculations.

A building permit may be issued while the final PCSMP is prepared. This is handled with a letter submitted to the City requesting a Hold on the Certificate of Occupancy (CO) until such time as the final PCSMP is appr oved.

The PCSMP shall include the following elements:

- PCSMP Application
- PCSMP Plan Sheets
- BMP Design Information
- Drainage Study
- BMP Maintenance Requirements
- Recorded Maintenanc Agreement (Maintenance Agreement will be required before Final Plat or Certificate of Occupancy is appr oved)

Conditional appr ov al will be issued once the PCSMP has been r eview ed and if minimum design standards ar e met. Final appr ov al of the PCSMP will be issued when the BMP certification and as-built dr a wings ar e provided by the owner.

For BMP Certification, the Designer shall submit the following elements to the City of Omaha Public Works Department:

- Record Drawings of the Final PCSMP Sheets.

8.5.3 Residential Disconnection of Impervious Area

Runoff from connected impervious areas often flows directly to a stormwater collection system with no possibility for infiltration into the soil. The direct runoff from these areas is one of the greatest contributors to nonpoint source pollution and stream hydromodification. The convergence of runoff from numerous impervious drainage areas combines volumes, runoff rates, and pollutant load. By disconnecting impervious areas, runoff from rooftops, driveways, and parking lots is diverted from a stormwater management system or a curb and gutter system. Water is instead directed to a vegetated area, a bioretention area, or a holding device. Disconnecting impervious areas can potentially reduce runoff volume and filter out pollutants. Disconnection is not a standalone BMP, but is part of a BMP control strategy.

Design Considerations	
Location Characteristics	Applicable to rooftops, driveways, and parking lots
Contributing drainage area	Variable
Design size	Variable
Detention time for WQCV treatment	Not applicable
Median Effluent Concentrations	Variable
Implementation and Maintenance Considerations	
Potential for use with other BMPs	High. Can be used as the first process in a treatment train.
Maintenance	Routine -Sediment/debris removal, general up-keep

8.5.3.1 General Application

Disconnection practices can be applied in almost any area containing impervious surfaces. However, the runoff must be able to discharge to a suitable receiving area, such as a densely vegetated lawn, in order for the BMP to be effective. Figure 8-11 provides an example of a downspout that is disconnected from the stormwater system.

Figure 8-11 Example of a Downspout that is Disconnected from the Stormwater System

NDOT STF Suitability Matrix

STF	Description	Treatment Type	Typical Drainage Area	Site Suitability	Soil Permeability	Groundwater Limitations	Best at Removing....	Construction Cost	Maintenance Cost	Comments
Vegetated Filter Strips	Densely vegetated strip of land designed to treat sheet flow	Water Quality Treatment Rate	Based on Sheet Flow Loading	Rural and Urban Section	Any (with soil conditioning)	≥ 2 feet	Suspended Solids	Low	Low	Maximum slope generally 6H:1V - longer filter strip needed on steeper slopes
Grass Swale	Densely vegetated drainage way designed to convey runoff slowly to allow for treatment	Water Quality Treatment Rate	≤ 5 acres	Rural and Urban Section	Any (with soil conditioning)	≥ 2 feet	Suspended Solids, Heavy Metals, Hydrocarbons	Low	Low	Limited depth of flow and velocity for effective treatment
Infiltration Trench	Aggregate-filled trench designed to capture runoff in the void space and infiltrate it	Water Quality Volume	≤ 5 acres	Rural and Urban Section	0.5 - 12 in/hr	≥ 4 feet	Suspended Solids, Nutrients, Heavy Metals	Moderate-High	Moderate	Width of Trench ≥ Depth
Infiltration Basin	Shallow basin designed to capture runoff above ground and infiltrate it through natural soils	Water Quality Volume	10-20 acres	Rural and Urban Section	0.5 - 12 in/hr	≥ 4 feet	Suspended Solids, Nutrients, Heavy Metals, Hydrocarbons	Moderate	Moderate	Drainage area limited if constructed online
Bioretention Basin	Shallow basin designed to capture runoff above ground and infiltrate it through an amended soil zone with underdrain	Water Quality Volume	≤ 5 acres	Rural and Urban Section	0 - 12 in/hr	≥ 4 feet	Suspended Solids, Heavy Metals	Moderate	Moderate	Landscape plantings typical with this BMP
Media Filter	Structure that includes a sedimentation chamber and sand filtration chamber to treat runoff	Water Quality Volume	≤ 2 acres	Urban and Ultra-Urban	Any	n/a	Suspended Solids	High	High	Typically a cast-in-place structure - check hydraulic grade lines and possibly buoyancy issues
Extended Dry Detention	Dry basin designed to capture runoff with drawdown to the basin bottom over an extended period	Water Quality Volume	≤ 5 acres	Rural and Urban Section	0 - 12 in/hr	0	n/a (see comments)	Low	Low	Only moderate treatment efficiency in general
Wet Detention	Basin with permanent pool of water designed to capture runoff with drawdown to the normal pool elevation over an extended period	Water Quality Volume	10 acres + (typ)	Rural and Urban Section	Depends on Design	Depends on Design	Suspended Solids	Low	Low	Minimum drainage area needed to maintain permanent pool
Stormwater Wetland	Basin or drainage way with a pool of water of varying depths designed to support wetland vegetation and treat water flowing through the system	Water Quality Volume	10 acres + (typ)	Rural and Urban Section	Depends on Design	Depends on Design	Suspended Solids, Heavy Metals	Moderate	Moderate	Minimum drainage area needed to maintain wetland
Pervious Pavement	Various types of pavement with the ability to pass stormwater through the surface to an underlying aggregate bed - the aggregate bed is designed to capture runoff in the void space and release it slowly through an underdrain	Water Quality Volume	≤ 5 acres	Urban and Ultra-Urban	0 - 12 in/hr	≥ 4 feet	Suspended Solids, Heavy Metals, Hydrocarbons	High	High	Protect adjacent pavement
Proprietary Structural Treatment Controls	Various types of proprietary devices designed to treat stormwater runoff	Water Quality Treatment Rate (Typical)	≤ 2 acres	Urban and Ultra-Urban	Any	n/a	Varies	High	High	Approval of device needed - check hydraulic grade lines and possibly buoyancy issues

Exhibit 3.10 STF Suitability Matrix

Description

Photograph GB-1. A flush curb allows roadway runoff to sheet flow through the grass buffer. Flows are then further treated by the grass swale. Photo courtesy of Muller Engineering.

Grass buffers are densely vegetated strips of grass designed to accept sheet flow from upgradient development. Properly designed grass buffers play a key role in LID, enabling infiltration and slowing runoff. Grass buffers provide filtration (straining) of sediment. Buffers differ from swales in that they are designed to accommodate overland sheet flow rather than concentrated or channelized flow.

Site Selection

Grass buffers can be incorporated into a wide range of development settings. Runoff can be directly accepted from a parking lot, roadway, or the roof of a structure, provided the flow is distributed in a uniform manner over the width of the buffer. This can be achieved through the use of flush curbs, slotted curbs, or level spreaders where needed. Grass buffers are often used in conjunction with grass swales. They are well suited for use in riparian zones to assist in stabilizing channel banks adjacent to major drainageways and receiving waters. These areas can also sometimes serve multiple functions such as recreation.

Hydrologic Soil Groups (HSG) A and B provide the best infiltration capacity for grass buffers. For Type C and D soils, buffers still serve to provide filtration (straining) although infiltration rates are lower. Refer to Fact Sheet T-0 to quantify volume reduction in grass buffers and understand how HSG effects reduction.

Grass Buffer	
Functions	
LID/Volume Red.	Yes
WQCV Capture	No
WQCV+Flood Control	No
Fact Sheet Includes EURV Guidance	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Good
Nutrients	Moderate
Total Metals	Good
Bacteria	Poor
Other Considerations	
Life-cycle Costs	Low

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

Designing for Maintenance

Recommended ongoing maintenance practices for all BMPs are provided in Chapter 6 of this manual. During design the following should be considered to ensure ease of maintenance over the long-term:

- Where appropriate (where vehicle safety would not be impacted), install the top of the buffer 1 to 3 inches below the adjacent pavement so that growth of vegetation and accumulation of sediment at the edge of the strip does not prevent runoff from entering the buffer. Alternatively, a sloped edge can be used adjacent to vehicular traffic areas.

- Amend soils to encourage deep roots and reduce irrigation requirements, as well as promote infiltration.

- Design and adjust the irrigation system (temporary or permanent) to provide water in amounts appropriate for the selected vegetation. Irrigation needs will change from month to month and year to year.

- Protect the grass buffer from vehicular traffic when using this BMP adjacent to roadways. This can be done with a slotted curb (or other type of barrier) or by constructing a reinforced grass shoulder (see Fact Sheet T-10.5).

Design Procedure and Criteria

The following steps outline the grass buffer design procedure and criteria. Figure GB-1 is a schematic of the facility and its components:

1. **Design Discharge**: Use the hydrologic procedures described in the *Runoff* chapter of Volume 1 to determine the 2-year peak flow rate (Q_2) of the area draining to the grass buffer.

2. **Minimum Width:** The width (W), normal to flow of the buffer, is typically the same as the contributing basin (see Figure GB-1). An exception to this is where flows become concentrated. Concentrated flows require a level spreader to distribute flows evenly across the width of the buffer. The minimum width should be:

$$W = \frac{Q_2}{0.05} \qquad \text{Equation GB-1}$$

   Where:

   W = width of buffer (ft)

   Q_2 = 2-year peak runoff (cfs)

3. **Length:** The recommended length (L), the distance along the sheet flow direction, should be a minimum of 14 feet. This value is based on the findings of Barrett et al. 2004 in *Stormwater Pollutant Removal in Roadside Vegetated Strips* and is appropriate for buffers with greater than 80% vegetative cover and slopes up to 10%. The study found that pollutant removal continues throughout a length of 14 feet. Beyond this length, a point of diminishing returns in pollutant reduction was found. It is important to note that shorter lengths or slightly steeper slopes will also provide some level of removal where site constraints dictate the geometry of the buffer.

Benefits

- Filters (strains) sediment and trash.
- Reduces directly connected impervious area. (See Chapter 3 for quantifying benefits.)
- Can easily be incorporated into a treatment train approach.
- Provides green space available for multiple uses including recreation and snow storage.
- Straightforward maintenance requirements when the buffer is protected from vehicular traffic.

Limitations

- Frequently damaged by vehicles when adjacent to roadways and unprotected.
- A thick vegetative cover is needed for grass buffers to be effective.
- Nutrient removal in grass buffers is typically low.
- High loadings of coarse solids, trash, and debris require pretreatment.
- Space for grass buffers may not be available in ultra urban areas (lot-line-to-lot-line).

4. **Buffer Slope:** The design slope of a grass buffer in the direction of flow should not exceed 10%. Generally, a minimum slope of 2% or more in turf is adequate to facilitate positive drainage. For slopes less than 2%, consider including an underdrain system to mitigate nuisance drainage.

5. **Flow Characteristics (sheet or concentrated)**: Concentrated flows can occur when the width of the watershed differs from that of the grass buffer. Additionally, when the product of the watershed flow length and the interface slope (the slope of the watershed normal to flow at the grass buffer) exceeds approximately one, flows may become concentrated. Use the following equations to determine flow characteristics:

Use of Grass Buffers

Sheet flow of stormwater through a grassed area provides some benefit in pollutant removal and volume reduction even when the geometry of the BMP does not meet the criteria provided in this Fact Sheet. These criteria provide a design procedure that should be used when possible; however, when site constraints are limiting, this treatment concept is still encouraged.

$$\text{Sheet Flow: } FL(SI) \leq 2 \qquad \text{Equation GB-2}$$

$$\text{Concentrated Flow: } FL(SI) > 2 \qquad \text{Equation GB-3}$$

Where:

FL = watershed flow length (ft)

SI = interface slope (normal to flow) (ft/ft)

6. **Flow Distribution:** Flows delivered to a grass buffer must be sheet flows. Slotted or flush curbing, permeable pavements, or other devices can be used to spread flows. The grass buffer should have relatively consistent slopes to avoid concentrating flows within the buffer.

   A level spreader should be used when flows are concentrated. A level spreader can be a slotted drain designed to discharge flow through the slot as shown in Photo GB-2. It could be an exfiltration trench filled with gravel, which allows water to infiltrate prior to discharging over a level concrete or rock curb. There are many ways to design and construct a level spreader. They can also be used in series when the length of the buffer allows flows to re-concentrate. See Figure GB-2 for various level spreader sections.

Photograph GB-2. This level spreader carries concentrated flows into a slotted pipe encased in concrete to distribute flows evenly to the grass buffer shown left in the photo. Photo courtesy of Bill Wenk.

Photos GB-3 and GB-4 show a level spreader that includes a basin for sedimentation. Concentrated flows enter the basin via stormsewer. The basin is designed to drain slowly while overflow is spread evenly to the downstream vegetation. A small notch, orifice, or pipe can be used to drain the level spreader completely. The opening should be small to encourage frequent flows to overtop the level spreader but not so small that it is frequently clogged.

Photograph GB-3. This level spreader includes the added benefit of a sedimentation basin prior to even distribution of concentrated flows from the roadway into the grass buffer. Photo courtesy of Bill Wenk.

7. **Soil Preparation**: In order to encourage establishment and long-term health of the selected vegetation, it is essential that soil conditions be properly prepared prior to installation. Following site grading, poor soil conditions often exist. When possible, remove, strip, stockpile, and reuse on-site topsoil. If the site does not contain topsoil, the soils should be amended prior to vegetation. Typically 3 to 5 cubic yards of soil amendment (compost) per 1,000 square feet, tilled 6 inches into the soil is required in order for vegetation to thrive, as well as to enable infiltration of runoff. Additionally, inexpensive soil tests can be conducted to determine required soil amendments. (Some local governments may also require proof of soil amendment in landscaped areas for water conservation reasons.)

Photograph GB-4. Maintenance access is provided via the ramp located at the end of the basin. Photo courtesy of Bill Wenk.

8. **Vegetation:** This is the most critical component for treatment within a grass buffer. Select durable, dense, and drought tolerant grasses to vegetate the buffer. Also consider the size of the watershed as larger watersheds will experience more frequent flows. The goal is to provide a dense mat of vegetative cover. Grass buffer performance falls off rapidly as the vegetation coverage declines below 80% (Barrett et al.2004).

Turf grasses such as Kentucky bluegrass are often selected due to these qualities[1]. Dense native turf grasses may also be selected where a more natural look is desirable. Once established, these provide the benefit of lower irrigation requirements. See the *Revegetation* chapter in Volume 2 of this manual with regard to seed mix selection, planting and ground preparation. Depending on soils and anticipated flows, consider erosion control measures until vegetation has been established.

9. **Irrigation**: Grass buffers should be equipped with irrigation systems to promote establishment and survival in Colorado's semi-arid environment. Systems may be temporary or permanent, depending on the type of vegetation selected. Irrigation application rates and schedules should be developed and adjusted throughout the establishment and growing season to meet the needs of the selected plant species. Initially, native grasses require the same irrigation requirements as bluegrass. After the grass is established, irrigation requirements for native grasses can be reduced. Irrigation practices have a significant effect on the function of the grass buffer. Overwatering decreases the permeability of the soil, reducing the infiltration capacity and contributing to nuisance baseflows. Conversely, under watering may result in delays in establishment of the vegetation in the short term and unhealthy vegetation that provides less filtering and increased susceptibility to erosion and rilling over the long term.

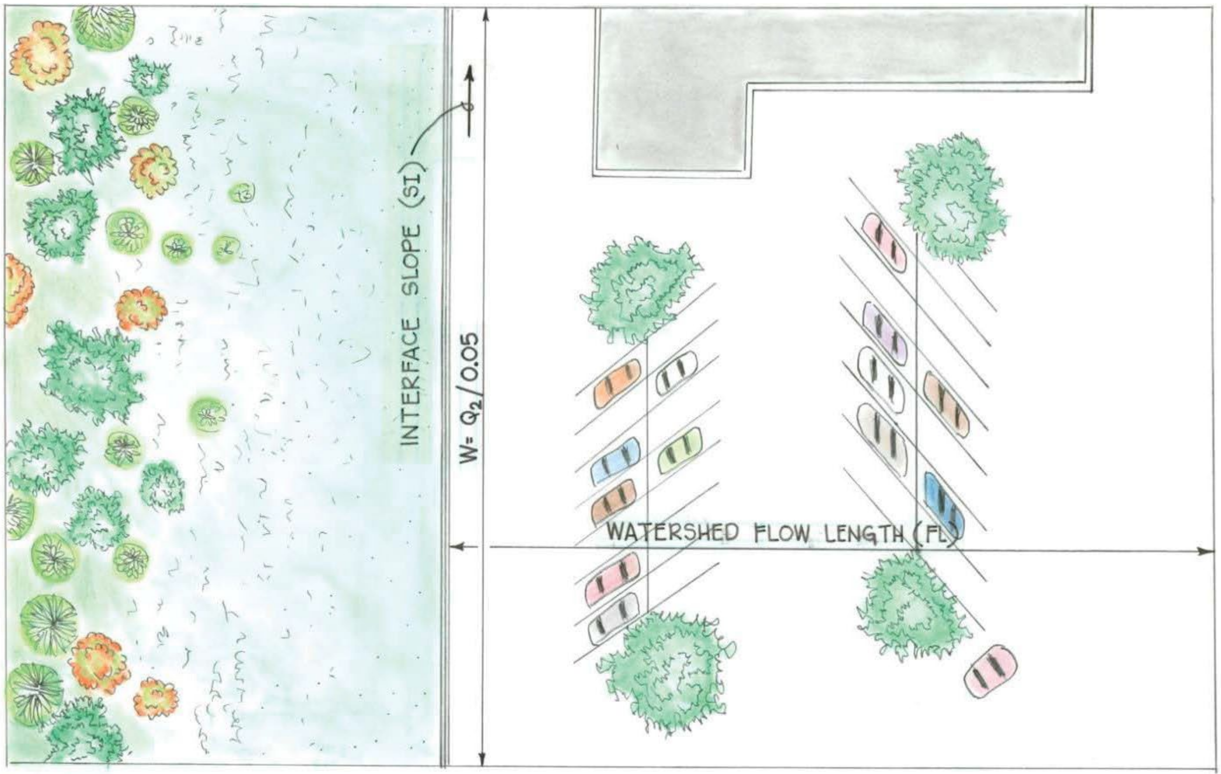
10. **Outflow Collection**: Provide a means for downstream conveyance. A grass swale can be used for this purpose, providing additional LID benefits.

Construction Considerations

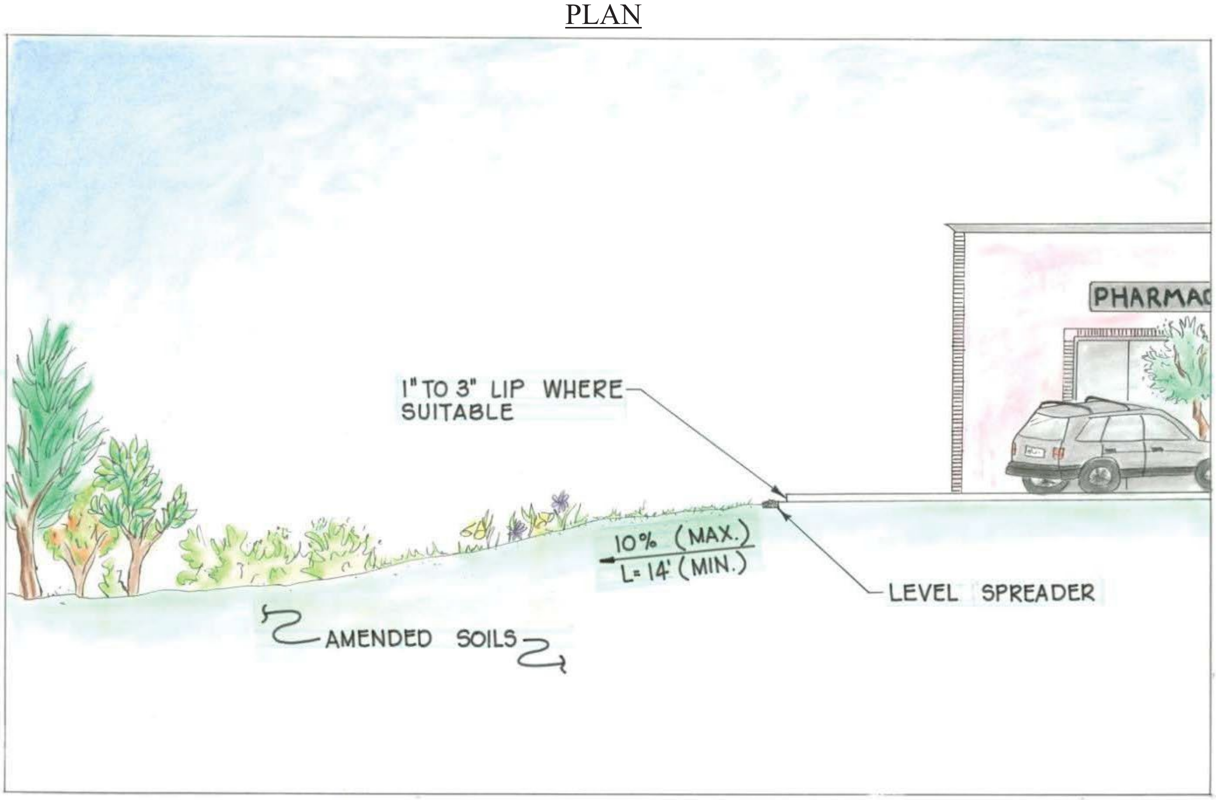
Success of grass buffers depends not only on a good design and long-term maintenance, but also on installing the facility in a manner that enables the BMP to function as designed. Construction considerations include:

- The final grade of the buffer is critical. Oftentimes, following soil amendment and placement of sod, the final grade is too high to accept sheet flow. The buffer should be inspected prior to placement of seed or sod to ensure appropriate grading.
- Perform soil amending, fine grading, and seeding only after tributary areas have been stabilized and utility work crossing the buffer has been completed.
- When using sod tiles stagger the ends of the tiles to prevent the formation of channels along the joints. Use a roller on the sod to ensure there are no air pockets between the sod and soil.
- Avoid over compaction of soils in the buffer area during construction to preserve infiltration capacities.
- Erosion and sediment control measures on upgradient disturbed areas must be maintained to prevent excessive sediment loading to grass buffer.

[1] Although Kentucky bluegrass has relatively high irrigation requirements to maintain a lush, green aesthetic, it also withstands drought conditions by going dormant. Over-irrigation of Kentucky bluegrass is a common problem along the Colorado Front Range, and it can be healthy, although less lush, with much less irrigation than is typically applied.



PLAN



PROFILE

Figure GB-1. Typical Grass Buffer Graphic by Adia Davis.

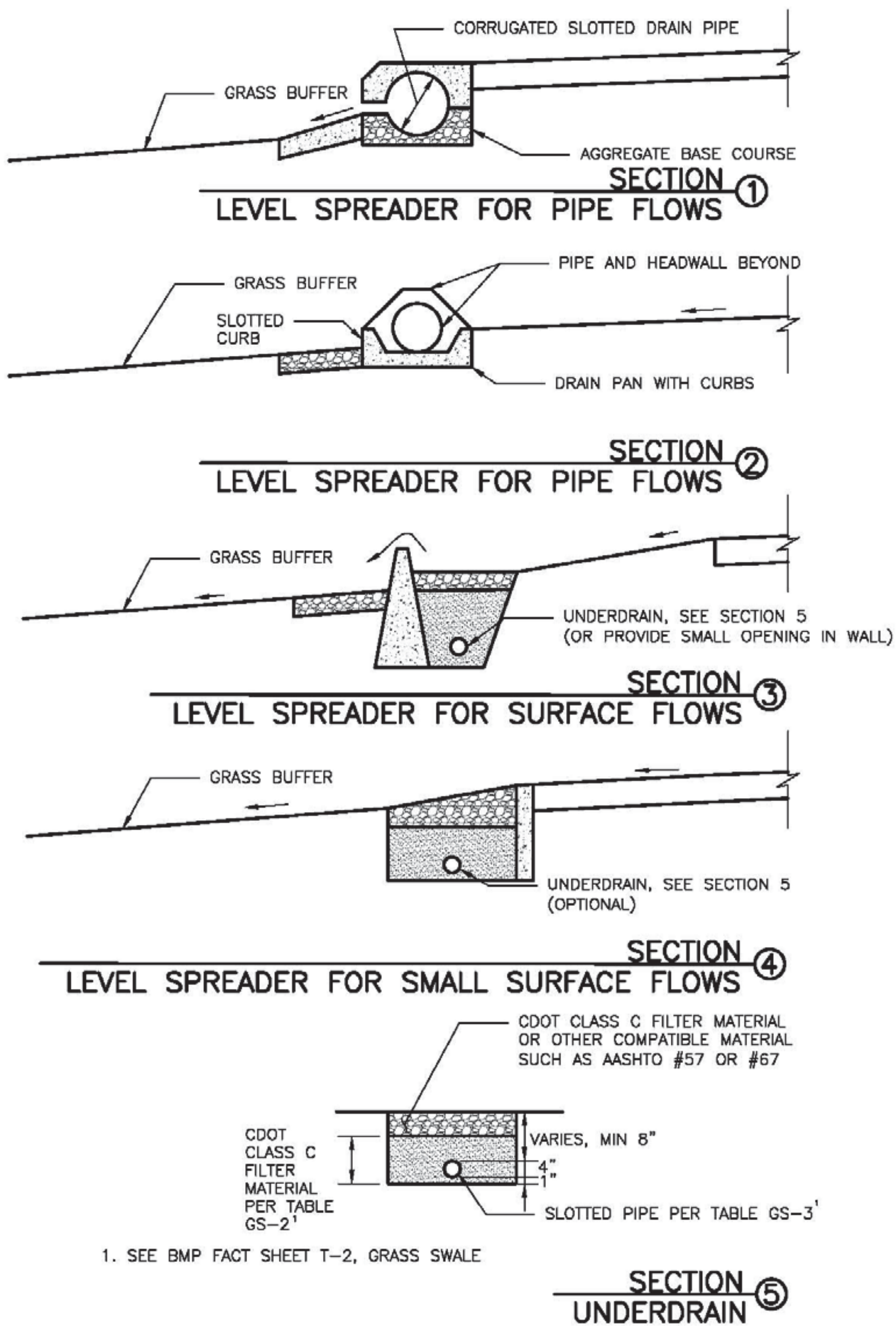


Figure GB-2. Typical Level Spreader Details

Design Example

The *UD-BMP* workbook, designed as a tool for both designer and reviewing agency is available at www.udfcd.org. This section provides a completed design form from this workbook as an example.

Design Procedure Form: Grass Buffer (GB)

Sheet 1 of 1

Designer: R. Dunn
Company: BMP, Inc.
Date: November 24, 2010
Project: Filing 37
Location: NE Corner of 34th Ave. and 105th St., north entrance road

1. Design Discharge A) 2-Year Peak Flow Rate of the Area Draining to the Grass Buffer	Q_2 = 5.0 cfs
2. Minimum Width of Grass Buffer	W_G = 100 ft
3. Length of Grass Buffer (14' or greater recommended)	L_G = 15 ft
4. Buffer Slope (in the direction of flow, not to exceed 0.1 ft / ft)	S_G = 0.100 ft / ft
5. Flow Characteristics (sheet or concentrated) A) Does runoff flow into the grass buffer across the entire width of the buffer?	Choose One ◉ Yes ◯ No
B) Watershed Flow Length	F_L= 20 ft
C) Interface Slope (normal to flow)	S_I= 0.020 ft / ft
D) Type of Flow Sheet Flow: $F_L * S_I \leq 1$ Concentrated Flow: $F_L * S_I > 1$	SHEET FLOW
6. Flow Distribution for Concentrated Flows	Choose One ◉ None (sheet flow) ◯ Slotted Curbing ◯ Level Spreader ◯ Other (Explain):
7 Soil Preparation (Describe soil amendment)	Till 5 CY of compost per 1000 SF to a depth of 6 inches.
8 Vegetation (Check the type used or describe "Other")	Choose One ◯ Existing Xeric Turf Grass ◉ Irrigated Turf Grass ◯ Other (Explain):
9. Irrigation (*Select None if existing buffer area has 80% vegetation AND will not be disturbed during construction.)	Choose One ◉ Temporary ◯ Permanent ◯ None*
10. Outflow Collection (Check the type used or describe "Other")	Choose One ◉ Grass Swale ◯ Street Gutter ◯ Storm Sewer Inlet ◯ Other (Explain):

Notes:

References

Barrett, M., Lantin, A. and S. Austrheim-Smith. 2004. *Stormwater Pollutant Removal in Roadside Vegetated Buffer Strips.* Prepared for the Transportation Research Board: Washington, DC.

California Stormwater Quality Association (CASQA). 2003. *California Stormwater BMP Handbook, Vegetated Buffer Strip*.

Description

Photograph GS-1. This grass swale provides treatment of roadway runoff in a residential area. Photo courtesy of Bill Ruzzo.

Grass swales are densely vegetated trapezoidal or triangular channels with low-pitched side slopes designed to convey runoff slowly. Grass swales have low longitudinal slopes and broad cross-sections that convey flow in a slow and shallow manner, thereby facilitating sedimentation and filtering (straining) while limiting erosion. Berms or check dams may be incorporated into grass swales to reduce velocities and encourage settling and infiltration. When using berms, an underdrain system should be provided. Grass swales are an integral part of the Low Impact Development (LID) concept and may be used as an alternative to a curb and gutter system.

Site Selection

Grass swales are well suited for sites with low to moderate slopes. Drop structures or other features designed to provide the same function as a drop structures (e.g., a driveway with a stabilized grade differential at the downstream end) can be integrated into the design to enable use of this BMP at a broader range of site conditions. Grass swales provide conveyance so they can also be used to replace curb and gutter systems making them well suited for roadway projects.

Grass Swale	
Functions	
LID/Volume Red.	Yes
WQCV Capture	No
WQCV+Flood Control	No
Fact Sheet Includes EURV Guidance	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Good
Nutrients	Moderate
Total Metals	Good
Bacteria	Poor
Other Considerations	
Life-cycle Costs	Low
[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).	

Designing for Maintenance

Recommended ongoing maintenance practices for all BMPs are provided in Chapter 6 of this manual. During design, the following should be considered to ensure ease of maintenance over the long-term:

- Consider the use and function of other site features so that the swale fits into the landscape in a natural way. This can encourage upkeep of the area, which is particularly important in residential areas where a loss of aesthetics and/or function can lead to homeowners filling in and/or piping reaches of this BMP.

- Provide access to the swale for mowing equipment and design sideslopes flat enough for the safe operation of equipment.
- Design and adjust the irrigation system (temporary or permanent) to provide appropriate water for the selected vegetation.
- An underdrain system will reduce excessively wet areas, which can cause rutting and damage to the vegetation during mowing operations.
- When using an underdrain, do not put a filter sock on the pipe. This is unnecessary and can cause the slots or perforations in the pipe to clog.

Benefits

- Removal of sediment and associated constituents through filtering (straining)
- Reduces length of storm sewer systems in the upper portions of a watershed
- Provides a less expensive and more attractive conveyance element
- Reduces directly connected impervious area and can help reduce runoff volumes.

Limitations

- Requires more area than traditional storm sewers.
- Underdrains are recommended for slopes under 2%.
- Erosion problems may occur if not designed and constructed properly.

Design Procedure and Criteria

The following steps outline the design procedure and criteria for stormwater treatment in a grass swale. Figure GS-1 shows trapezoidal and triangular swale configurations.

1. **Design Discharge**: Determine the 2-year flow rate to be conveyed in the grass swale under fully developed conditions. Use the hydrologic procedures described in the *Runoff* Chapter in Volume 1.

2. **Hydraulic Residence Time**: Increased hydraulic residence time in a grass swale improves water quality treatment. Maximize the length of the swale when possible. If the length of the swale is limited due to site constraints, the slope can also be decreased or the cross-sectional area increased to increase hydraulic residence time.

3. **Longitudinal Slope**: Establish a longitudinal slope that will meet Froude number, velocity, and depth criteria while ensuring that the grass swale maintains positive drainage. Positive drainage can be achieved with a minimum 2% longitudinal slope or by including an underdrain system (see step 8). Use drop structures as needed to accommodate site constraints. Provide for energy dissipation downstream of each drop when using drop structures.

4. **Swale Geometry**: Select geometry for the grass swale. The cross section should be either trapezoidal or triangular with side slopes not exceeding 4:1 (horizontal: vertical), preferably flatter. Increase the wetted area of the swale to reduce velocity. Lower velocities result in improved pollutant removal efficiency and greater volume reduction. If one or both sides of the grass swale are also to be used as a grass buffer, follow grass buffer criteria.

5. **Vegetation**: Select durable, dense, and drought tolerant grasses. Turf grasses, such as Kentucky bluegrass, are often selected due to these qualities[1]. Native turf grasses may also be selected where a more natural look is desirable. This will also provide the benefit of lower irrigation requirements, once established. Turf grass is a general term for any grasses that will form a turf or mat as opposed to bunch grass, which will grow in clumplike fashion. Grass selection should consider both short-term (for establishment) and long-term maintenance requirements, given that some varieties have higher maintenance requirements than others. Follow criteria in the *Revegetation* Chapter of Volume 2, with regard to seed mix selection, planting, and ground preparation.

Native grasses provide a more natural aesthetic and require less water once established.

6. **Design Velocity**: Maximum flow velocity in the swale should not exceed one foot per second. Use the Soil Conservation Service (now the NRCS) vegetal retardance curves for the Manning coefficient (Chow 1959). Determining the retardance coefficient is an iterative process that the UD-BMP workbook automates. When starting the swale vegetation from sod, curve "D" (low retardance) should be used. When starting vegetation from seed, use the "E" curve (very low vegetal retardance).

7. **Design Flow Depth**: Maximum flow depth should not exceed one foot at the 2-year peak flow rate. Check the conditions for the 100-year flow to ensure that drainage is being handled without flooding critical areas, structures, or adjacent streets.

Table GS-1. Grass Swale Design Summary for Water Quality

Design Flow	Maximum Froude Number	Maximum Velocity	Maximum Flow Depth
2-year event	0.5	1 ft/s	1 ft

Use of Grass Swales

Vegetated conveyance elements provide some benefit in pollutant removal and volume reduction even when the geometry of the BMP does not meet the criteria provided in this Fact Sheet. These criteria provide a design procedure that should be used when possible; however, when site constraints are limiting, vegetated conveyance elements designed for stability are still encouraged.

[1] Although Kentucky bluegrass has relatively high irrigation requirements to maintain a lush, green aesthetic, it also withstands drought conditions by going dormant. Over-irrigation of Kentucky bluegrass is a common problem along the Colorado Front Range. It can be healthy, although less lush, with much less irrigation than is typically applied.

8. **Underdrain:** An underdrain is necessary for swales with longitudinal slopes less than 2.0%. The underdrain can drain directly into an inlet box at the downstream end of the swale, daylight through the face of a grade control structure or continue below grade through several grade control structures as shown in Figure GS-1.

   The underdrain system should be placed within an aggregate layer. If no underdrain is required, this layer is not required. The aggregate layer should consist of an 8-inch thick layer of CDOT Class C filter material meeting the gradation in Table GS-2. Use of CDOT Class C Filter material with a slotted pipe that meets the slot dimensions provided in Table GS-3 will eliminate the need for geotextile fabrics. Previous versions of this manual detailed an underdrain system that consisted of a 3- to 4-inch perforated HDPE pipe in a one-foot trench section of AASHTO #67 coarse aggregate surrounded by geotextile fabric. If desired, this system continues to provide an acceptable alternative for use in grass swales. Selection of the pipe size may be a function of capacity or of maintenance equipment. Provide cleanouts at approximately 150 feet on center.

Table GS-2. Gradation Specifications for Class C Filter Material
(Source: CDOT Table 703-7)

Sieve Size	Mass Percent Passing Square Mesh Sieves
19.0 mm (3/4")	100
4.75 mm (No. 4)	60 – 100
300 µm (No. 50)	10 – 30
150 µm (No. 100)	0 – 10
75 µm (No. 200)	0 - 3

Table GS-3. Dimensions for Slotted Pipe

Pipe Diameter	Slot Length[1]	Maximum Slot Width	Slot Centers[1]	Open Area[1] (per foot)
4”	1-1/16”	0.032”	0.413”	1.90 in^2
6”	1-3/8”	0.032”	0.516”	1.98 in^2

[1] Some variation in these values is acceptable and is expected from various pipe manufacturers. Be aware that both increased slot length and decreased slot centers will be beneficial to hydraulics but detrimental to the structure of the pipe.

9. **Soil preparation:** Poor soil conditions often exist following site grading. When the section includes an underdrain, provide 4 inches of sandy loam at the invert of the swale extending up to the 2-year water surface elevation. This will improve infiltration and reduce ponding. For all sections, encourage establishment and long-term health of the bottom and side slope vegetation by properly preparing the soil. If the existing site provides a good layer of topsoil, this should be striped, stockpiled, and then replaced just prior to seeding or placing sod. If not available at the site, topsoil can be imported or the existing soil may be amended. Inexpensive soil tests can be performed following rough grading, to determine required soil amendments. Typically, 3 to 5 cubic yards of soil amendment per 1,000 square feet, tilled 4 to 6 inches into the soil is required in order for vegetation to thrive, as well as to enable infiltration of runoff.

10. **Irrigation:** Grass swales should be equipped with irrigation systems to promote establishment and survival in Colorado's semi-arid environment. Systems may be temporary or permanent, depending on the type of grass selected. Irrigation practices have a significant effect on the function of the grass swale. Overwatering decreases the permeability of the soil, reducing the infiltration capacity of the soil and contributing to nuisance baseflows. Conversely, under watering may result in delays in establishment of the vegetation in the short term and unhealthy vegetation that provides less filtering (straining) and increased susceptibility to erosion and riling over the long term.

Construction Considerations

Success of grass swales depends not only on a good design and maintenance, but also on construction practices that enable the BMP to function as designed. Construction considerations include:

- Perform fine grading, soil amendment, and seeding only after upgradient surfaces have been stabilized and utility work crossing the swale has been completed.
- Avoid compaction of soils to preserve infiltration capacities.
- Provide irrigation appropriate to the grass type.
- Weed the area during the establishment of vegetation by hand or mowing. Mechanical weed control is preferred over chemical weed killer.

Photograph GS-2. This community used signage to mitigate compaction of soils post-construction. Photo courtesy of Nancy Styles.

- Protect the swale from other construction activities.
- When using an underdrain, ensure no filter sock is placed on the pipe. This is unnecessary and can cause the slots or perforations in the pipe to clog.

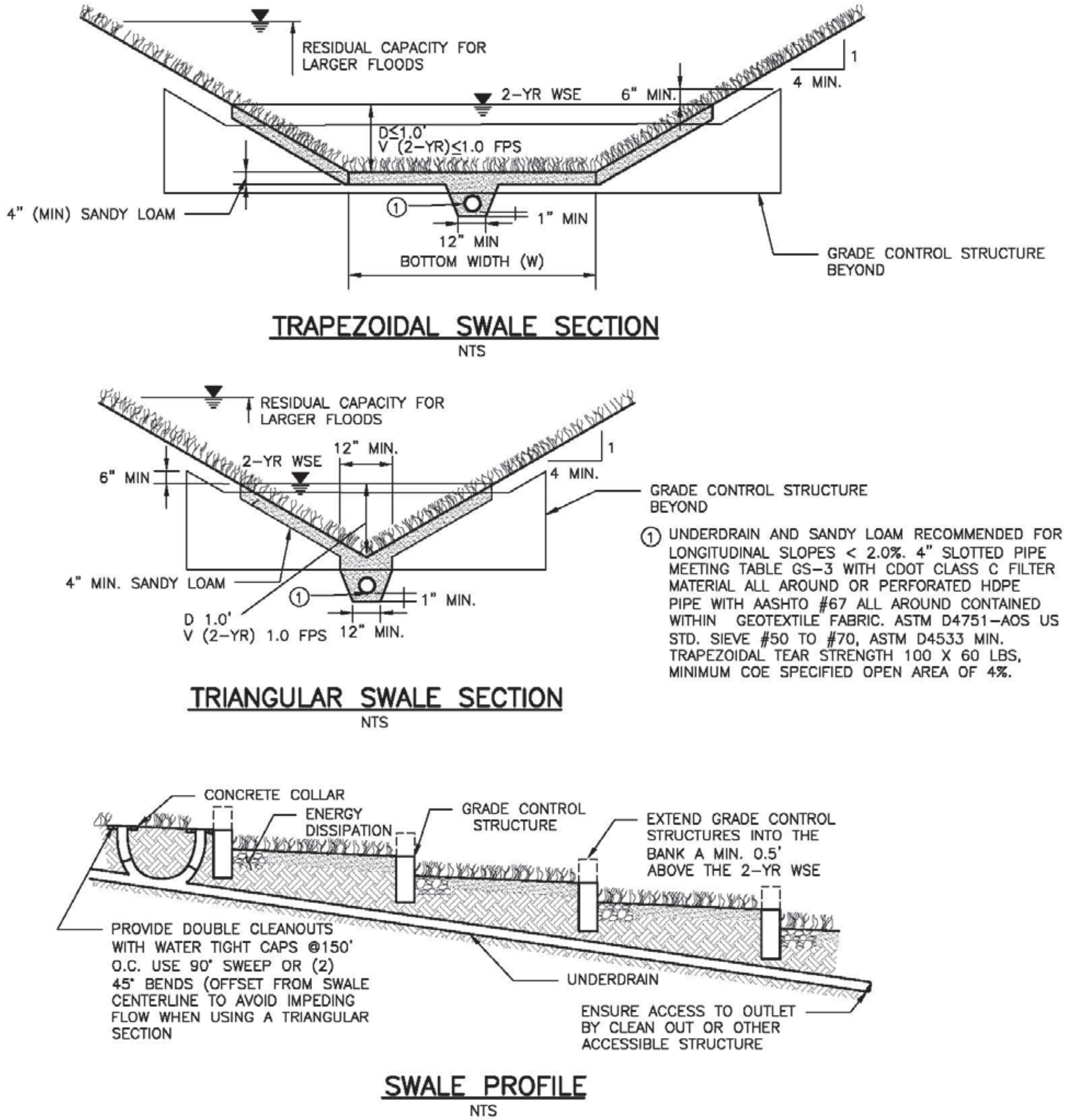


Figure GS-1. Grass Swale Profile and Sections

Design Example

The *UD-BMP* workbook, designed as a tool for both designer and reviewing agency is available at www.udfcd.org. This section provides a completed design form from this workbook as an example.

Design Procedure Form: Grass Swale (GS)

Sheet 1 of 1

Designer:	M. Levine
Company:	BMP Inc.
Date:	November 24, 2010
Project:	Filing 30
Location:	Swale between north property line and 52nd Ave.

1. Design Discharge for 2-Year Return Period	Q_2 = 4.00 cfs
2. Hydraulic Residence Time	
A) : Length of Grass Swale	L_S = 400.0 ft
B) Calculated Residence Time (based on design velocity below)	T_{HR}= 6.7 minutes
3. Longitudinal Slope (vertical distance per unit horizontal)	
A) Available Slope (based on site constraints)	S_{avail} = 0.020 ft / ft
B) Design Slope	S_D = 0.010 ft / ft
4. Swale Geometry	
A) Channel Side Slopes (Z = 4 min., horiz. distance per unit vertical)	Z = 4.00 ft / ft
B) Bottom Width of Swale (enter 0 for triangular section)	W_B = 4.00 ft
5. Vegetation	Choose One
A) Type of Planting (seed vs. sod, affects vegetal retardance factor)	○ Grass From Seed ◉ Grass From Sod
6. Design Velocity (1 ft / s maximum)	V_2 = 1.00 ft / s
7. Design Flow Depth (1 foot maximum)	D_2 = 0.62 ft
A) Flow Area	A_2 = 4.0 sq ft
B) Top Width of Swale	W_T = 9.0 ft
C) Froude Number (0.50 maximum)	F = 0.26
D) Hydraulic Radius	R_H = 0.44
E) Velocity-Hydraulic Radius Product for Vegetal Retardance	VR = 0.44
F) Manning's n (based on SCS vegetal retardance curve D for sodded grass)	n = 0.088
G) Cumulative Height of Grade Control Structures Required	H_D = 4.00 ft
8. Underdrain (Is an underdrain necessary?)	Choose One ◉ YES ○ NO AN UNDERDRAIN IS REQUIRED IF THE DESIGN SLOPE < 2.0%
9. Soil Preparation (Describe soil amendment)	Till 5 CY of compost per 1000 SF to a depth of 6 inches.
10. Irrigation	Choose One ◉ Temporary ○ Permanent

Notes:

References

Chow, Ven Te. 1959. *Open Channel Flow.* McGraw Hill: New York, NY.

Description

A BMP that utilizes bioretention is an engineered, depressed landscape area designed to capture and filter or infiltrate the water quality capture volume (WQCV). BMPs that utilize bioretention are frequently referred to as rain gardens or porous landscape detention areas (PLDs). The term PLD is common in the UDFCD region as this manual first published the BMP by this name in 1999. In an effort to be consistent with terms most prevalent in the stormwater industry, this document generally refers to the treatment process as *bioretention* and to the BMP as a *rain garden*.

Photograph B-1. This recently constructed rain garden provides bioretention of pollutants, as well as an attractive amenity for a residential building. Treatment should improve as vegetation matures.

The design of a rain garden may provide detention for events exceeding that of the WQCV. There are generally two ways to achieve this. The design can provide the flood control volume above the WQCV or the design can provide and slowly release the flood control volume in an area downstream of one or more rain gardens. See the *Storage* chapter in Volume 2 of the USDCM for more information.

This infiltrating BMP requires consultation with a geotechnical engineer when proposed adjacent to a structure. A geotechnical engineer can assist with evaluating the suitability of soils, identifying potential impacts, and establishing minimum distances between the BMP and structures.

Bioretention (Rain Garden)	
Functions	
LID/Volume Red.	Yes
WQCV Capture	Yes
WQCV+Flood Control	Yes
Fact Sheet Includes EURV Guidance	No
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Very Good[1]
Nutrients	Moderate
Total Metals	Good
Bacteria	Moderate
Other Considerations	
Life-cycle Costs[4]	Moderate

[1] Not recommended for watersheds with high sediment yields (unless pretreatment is provided).

[3] Based primarily on data from the International Stormwater BMP Database (www.bmpdatabase.org).

[4] Based primarily on BMP-REALCOST available at www.udfcd.org. Analysis based on a single installation (not based on the maximum recommended watershed tributary to each BMP).

Terminology

The term *bioretention* refers to the treatment process although it is also frequently used to describe a BMP that provides biological uptake and retention of the pollutants found in stormwater runoff. This BMP is sometimes referred to as a *porous landscape detention (PLD) area* or *rain garden*.

Site Selection

This BMP allows WQCV treatment within one or more areas designated for landscape (see design step 7 for suggusted vegetation). In this way, it is an excellent alternative to extended detention basins for small sites. A typical rain garden serves a tributary area of one impervious acre or less, although they can be designed for larger tributary areas. Multiple installations can be used within larger sites. Rain gardens should not be used when a baseflow is anticipated. They are typically small and installed in locations such as:

- Parking lot islands
- Street medians
- Landscape areas between the road and a detached walk
- Planter boxes that collect roof drains

Bioretention requires a stable watershed. Retrofit applications are typically successful for this reason. When the watershed includes phased construction, sparsely vegetated areas, or steep slopes in sandy soils, consider another BMP or provide pretreatment before runoff from these areas reaches the rain garden.

The surface of the rain garden should be flat. For this reason, rain gardens can be more difficult to incorporate into steeply sloping terrain; however, terraced applications of these facilities have been successful in other parts of the country.

Benefits

- Bioretention uses multiple treatment processes to remove pollutants, including sedimentation, filtering, adsorption, evapotranspiration, and biological uptake of constituents.
- Stormwater treatment occurs within attractive landscaped areas.
- There is a potential reduction of irrigation requirements by taking advantage of site runoff.

Limitations

- Additional design and construction steps are required for placement of any ponding or infiltration area near or upgradient from a building foundation and/or when expansive (low to high swell) soils exist. This is discussed in the design procedure section.
- In developing or otherwise erosive watersheds, high sediment loads can clog the facility.

When bioretention (and other BMPs used for infiltration) are located adjacent to buildings or pavement areas, protective measures should be implemented to avoid adverse impacts to these structures. Oversaturated subgrade soil underlying a structure can cause the structure to settle or result in moisture-related problems. Wetting of expansive soils or bedrock can cause swelling, resulting in structural movements. A geotechnical engineer should evaluate the potential impact of the BMP on adjacent structures based on an evaluation of the subgrade soil, groundwater, and bedrock conditions at the site. Additional minimum requirements include:

- In locations where subgrade soils do not allow infiltration and/or where infiltration could adversely impact adjacent structures, include a drainage layer (with underdrain) under the growing medium.
- In locations where potentially expansive soils or bedrock exist, placement of a rain garden adjacent to structures and pavement should only be considered if the BMP includes a drainage layer (with underdrain) and an impermeable geomembrane liner designed to restrict seepage.

Designing for Maintenance

Recommended maintenance practices for all BMPs are in Chapter 6 of this manual. During design, consider the following to ensure ease of maintenance over the long-term:

- Do not put a filter sock on the underdrain. This is not necessary and can cause the underdrain to clog.
- The best surface cover for a rain garden is full vegetation. Use rock mulch sparingly within the rain garden because rock mulch limits infiltration and is more difficult to maintain. Wood mulch handles sediment build-up better than rock mulch; however, wood mulch floats and may clog the overflow depending on the configuration of the outlet or settle unevenly. Some municipalities may not allow wood mulch for this reason.
- Consider all potential maintenance requirements such as mowing (if applicable) and replacement of the growing medium. Consider the method and equipment for each task required. For example, in a large rain garden where the use of hand tools is not feasible, does the shape and configuration of the rain garden allow for removal of the growing medium using a backhoe?
- Provide pre-treatment when it will reduce the extent and frequency of maintenance necessary to maintain function over the life of the BMP. For example, if the tributary is larger than one acre, prone to debris or the use of sand for ice control, consider a small forebay.
- Make the rain garden as shallow as possible. Increasing the depth unnecessarily can create erosive side slopes and complicate maintenance. Shallow rain gardens are also more attractive.
- Design and adjust the irrigation system (temporary or permanent) to provide appropriate water for the establishment and maintenance of selected vegetation.

Is Pretreatment Needed?

Designing the inflow gutter to the rain garden at a minimal slope of 0.5% can facilitate sediment and debris deposition prior to flows entering the BMP. Be aware, this will reduce maintenance of the BMP, but may require more frequent sweeping of the gutter to ensure that the sediment does not impede flow into the rain garden.

Design Procedure and Criteria

1. **Subsurface Exploration and Determination of a No-Infiltration, Partial Infiltration, or Full Infiltration Section**: Infiltration BMPs can have three basic types of sections. The appropriate section will depend on land use and activities, proximity to adjacent structures and soil characteristics. Sections of each installation type are shown in Figure B-1.
   - **No-Infiltration Section**: This section includes an underdrain and an impermeable liner that prevents infiltration of stormwater into the subgrade soils. Consider using this section when any of the following conditions exist:
     - The site is a stormwater hotspot and infiltration could result in contamination of groundwater.
     - The site is located over contaminated soils and infiltration could mobilize these contaminants.
     - The facility is located over potentially expansive soils or bedrock that could swell due to infiltration and potentially damage adjacent structures (e.g., building foundation or pavement).
   - **Partial Infiltration Section**: This section does not include an impermeable liner, and allows some infiltration. Stormwater that does not infiltrate is collected and removed by an underdrain

system.

- **Full Infiltration Section**: This section is designed to infiltrate the water stored in the basin into the subgrade below. UDFCD recommends a minimum infiltration rate of 2 times the rate needed to drain the WQCV over 12 hours. A conservative design could utilize the partial infiltration section with the addition of a valve at the underdrain outlet. In the event that infiltration does not remain adequate following construction, the valve could be opened and allow this section to operate as a partial infiltration section.

A geotechnical engineer should scope and perform a subsurface study. Typical geotechnical investigation needed to select and design the section includes:

- Prior to exploration review geologic and geotechnical information to assess near-surface soil, bedrock and groundwater conditions that may be encountered and anticipated ranges of infiltration rate for those materials. For example, if the facility is located adjacent to a structure and the site is located in a general area of known shallow, potentially expansive bedrock, a no-infiltration section will likely be required. It is also possible that this BMP may be infeasible, even with a liner, if there is a significant potential for damage to the adjacent structures (e.g., areas of dipping bedrock).
- Drill exploratory borings or exploratory pits to characterize subsurface conditions beneath the subgrade and develop requirements for subgrade preparation. Drill at least one boring or pit for every 40,000 ft^2, and at least two borings or pits for sites between 10,000 ft^2 and 40,000 ft^2. The boring or pit should extend at least 5 feet below the bottom of the base, and at least 20 feet in areas where there is a potential of encountering potentially expansive soils or bedrock. More borings or pits at various depths may be required by the geotechnical engineer in areas where soil types may change, in low-lying areas where subsurface drainage may collect, or where the water table is likely within 8 feet below the planned bottom of the base or top of subgrade. Installation of temporary monitoring wells in selected borings or pits for monitoring groundwater levels over time should be considered where shallow groundwater is encountered.
- Perform laboratory tests on samples obtained from the borings or pits to initially characterize the subgrade, evaluate the possible section type, and to assess subgrade conditions for supporting traffic loads. Consider the following tests: moisture content (ASTM D 2216); dry density (ASTM D 2936); Atterberg limits (ASTM D 4318); gradation (ASTM D 6913); swell-consolidation (ASTM D 4546); subgrade support testing (R-value, CBR or unconfined compressive strength); and hydraulic conductivity. A geotechnical engineer should determine the appropriate test method based on the soil type.
- For sites where a full infiltration section may be feasible, perform on-site infiltration tests using a double-ring infiltrometer (ASTM D 3385). Perform at least one test for every 160,000 ft^2 and at least two tests for sites between 40,000 ft^2 and 160,000 ft^2. The tests should be located near completed borings or pits so the test results and subsurface conditions encountered in the borings can be compared, and at least one test should be located near the boring or pit showing the most unfavorable infiltration condition. The test should be performed at the planned top of subgrade underlying the growing media.
- Be aware that actual infiltration rates are highly variable dependent on soil type, density and moisture content and degree of compaction as well as other environmental and construction influences. Actual rates can differ an order of magnitude or more from those indicated by infiltration or permeability testing. Select the type of section based on careful assessment of the subsurface exploration and testing data.

The following steps outline the design procedure and criteria, with Figure B-1 providing a corresponding cross-section.

2. **Basin Storage Volume**: Provide a storage volume based on a 12-hour drain time.

   Find the required WQCV (watershed inches of runoff). Using the imperviousness of the tributary area (or effective imperviousness where LID elements are used upstream), use Figure 3-2 located in Chapter 3 of this manual to determine the WQCV based on a 12-hour drain time.

   Calculate the design volume as follows:

$$V = \left[\frac{\mathrm{WQCV}}{12}\right] A \qquad \text{Equation B-1}$$

   Where:

   V= design volume (ft^3)

   A = area of watershed tributary to the rain garden (ft^2)

3. **Basin Geometry:** UDFCD recommends a maximum WQCV ponding depth of 12 inches to maintain vegetation properly. Provide an inlet or other means of overflow at this elevation. Depending on the type of vegetation planted, a greater depth may be utilized to detain larger (more infrequent) events. The bottom surface of the rain garden, also referred to here as the filter area, should be flat. Sediment will reside on the filter area of the rain garden; therefore, if the filter area is too small, it may clog prematurely. If the filter area is not flat, the lowest area of the filter is more likely to clog as it will have a higher sediment loading. Increasing the filter area will reduce clogging and decrease the frequency of maintenance. Equation B-2 provides a minimum filter area allowing for some of the volume to be stored beyond the area of the filter (i.e., above the sideslopes of the rain garden).

Note that the total surcharge volume provided by the design must also equal or exceed the design volume. Where needed to meet the the required volume, also consider the porosity of the media at 14 percent. Use vertical walls or slope the sides of the basin to achieve the required volume. Sideslopes should be no steeper than 4:1 (horizontal:vertical).

$$A_F = 0.02\, AI \qquad \text{Equation B-2}$$

Where:

A_F= minimum (flat) filter area (ft^2)

A = area tributary to the rain garden (ft^2)

I = imperviousness of area tributary to the rain garden (percent expressed as a decimal)

4. **Growing Medium:** Provide a minimum of 18 inches of growing medium to enable establishment of the roots of the vegetation (see Figure B-1). A previous version of this manual specified a mixture consisting of 85% coarse sand and a 15% compost/shredded paper mixture (by volume). Based on field monitoring of this medium, compost was removed to reduce export of nutrients and fines and silts were added to both benefit the vegetation and increase capture of metals in stormwater.

Table B-1 specifies the growing media as well as other materials discussed in this Fact Sheet. Growing media is engineered media that requires a high level of quality control and must almost always be imported. Obtaining a particle size distribution and nutrient analysis is the only way to ensure that the media is acceptable. UDFCD has identified placement of media not meeting the specification as the most frequent cause of failure. Sample the media after delivery and prior to placement or obtain a sample from the supplier in advance of delivery and placement and have this analyzed prior to delivery.

Other Rain Garden Growing Medium Amendments

The specified growing medium was designed for filtration ability, clogging characteristics, and vegetative health. It is important to preserve the function provided by the rain garden growing medium when considering additional materials for incorporation into the growing medium or into the standard section shown in Figure B-1. When desired, amendments may be included to improve water quality or to benefit vegetative health as long as they do not add nutrients, pollutants, or modify the infiltration rate. For example, a number of products, including steel wool, capture and retain dissolved phosphorus (Erickson 2009). When phosphorus is a target pollutant, proprietary materials with similar characteristics may be considered. Do not include amendments such as top soil, sandy loam, and compost.

Table B-1. Material specification for bioretention/rain garden facilities

Material		Specification			Submittals	Testing	Notes
Bioretention Growing Media (soil + organics)	Bioretention soil	Particle size distribution: 80-90% sand (0.05 - 2.0 mm diameter) 3-17% silt (0.002-0.5 mm diameter) 3-17% clay (<0.002 diameter) Chemical attribute and nutrient analysis: pH 6.8 - 7.5 organic matter < 1.5% nitrogen <15 ppm phosphorus < 15 ppm salinity < 6 mmhos/cm			Particle size distribution and nutrient analysis required.		Percentages are in weight.
	Bioretention organics	3 to 5% shredded mulch (by weight of growing media)					bioretention soil required. Aged 6 months (minimum).
Landscape mulch		Shredded hardwood					Aged 6 months (minimum). No weed fabric allowed.
Underdrain aggregate	CDOT filter material (Class B or C as specified)		Mass Percent Passing Square Mesh Siev				
		Sieve Size	Class B	Class C	Particle size distribution required.		
		37.5 mm (1.5")	100				
		19.0 mm (0.75")		100			
		4.75 mm (No.4)	20-60	60-100			
		1.18 um (No. 16)	10-30				
		300 um (No. 50)	0-10	10-30			
		150 um (No. 100)		0-10			
		75 um (No. 200)	0-3	0-3			
Underdrain Pipe		Pipe diameter and type	Maximum slot width (inches)	Minimum open area (per foot)	Required	Pipe must conform to requirements of ASTM designation F949. There shall be no evidence of splitting, cracking, or breaking when the pipe is tested per ASTM test method D2412 in accordance with F949 section 7.5 and ASTM F794 section 8.5.	Contech A-2000 slotted pipe (or equal)
		4-inch slotted PVC	0.032	1.90 in.²			
		6-inch slotted PVC	0.032	1.98 in.²			
Impermeable liner			Thickness 0.76 mm (30 mil)	Test method	Required	Thermal welding required for fully lined facilities (not a cutain). Leak testing in the field required.	
		Thickness, % Tolerance	+/-5	ASTM D 1593			
		Tensile strength, kN/m (lb/in)	12.25 (70)	ASTM D8 82, method B			
		Modulus at 100% elongation, kN/m	5.25 (30)	ASTM D8 82, method B			
		Ultimate elongation, %	350	ASTM D8 82, method A			
		Tear resistance, N(lbs)	38 (8.5)	ASTM D 1004			
		Low temperature impact, ° C (° F)	-29 (-20)	ASTM D 1790			
		Volatile loss, % maximum	0.7	ASTM D8 82, method A			
		Pinholes, no. per 8 m² (no. per 10 yd.²)	1 (max)	N/A			
		Bonded seam strength, % of tensile	80	N/A			

5. **Underdrain System**: When using an underdrain system, provide a control orifice sized to drain the design volume in 12 hours or more (see Equation B-3). Use a minimum orifice size of 3/8 inch to avoid clogging. This will provide detention and slow release of the WQCV, providing water quality benefits and reducing impacts to downstream channels. Space underdrain pipes a maximum of 20 feet on center. Provide cleanouts to enable maintenance of the underdrain. Cleanouts can also be used to conduct an inspection (by camera) of the underdrain system to ensure that the pipe was not crushed or disconnected during construction.

Calculate the diameter of the orifice for a 12-hour drain time using Equation B-3 (Use a minimum orifice size of 3/8 inch to avoid clogging.):

$$D_{12\,\text{hour drain time}} = \sqrt{\frac{V}{1414\ y^{0.41}}} \qquad \text{Equation B-3}$$

Where:

D = orifice diameter (in)

y = distance from the lowest elevation of the storage volume (i.e., surface of the filter) to the center of the orifice (ft)

V = volume (WQCV or the portion of the WQCV in the rain garden) to drain in 12 hours (ft^3)

In previous versions of this manual, UDFCD recommended that the underdrain be placed in an aggregate layer and that a geotextile (separator fabric) be placed between this aggregate and the growing medium. This version of the manual replaces that section with materials that, when used together, eliminate the need for a separator fabric.

The underdrain system should be placed within an 6-inch-thick section of CDOT Class B or Class C filter material meeting the gradation in Table B-1. Use slotted pipe that meets the slot dimensions provided in Table B-3.

6. **Impermeable Geomembrane Liner and Geotextile Separator Fabric:** For no-infiltration sections, install a 30 mil (minimum) PVC geomembrane liner, per Table B-1, on the bottom and sides of the basin, extending up at least to the top of the underdrain layer. Provide at least 9 inches (12 inches if possible) of cover over the membrane where it is attached to the wall to protect the membrane from UV deterioration. The geomembrane should be field-seamed using a dual track welder, which allows for non-destructive testing of almost all field seams. A small amount of single track is allowed in limited areas to seam around pipe perforations, to patch seams removed for destructive seam testing, and for limited repairs. The liner should be installed with slack to prevent tearing due to backfill, compaction, and settling. Place CDOT Class B geotextile separator fabric above the geomembrane to protect it from being punctured during the placement of the filter material above the liner. If the subgrade contains angular rocks or other material that could puncture the geomembrane, smooth-roll the surface to create a suitable surface. If smooth-rolling the surface does not provide a suitable surface, also place the separator fabric between the geomembrane and the underlying subgrade. This should only be done when necessary because fabric placed under the geomembrane can increase seepage losses through pinholes or other geomembrane defects. Connect the geomembrane to perimeter concrete walls around the basin perimeter, creating a watertight seal between the geomembrane and the walls using a continuous batten bar and anchor connection (see Figure B-3). Where the need for the impermeable membrane is not as critical, the membrane can be attached with a nitrile-based vinyl adhesive. Use watertight PVC boots for underdrain pipe penetrations through the liner (see Figure B-2) or the technique shown in photo B-3.

Photograph B-2. The impermeable membrane in this photo has ripped from the bolts due to placement of the media without enough slack in the membrane.

Photograph B-3. Ensure a water-tight connection where the underdrain penetrated the liner. The heat-welded "boot" shown here is an alternative to the clamped detail shown in Figure B-2.

Table B-2. Physical requirements for separator fabric[1]

Property	Class B		Test Method
	Elongation < 50%[2]	Elongation > 50%[2]	
Grab Strength, N (lbs.)	800 (180)	510 (115)	ASTM D 4632
Puncture Resistance, N (lbs.)	310 (70)	180 (40)	ASTM D 4833
Trapezoidal Tear Strength, N (lbs.)	310 (70)	180 (40)	ASTM D 4533
Apparent Opening Size, mm (US Sieve Size)	AOS < 0.3mm (US Sieve Size No. 50)		ASTM D 4751
Permittivity, sec^{-1}	0.02 default value, must also be greater than that of soil		ASTM D 4491
Permeability, cm/sec	k fabric > k soil for all classes		ASTM D 4491
Ultraviolet Degradation at 500 hours	50% strength retained for all classes		ASTM D 4355

[1] Strength values are in the weaker principle direction

[2] As measured in accordance with ASTM D 4632

7. **Inlet and Outlet Control:** In order to provide the proper drain time, the bioretention area can be restricted at the underdrain outlet with an orifice plate or can be designed without an underdrain (provided the subgrade meets the requirements above). Equation B-3 is a simplified equation for sizing an orifice plate for a 12-hour drain time. UD-BMP or UD-Detention, available at www.udfcd.org, also perform this calculation.

Photograph B-4. The curb cut shown allows flows to enter this rain garden while excess flows bypass the facility.

How flow enters and exits the BMP is a function of the overall drainage concept for the site. Curb cuts can be designed to both allow stormwater into the rain garden as well as to provide release of stormwater in excess of the WQCV. Roadside rain gardens located on a steep site might pool and overflow into downstream cells with a single curb cut, level spreader, or outlet structure located at the most downstream cell. When selecting the type and location of the outlet structure, ensure runoff will not short-circuit the rain garden. This is a frequent problem when using a curb inlet located outside the rain garden for overflow.

For rain gardens with concentrated points of inflow, provide a forebay and energy dissipation. A depressed concrete slab works best for a forebay. It helps maintain a vertical drop at the inlet and allows for easily removal of sediment using a square shovel. Where rock is used for energy dissipation, provide separator fabric between the rock and growing medium to minimize subsidence.

8. **Vegetation:** UDFCD recommends that the filter area be vegetated with drought tolerant species that thrive in sandy soils. Table B-3 provides a suggested seed mix for sites that will not need to be irrigated after the grass has been established.

   Mix seed well and broadcast, followed by hand raking to cover seed and then mulched. Hydromulching can be effective for large areas. Do not place seed when standing water or snow is present or if the ground is frozen. Weed control is critical in the first two to three years, especially when starting with seed.

   When using sod, specify sand-grown sod. Do not use conventional sod. Conventional sod is grown in clay soil that will seal the filter area, greatly reducing overall function of the BMP.

   When using an impermeable liner, select plants with diffuse (or fibrous) root systems, not taproots. Taproots can damage the liner and/or underdrain pipe. Avoid trees and large shrubs that may interfere with restorative maintenance. Plant these outside of the area of growing medium. Use a cutoff wall to ensure that roots do not grow into the underdrain or place trees and shrubs a conservative distance from the underdrain.

9. **Irrigation:** Provide spray irrigation at or above the WQCV elevation or place temporary irrigation on top of the rain garden surface. Do not place sprinkler heads on the flat surface. Remove temporary irrigation when vegetation is established. If left in place this will become buried over time and will be damaged during maintenance operations.

   Adjust irrigation schedules during the growing season to provide the minimum water necessary to maintain plant health and to maintain the available pore space for infiltration.

Designing for Flood Protection

Provide the WQCV in rain gardens that direct excess flow into to a landscaped basin designed for flood control or design a single basin to provide water quality and flood control. See the *Storage* chapter in Volume 2 of the USDCM for more information. UD-Detention, available at www.udfcd.org, will facilitate design either alternative.

Table B-3. Native seed mix for rain gardens

Common Name	Scientific Name	Variety	PLS[2] lbs per Acre	Ounces per Acre
Sand bluestem	Andropogon hallii	Garden	3.5	
Sideoats grama	Bouteloua curtipendula	Butte	3	
Prairie sandreed	Calamovilfa longifolia	Goshen	3	
Indian ricegrass	Oryzopsis hymenoides	Paloma	3	
Switchgrass	Panicum virgatum	Blackwell	4	
Western wheatgrass	Pascopyrum smithii	Ariba	3	
Little bluestem	Schizachyrium scoparium	Patura	3	
Alkali sacaton	Sporobolus airoides		3	
Sand dropseed	Sporobolus cryptandrus		3	
Pasture sage[1]	Artemisia frigida			2
Blue aster[1]	Aster laevis			4
Blanket flower[1]	Gaillardia aristata			8
Prairie coneflower[1]	Ratibida columnifera			4
Purple prairieclover[1]	Dalea (Petalostemum) purpurea			4
Sub-Totals:			27.5	22
Total lbs per acre:			**28.9**	

[1] Wildflower seed (optional) for a more diverse and natural look.
[2] PLS = Pure Live Seed.

Aesthetic Design

In addition to effective stormwater quality treatment, rain gardens can be attractively incorporated into a site within one or several landscape areas. Aesthetically designed rain gardens will typically either reflect the character of their surroundings or become distinct features within their surroundings. Guidelines for each approach are provided below.

Reflecting the Surrounding

- Determine design characteristics of the surrounding. This becomes the context for the drainage improvement. Use these characteristics in the structure.
- Create a shape or shapes that "fix" the forms surrounding the improvement. Make the improvement part of the existing surrounding.
- The use of material is essential in making any new improvement an integral part of the whole. Select materials that are as similar as possible to the surrounding architectural/engineering materials. Select materials from the same source if possible. Apply materials in the same quantity, manner, and method as original material.
- Size is an important feature in seamlessly blending the addition into its context. If possible, the overall size of the improvement should look very similar to the overall sizes of other similar objects in the improvement area.

Reflective Design

A reflective design borrows the characteristics, shapes, colors, materials, sizes and textures of the built surroundings. The result is a design that fits seamlessly and unobtrusively in its environment.

- The use of the word texture in terms of the structure applies predominantly to the selection of plant material. The materials used should as closely as possible, blend with the size and texture of other plant material used in the surrounding. The plants may or may not be the same, but should create a similar feel, either individually or as a mass.

Creating a Distinct Feature

Designing the rain garden as a distinct feature is limited only by budget, functionality, and client preference. There is far more latitude in designing a rain garden that serves as a distinct feature. If this is the intent, the main consideration beyond functionality is that the improvement create an attractive addition to its surroundings. The use of form, materials, color, and so forth focuses on the improvement itself and does not necessarily reflect the surroundings, depending on the choice of the client or designer.

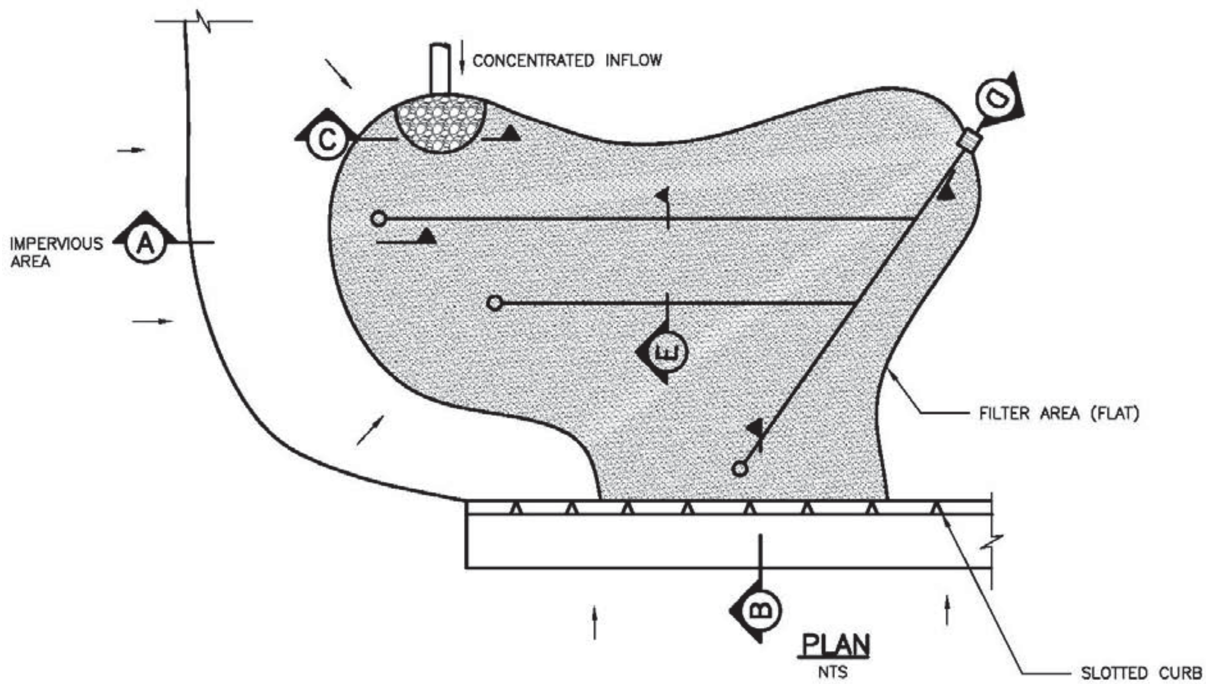
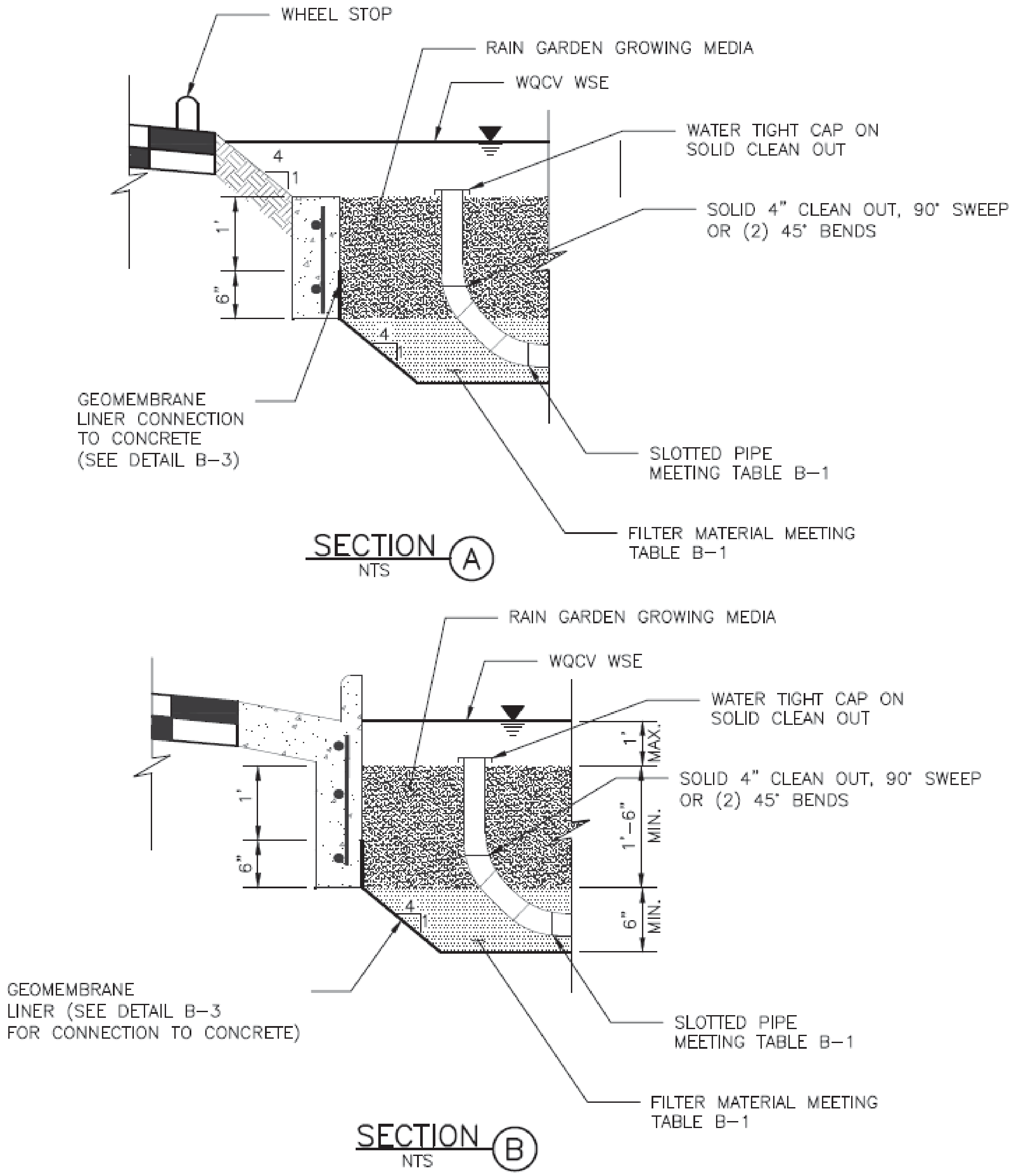
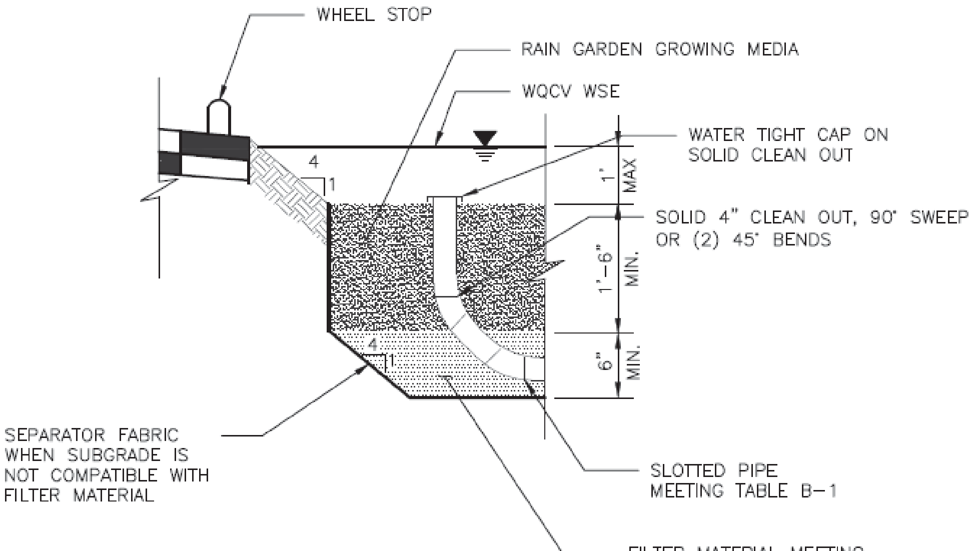


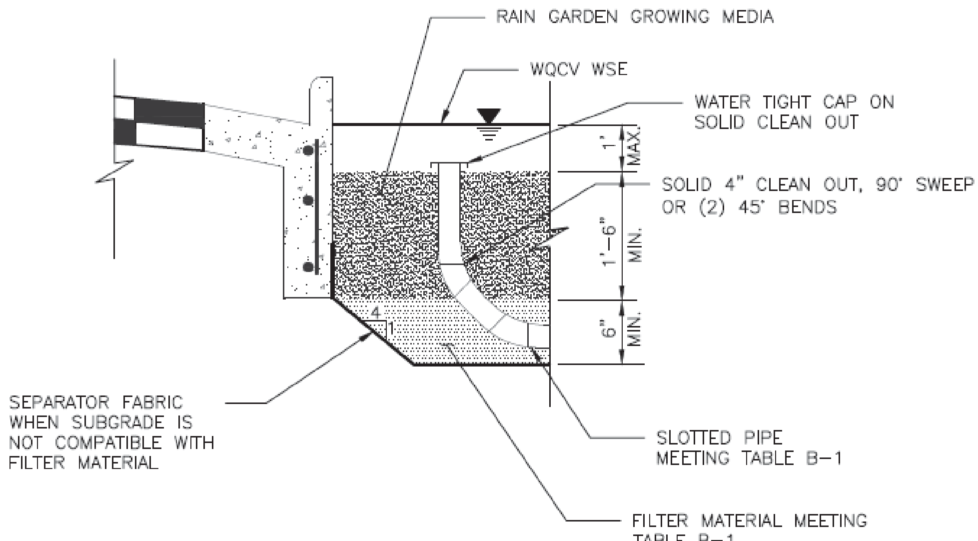
Figure B-1 – Typical rain garden plan and sections



NO-INFILTRATION SECTIONS

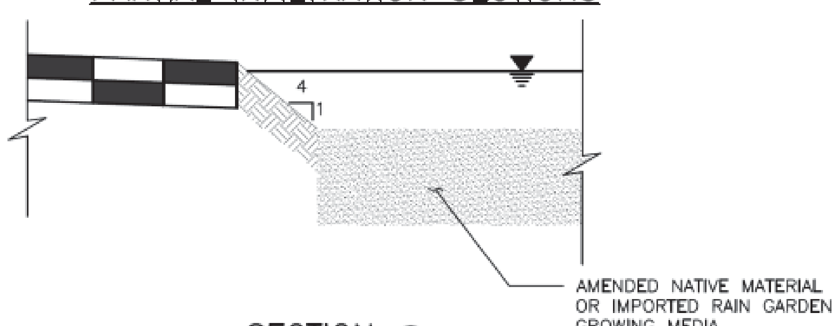


SECTION (A)
NTS



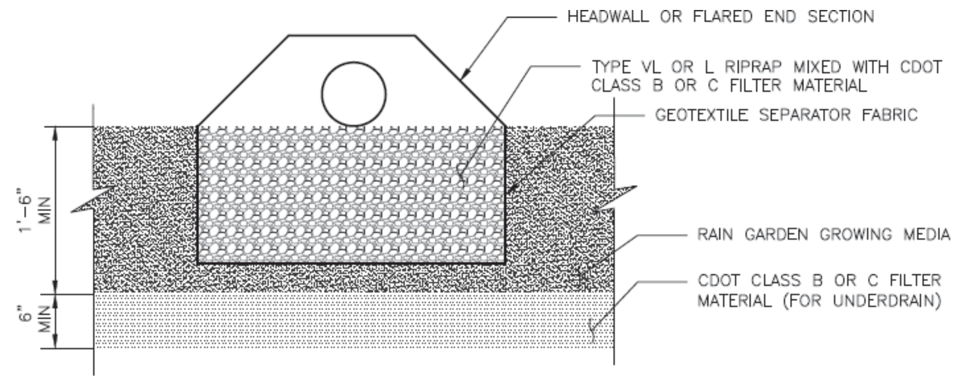
SECTION (B)
NTS

PARTIAL INFILTRATION SECTIONS

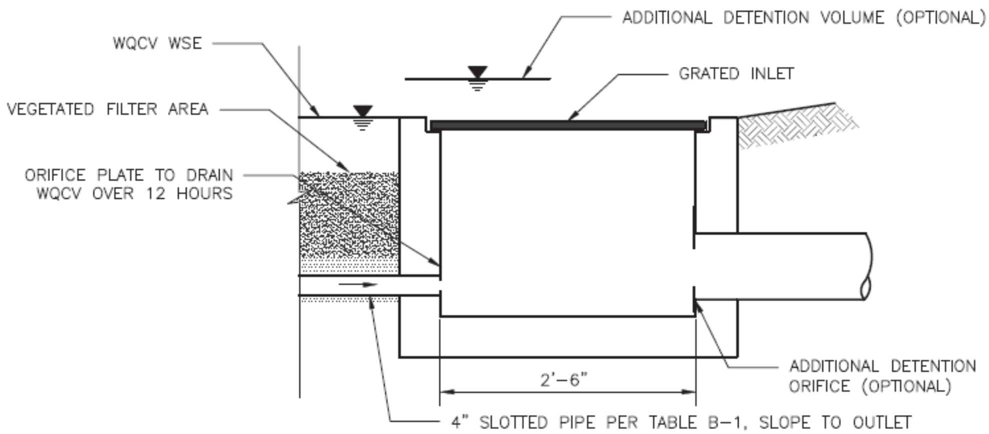


SECTION (A)
NTS

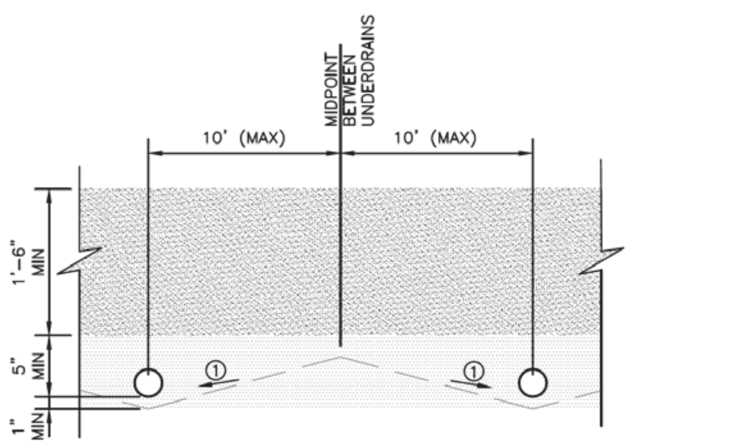
FULL INFILTRATION SECTION



SECTION C
NTS



SECTION D
NTS



1 SLOPE (STRAIGHT GRADE) SUBGRADE (2–10%) TO UNDERDRAIN TO REDUCE SATURATED SOIL CONDITIONS BETWEEN STORM EVENTS (OPTIONAL)

SECTION E
NTS

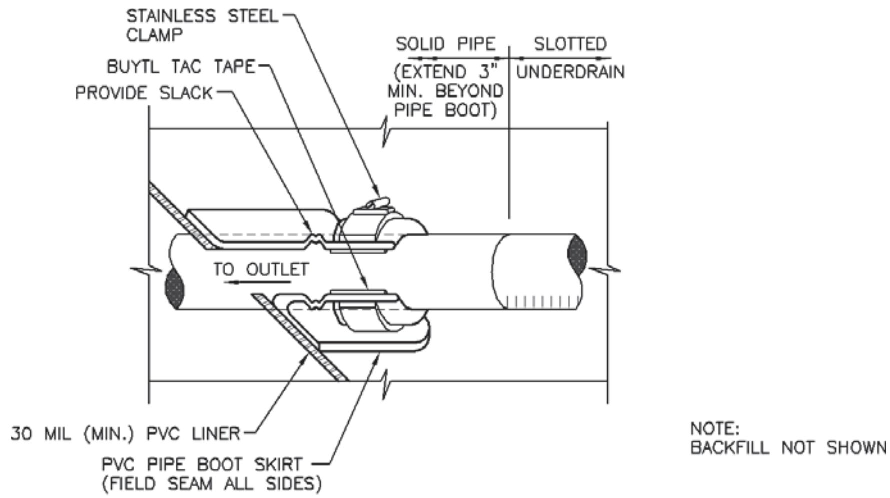


Figure B-2. Geomembrane Liner/Underdrain Penetration Detail

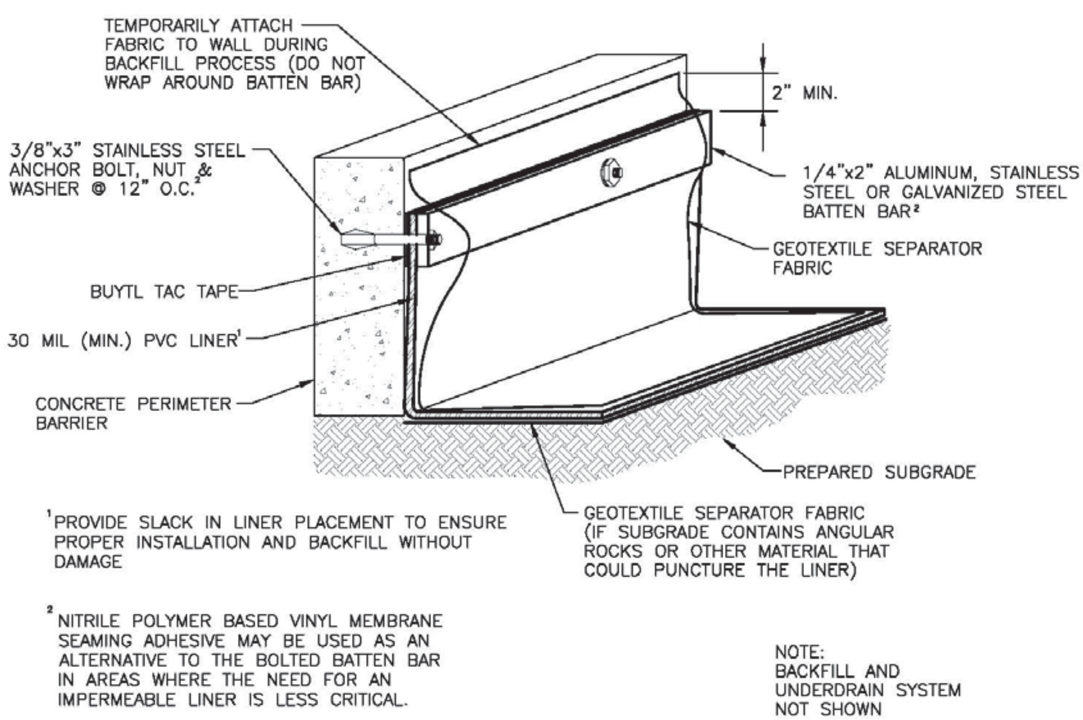


Figure B-3. Geomembrane Liner/Concrete Connection Detail

Construction Considerations

Proper construction of rain gardens involves careful attention to material specifications, final grades, and construction details. For a successful project, implement the following practices:

- Protect area from excessive sediment loading during construction. This is the most common cause of clogging of rain gardens. The portion of the site draining to the rain garden must be stabilized before allowing flow into the rain garden. This includes completion of paving operations.

- Avoid over compaction of the area to preserve infiltration rates (for partial and full infiltration sections).

- Provide construction observation to ensure compliance with design specifications. Improper installation, particularly related to facility dimensions and elevations and underdrain elevations, is a common problem with rain gardens.

Photograph B-3. Inadequate construction staking may have contributed to flows bypassing this rain garden.

- When using an impermeable liner, ensure enough slack in the liner to allow for backfill, compaction, and settling without tearing the liner.

- Provide necessary quality assurance and quality control (QA/QC) when constructing an impermeable geomembrane liner system, including but not limited to fabrication testing, destructive and non-destructive testing of field seams, observation of geomembrane material for tears or other defects, and air lace testing for leaks in all field seams and penetrations. QA/QC should be overseen by a professional engineer. Consider requiring field reports or other documentation from the engineer.

Photograph B-4. Runoff passed the upradient rain garden, shown in Photo B-3, and flooded this downstream rain garden.

- Provide adequate construction staking to ensure that the site properly drains into the facility, particularly with respect to surface drainage away from adjacent buildings. Photo B-3 and Photo B-4 illustrate a construction error for an otherwise correctly designed series of rain gardens.

References

Erickson, Andy. 2009. Field Applications of Enhanced Sand Filtration. University of Minnesota *Stormwater Management Practice Assessment Project Update*. http://wrc.umn.edu.

Hunt, William F., Davis, Allen P., Traver, Robert. G. 2012. "Meeting Hydrologic and Water Quality Goals through Targeted Bioretention Design" *Journal of Environmental Engineering*. (2012) 138:698-707. Print.

FELSBURG HOLT & ULLEVIG
connecting and enhancing communities

FINAL Nebraska H_2O Post-Construction Stormwater Program Design Standards and Procedures Memorandum

To:	Participating Nebraska H_2O Members
Project:	NE H_2O Post Construction Stormwater Management Program Development – Phase 2 (FHU No. 12-221-XX)
From:	Felsburg Holt & UIlevig
Date:	August 26, 2015

1.0 Objective and Purpose

The Clean Water Act requires select communities in Nebraska to implement treatment practices to manage urban stormwater runoff in a manner that protects receiving water quality. These requirements are enforced through the National Pollutant Discharge Elimination System (NPDES) permit for each Municipal Separate Storm Sewer System (MS4). This programmatic permit is issued by the Nebraska Department of Environmental Quality (NDEQ).

Nebraska H_2O is a working group of Phase II communities in Nebraska that collaborate to develop solutions for common challenges in meeting MS4 permit requirements. Post-Construction Stormwater Management is one of six minimum control measures that each Nebraska H_2O community must satisfy. Each community is required to establish a Post-Construction Stormwater Management Program that meets Phase II MS4 permit general conditions as required by NDEQ.

The purpose of this memorandum is to provide the framework and guidance that each Nebraska H_2O community can use to satisfy part of their post-construction stormwater management program. Establishing this framework helps a community meet MS4 permit requirements and promotes sustainable watershed management policies. Whereas traditional storm sewer design and stormwater management focused on addressing water quantity and potential flood issues, the post-construction program also addresses water quality in each community. The framework includes establishment of minimum treatment and design standards, submittal and review process procedures, as well as maintenance, inspection and enforcement protocol.

2.0 Applicability

Post-construction stormwater program requirements shall be applicable to all construction activity and land developments requiring; including, but not limited to site plan applications, subdivision applications, building applications, and right-of-way applications from the City, unless exempt below. These provisions apply to all portions of any common plan of development or sale which would cause the disturbance of at least one acre of soil even though multiple, separate and distinct land development activities may take place at different times on different schedules.

The following activities are exempt from these requirements:

(1) Any emergency activity that is necessary for the immediate protection of life, property, or natural resources; and

(2) Construction activity that provides maintenance and repairs performed to maintain the original line and grade, hydraulic capacity, or original purpose of a facility.

3.0 Definitions

Definitions applicable to this memorandum are as follows:

70th Percentile Rain Event: A rainfall storm event equivalent to a depth of rainfall which is not exceeded in 70 percent of the historic runoff producing rainfall events. The depth of rainfall to be used shall be that which is identified in this memorandum or by a specific community using local precipitation data. The depth of rainfall is used in hydrologic calculations to determine the water quality volume or rate of discharge to be controlled for.

80th Percentile Rain Event: A rainfall storm event equivalent to a depth of rainfall which is not exceeded in 80 percent of the historic runoff producing rainfall events. The depth of rainfall to be used shall be that which is identified in this memorandum or by a specific community using local precipitation data. The depth of rainfall is used in hydrologic calculations to determine the water quality volume or rate of discharge to be controlled for.

Best Management Practices (BMPs): Schedules of activities, prohibitions of practices, general good housekeeping practices, pollution prevention and educational practices, maintenance procedures, and other management practices to prevent or reduce the discharge of pollutants directly or indirectly to storm water, receiving waters, or storm water conveyance systems.

To avoid confusion with temporary and permanent BMPs used during construction; best management practices associated with the post-construction stormwater management program shall be referred to as stormwater treatment facilities (STFs).

Builder: shall mean the general contractor responsible for permitting and constructing a structure and associated construction activity.

Common Plan of Development or Sale: A contiguous area where multiple separate and distinct land disturbing activities may be taking place at different times, on different schedules, but under one proposed plan which may include, but is not limited to, any announcement or piece of documentation (including a sign, public notice or hearing, sales pitch, advertisement, drawing, permit application, zoning request, computer design, etc.) or physical demarcation (including boundary signs, lot stakes, surveyor markings, etc.) indicating construction activities may occur on a specific plot.

Construction Activity: Such activities include but are not limited to clearing and grubbing, grading, excavating, demolition and other land disturbing actions.

Construction Site: Any location where construction activity occurs.

Contractor: Any person performing or managing construction work at a construction site, including, but not limited to, any construction manager, general contractor or subcontractor, and any person engaged in any one or more of the following: earthwork, pipe work, paving, building, plumbing, mechanical, electrical, landscaping or material supply.

Clearing: Any activity that removes the vegetative surface cover.

Drainage Design Guidance or Manual: Documentation that references design criteria and guidance by a community for stormwater management.

Disturbed Area: Area of the lands surface disturbed by any work or activity upon the property by means including, but not limited to, grading; excavating; stockpiling soil, fill, or other materials; clearing; vegetation removal; removal or deposit of any rock, soil, or other materials; or other activities which expose soil. Disturbed area does not include the tillage of land that is zoned for agricultural use.

Earthwork: The disturbance of soil on a site associated with construction activities.

Final Drainage Plan: A plan that indicates the characteristics of the complete project. The plan will also indicate the future conditions post-construction STFs will be maintained under.

Grading: Excavation or fill of material, including the resulting conditions thereof.

Municipal Separate Storm Sewer System (MS4): Publicly-owned facilities by which storm water is collected and/or conveyed, including, but not limited to, any roads with drainage systems, municipal streets, gutters, curbs, catch basins, inlets, piped storm drains, pumping facilities, retention and detention basins, natural and human-made or altered drainage ditches/channels, reservoirs, and other drainage structures.

Land Development: Any land change, including, but not limited to, clearing, digging, grubbing, stripping, removal of vegetation, dredging, grading, excavating, transporting and filling of land, construction, paving, and any other installation of impervious cover.

Maintenance Agreement: A binding document between an owner or developer and the community that outlines responsibilities of maintenance and inspection for STFs associated with land development along with recourse by the community upon default of said responsibilities.

MS4 Boundary: The boundary defined by each individual community that is subject to the requirements of their MS4 program. In no instance shall the MS4 boundary be less inclusive than the Urbanized Area map boundary prepared by the U.S. Census Bureau, the minimum boundary adopted by the EPA for Phase II communities as part of the MS4 program.

National Pollutant Discharge Elimination System (NPDES) Storm Water Discharge Permit: A permit issued by the EPA (or by a State under authority delegated pursuant to 33 USC § 1342(b) i.e. Nebraska Department of Environmental Quality) that authorizes the discharge of pollutants to waters of the State.

Owner: The person who owns a facility, development, part of a facility, or land.

Person: Means any individual, association, organization, partnership, firm, corporation, cooperative, limited liability company or other entity recognized by law.

Pollutant: Anything which causes or contributes to pollution. Pollutants may include, but are not limited to: paints, varnishes, and solvents; oil and other automotive fluids; non-hazardous liquid and solid wastes and yard wastes; refuse, rubbish, garbage, litter, or other discarded or abandoned objects, ordinances, and accumulations, so that same may cause or contribute to pollution; floatables; pesticides, herbicides, and fertilizers; hazardous substances and wastes; sewage, fecal coli form and pathogens; dissolved and particulate metals; animal wastes; wastes and residues that result from constructing a building or structure; wastes and residues that result from mobile washing operations; and noxious or offensive matter of any kind.

Pollution: The presence in waters of the State of any substances, contaminants, pollutants, or manmade or man-induced impairment of waters or alteration of the chemical, physical, biological, or radiological integrity of water in quantities or at levels which are or may be potentially harmful or injurious to human health or welfare, animal or plant life, or property or which unreasonably interfere with the enjoyment of life or property, including outdoor recreation unless authorized by applicable law.

Post-Construction Stormwater Management: The management of stormwater for a period of time in perpetuity from approval for final acceptance of the construction phase of any construction activity. The management of stormwater includes the use of STFs that meet minimum site performance standards in accordance with a community's MS4 permit. STFs are intended to provide stormwater treatment during this time period and are considered functional after vegetation has been established.

Post-Construction Stormwater Management Plan: Documentation supporting analysis, design, maintenance and inspection of STFs installed on a site in order to meet minimum site performance standards in accordance with a community's MS4 permit.

Receiving Water: Any water of the State of Nebraska, including any and all surface waters that are contained in or flow in or through the State of Nebraska, all watercourses, even if they are usually dry, irrigation ditches that receive municipal storm water, and storm sewer systems owned by other entities.

Sediment: Soil (or mud) that has been disturbed or eroded and transported naturally by water, wind or gravity, or mechanically by any person.

Site: The land or water area where any facility or activity is physically located or conducted, including adjacent land used in connection with the facility or activity.

Stormwater: Any surface flow, runoff, and drainage consisting entirely of water from any form of natural precipitation, and resulting from such precipitation.

Stormwater Treatment Facilities (STFs): Permanent best management practices put in place to provide control and treatment of stormwater runoff after construction activity for land development is complete. These facilities are physical in nature and sometimes referred to as "structural" BMPs.

Subdivision: Includes activities associated with the platting of any parcel of land into two or more lots and all construction activity taking place thereon.

Utilities: Infrastructure constructed to provide services that support land development such as water, sanitary sewer, storm sewer, electric, gas, telephone, television and communication services.

Waters of the State: Any and all surface and subsurface waters that are contained in or flow in or through the State of Nebraska. The definition includes all watercourses, even if they are usually dry.

4.0 Requirements

Each MS4 will implement a set of minimum programmatic requirements for new and redevelopment projects that disturb one acre of soil or more within their jurisdiction. This collection of requirements is generally referred to as the Permanent Stormwater Treatment for Post-Construction program. NDEQ has not dictated what minimum program requirements must be implemented, but five content areas must be satisfied according to Part IV.D.4 of the MS4 Permit. The five content areas include:

1. Minimum Site Performance Standards
2. Site Plan Review
3. Maintenance of Controls
4. Tracking Controls
5. Inspection and Enforcement

4.1 Minimum Site Peformance Standards

Each MS4 will require new and redevelopment projects to satisfy minimum site performance standards that address water quality. Minimum site performance standards vary in each of these instances however the methodology for calculating the minimum water quality control volume (WQCV) and water quality volume discharge rate (Q_{WQ}) remain the same. The methodology is based on average daily rainfall data gathered regionally and applied to three specific zones across the state. From that data, the runoff amount is calculated and applied to the treatment drainage area to get the WQCV or Q_{WQ}.

New Development

New development requirements apply to those areas which are being platted for development or have been platted but not built and are within the community's "MS4 boundary". The percentile rainfall event used as a minimum standard for new development is the 80^{th} percentile rainfall event.

> *Example 1) A parcel that had not been platted or zoned for development (i.e. agricultural land) is being platted as a subdivision for single family residential and is greater than 1 acre. The subdivision would be required to meet the minimum standard set forth herein for new development.*
>
> *Example 2) Several parcels are being replatted for development and the total area being replatted is greater than 1 acre. The replatted parcels would be required to follow new development standards.*
>
> *Example 3) An undeveloped parcel is being rezoned for another use and is greater than 1 acre. The rezoned parcel would be required to follow new development standards.*
>
> *Example 4) A warehouse has been proposed on an undeveloped parcel in an industrial area. Site disturbance is greater than 1 acre. The proposed development would be required to follow new development standards.*

Redevelopment

Redevelopment requirements apply to those areas which have been platted and built on within the community's "MS4 boundary". The percentile rainfall event used as a minimum standard for new development is the 70^{th} percentile rainfall event.

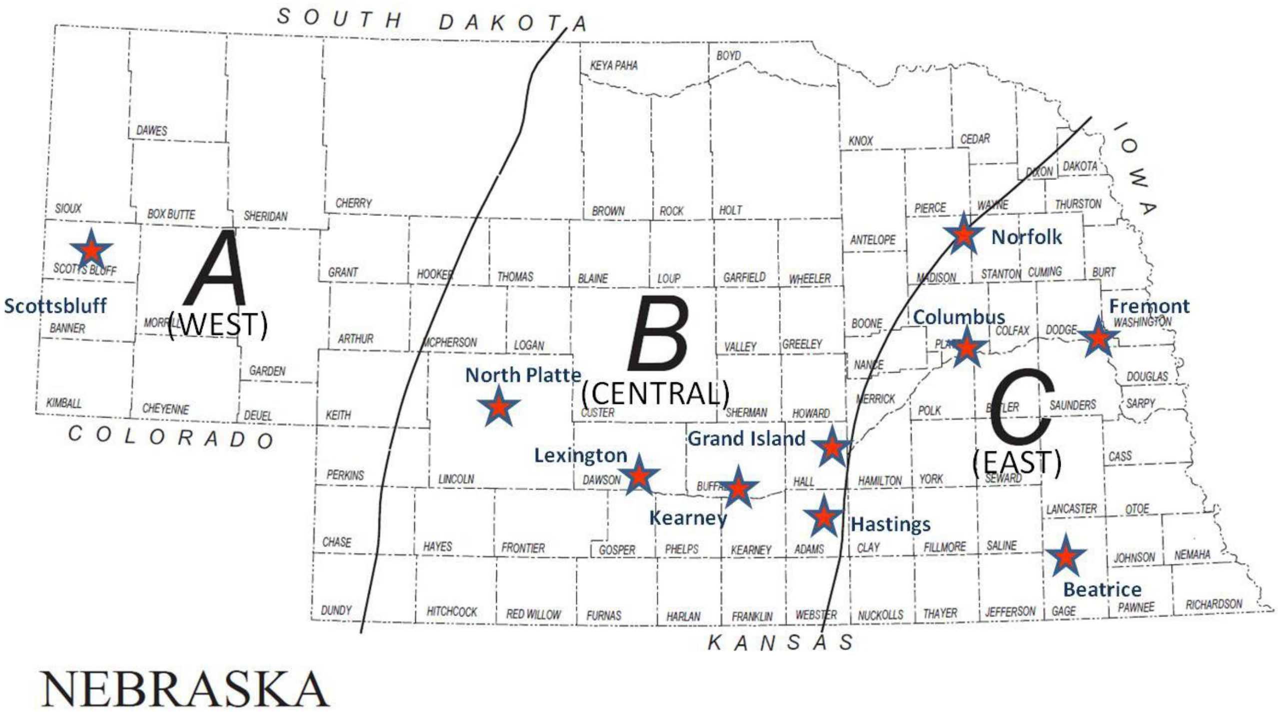
> *Example 1) A parcel that included a structure that was purchased and demolished by the City or other entity, and was sold or deeded over to a new property owner for constructing his or her own building. Site disturbance is greater than 1 acre. This site would be required to meet the minimum standard set forth herein for redevelopment.*
>
> *Example 2) A parcel with a building has been sold and is being converted into a new use with expanded parking. Site disturbance is greater than 1 acre. This parcel would be subject to requirements for redevelopment.*

Rainfall Zones

The percentile rainfall event varies across the state. Three regional rainfall zones have been established to support the calculation of WQCV or Q_{WQ} by any MS4 in Nebraska. These zones are displayed in Figure 1 and are the same as the zones portrayed in the Nebraska Department of Roads (NDOR), *"Drainage and Erosion Control Manual"*, Chapter One.

Rainfall values were interpolated between the depth of rainfall identified in Urban Drainage and Flood Control District's (UDFCD) *"Urban Storm Drainage Criteria Manual"* for the Denver, Colorado area for Region A (West Region) and the City of Lincoln's *"Drainage Criteria Manual"* for Region C (East Region).

Figure 1. Nebraska Regional Rainfall Zones



Adapted from NDOR Drainage and Erosion Control Manual Ch. 1

Rainfall amounts by region for new and redevelopment are provided in Table 1. These values will be used to calculate runoff and water quality control volume (WQCV).

Table 1. Rainfall Depth (P) By Region for Defined Percentile Rainfall Events

Applicable Region	Rainfall, P	
	80th Percentile Event (New Development)	**70th Percentile Event (Redevelopment)**
A (West)	0.61”	0.44”
B (Central)	0.72”	0.53”
C (East)	0.83”	0.62”

Minimum Design Criteria

STFs must be sized to handle the appropriate WQCV or equivalent water quality discharge rate to properly treat stormwater. Best Management Practices include retention-based stormwater treatment facilities that typically require or encourage using infiltration, evapotranspiration, or harvest practices to control a specified volume of stormwater within each development site.

The regulatory logic of controlling volume is that the stormwater pollutants contained in the volume of runoff captured are prevented from reaching the receiving water, and the remaining volume that does reach the receiving water is less polluted and erosive to the receiving waterbody.

The regulatory logic of controlling discharge rate is that the stormwater pollutants contained in stormwater runoff can be reasonably treated and that volume that does reach the receiving water is less polluted and erosive to the receiving waterbody.

Water Quality Volume

Design criteria to meet minimum site performance standards for new and redevelopment are expressed as the runoff from a specified percentile rainfall event applied across the treatment drainage area. The minimum WQCV for new and redevelopment can be calculated as follows:

WQCV = P x (0.05 + 0.009 x %Imp) x A x 1/12 x 43,560

Where, P = rainfall depth, in (from Table 1)

A = treatment drainage area, ac

%Imp = maximum percent imperviousness (expressed as a whole number not as a decimal) for proposed zoning type (varies by community)

The following example illustrates use of the WQCV equation:

Example 1) A 4.2 acre parcel in Kearney was purchased to construct a storage facility. The parcel is one of 4 in a new development that was zoned limited industrial district (M-1) . Light industrial zoning in Kearney has a maximum impervious percentage of 90%. On that parcel, 2.4 acres will be disturbed to construct the facility. An additional 0.4 acres, also zoned M-1, drain directly onto the site from adjacent property. The WQCV for the site Is calculated as follows:

WQCV = 0.72” x (0.05 + 0.009 x 90) x (2.4 ac + 0.4 ac) x 1/12 x 43,560 = 6,294 cubic feet

If there are multiple land uses within the treatment drainage area, the effective maximum percent imperviousness should be pro-rated based on the area of each zone as a percentage of the total area.

Stormwater runoff from all disturbed areas shall be treated before leaving the site. The treatment drainage area shall include all disturbed areas on the site and upstream drainage or “runon” unless the runon is diverted or bypasses the disturbed site (i.e. by pipe or swale) so that STFs are not overwhelmed. STFs may be distributed across the site to provide the required treatment.

Additional storage in the STF may be allowed, depending on the type of STF selected, to address stormwater detention requirements to control runoff from larger storm events such as the 2-, 10-, or 100-year event.

Water Quality Volume Discharge Rate

STFs that are sized based on a flow rate (i.e. swales, filter strips, manufactured systems, etc.) shall use the water quality volume discharge rate (Q_{WQ}). The Q_{WQ} is the peak runoff from the design water quality volume rainfall event. This peak runoff equivalent shall be calculated using the Natural Resources Conservation Service (NRCS) Curve Number (CN) procedure. The calculation is based on the 80th percentile rainfall event depth by region, a 24 hour duration storm event, and a time of concentration of 5 minutes. The area used is the impervious surface only within the treatment drainage area.

Table 2 has been prepared to provide the Q_{WQ} in each Region for sites with up to 6 acres of impervious area. These values shall be used to size STFs for the area of impervious surface within a given treatment drainage area. For sites greater than 6 acres, the designer shall use the methods and criteria specified above in a suitable model to calculate the discharge rate.

Table 2. Water Quality Discharge Rate (Q_{WQ}) for Selected Impervious Areas By Region

Impervious Area (Acres)	Q_{WQ} (cfs) West | Central | East	Impervious Area (Acres)	Q_{WQ} (cfs) West | Central | East	Impervious Area (Acres)	Q_{WQ} (cfs) West | Central | East
0.2	0.1 | 0.2 | 0.2	2.2	1.5 | 1.9 | 2.2	4.2	2.9 | 3.6 | 4.2
0.4	0.3 | 0.3 | 0.4	2.4	1.6 | 2.0 | 2.4	4.4	3.0 | 3.7 | 4.4
0.6	0.4 | 0.5 | 0.6	2.6	1.8 | 2.2 | 2.6	4.6	3.2 | 3.9 | 4.6
0.8	0.5 | 0.7 | 0.8	2.8	1.9 | 2.4 | 2.8	4.8	3.3 | 4.1 | 4.8
1.0	0.7 | 0.8 | 1.0	3.0	2.1 | 2.5 | 3.0	5.0	3.4 | 4.2 | 5.0
1.2	0.8 | 1.0 | 1.2	3.2	2.2 | 2.7 | 3.2	5.2	3.6 | 4.4 | 5.2
1.4	1.0 | 1.2 | 1.4	3.4	2.3 | 2.9 | 3.4	5.4	3.7 | 4.6 | 5.4
1.6	1.1 | 1.4 | 1.6	3.6	2.5 | 3.0 | 3.6	5.6	3.8 | 4.7 | 5.6
1.8	1.2 | 1.5 | 1.8	3.8	2.6 | 3.2 | 3.8	5.8	4.0 | 4.9 | 5.8
2.0	1.4 | 1.7 | 2.0	4.0	2.7 | 3.4 | 4.0	6.0	4.1 | 5.1 | 6.0

4.2 Platting and Site Plan Review

Land development that meets the land disturbance criteria of this memorandum must address storm water runoff quality through the use of STFs. STFs shall be provided for in the drainage plan for any subdivision plat, annexation plat, development agreement, subdivision agreement or other local development plan.

Implementation Schedule

Each Nebraska H2O partner will adopt a post-construction stormwater management program based on the guidance in this memorandum. Each community must consider local conditions, criteria, and procedures that are compatible or conflict with these recommendations and advance the final post-construction stormwater management program for local adoption. Each community will implement their program independently and under their own schedule; however, the implementation schedule for the post-construction stormwater program for Nebraska H2O partners should not exceed the following:

January 1, 2016: Local MS4 shall begin or continue a public involvement process with local leaders, engineers, the development community and the general public that will lead to adoption of the post construction stormwater management program no later than January 1, 2017.

January 1, 2017: For all developments that have not had a preliminary plat approved, the post-construction stormwater management plan MAY BE required to be satisfied. The MS4 MAY elect to require minimum stormwater treatment practices for replats that significantly increase the amount of impervious area in a preliminarily platted subdivision previously approved by this date. During this period, the municipality shall make known to the owners of all preliminarily platted subdivision that implementation of stormwater treatment controls SHALL BE required if a replat is January 1, 2019 or later The method of notification will be left up to the individual communities and make take the form of a Public Notice.

January 1, 2019: For all developments that have not had a preliminary plat approved, the post-construction stormwater management plan SHALL BE required to be satisfied. The MS4 SHALL require minimum stormwater treatment practices for all replats and modifications of preliminary platted subdivisions.

Procedures

Platting

For major subdivision applications drainage and post-construction shall be discussed at the pre-application conference. This would be followed by an initial review of the general design at the preliminary platting stage and detailed design carrying over into final design review.

The plat applicant shall identify, through the Subdivision Agreement or other City-approved means, whether post-construction stormwater management facilities will be (1) constructed by each lot owner on their own lot (Lot Level STFs); (2) constructed for the subdivision by the developer with reimbursement sought from individual lot builders (Neighborhood STFs); (3) mitigated off-site at regional facilities (Regional STFs), or (4) addressed by other means approved by the City. Any other conditions agreed to between the two parties, including inspections, maintenance, and funding of maintenance shall be included in that agreement.

Building Permits

When seeking a building permit, the City will need to investigate how drainage and post-construction stormwater management is being handled. If Lot Level STFs are required per the Subdivision Agreement or other agreement, then the lot builder will need to develop and have approved a drainage study, post-construction stormwater management plan, and maintenance agreement. A maintenance agreement for an individual lot shall include provisions for maintenance that shall be binding on all subsequent owners.

Submittals

Post Construction Stormwater Management Plan (PCSMP) Submittal

The PCSMP submittal will include the following components:

Plans

Plans showing topographic survey information along with proposed, grading, stormwater infrastructure (including STFs), pavement, and structures shall accompany any PCSMP submittal. Specifically, plans shall include the following information:

- Site topography including existing contours, property lines and easements, utilities, and site features such as existing water bodies, trees and shrubs, pavement and other structures
- Proposed contours
- Proposed inlets, storm sewer, culverts, and drainageways
- Proposed STFs and/or detention facilities
- Proposed roadways, parking, building footprints, and other structures

A table shall be provided in construction drawings that include, for each STF; (1) a location identifier, (2) the type of STF, (3) the location for each STF in latitude/longitude format, (4) the drainage area, and (5) the water quality volume/water quality volume discharge rate. The designer shall differentiate between the amount required by design and the amount that will be provided. Any discrepancies should be discussed with and approved by the City. The information shall be provided on drawings in a format that is consistent with the following:

STF Identification Number	STF Type	STF Location (Lat/Long)	Drainage Area (Acres)	Design WQCV (cf) or Q_{WQ} (cfs)	WQCV (cf) or Q_{WQ} (cfs) Provided

Preliminary submittals required by the City will include preliminary information. Final plans shall be representative of the intended construction bid package.

Calculations

All calculations for water quality volume and water quality volume discharge rate shall be submitted to the City as part of the site development drainage study. Calculations shall be completed as described herein for the appropriate STFs. Design criteria specific to the various STFs shall also be shown in the drainage study (i.e. calculations for drain down and infiltration).

When combining stormwater detention with STFs, the designer shall provide calculations that address both water quality volume and stormwater detention requirements using methodology approved by the community.

STFs shall be clearly shown on the drainage map along with other stormwater infrastructure and drainage basin boundaries.

Certification of Permanent STFs

Upon completion of a project the City shall be provided a written certification, by qualified personnel, stating that the completed project is in compliance with the approved Final Drainage Plan. Qualified personnel shall be a professional civil engineer licensed in the State of Nebraska or person(s) under the direct supervision of a professional engineer licensed in the State of Nebraska.

For commercial and industrial construction, certification will be required before a Certificate of Occupancy is granted (unless authorized by the community). All applicants shall submit “as built” plans certified by a professional engineer licensed in the State of Nebraska once final construction is completed. A final inspection by the City of all post-construction STFs shall be required before a Certificate of Occupancy will be issued or any public infrastructure is accepted.

Ongoing Inspection and Maintenance of STFs

A maintenance agreement will be required by the developer or builder for proposed STFs. The maintenance agreement shall include provisions that outline regular maintenance activity, and a schedule of periodic inspections by the Owner or Designees. Inspection frequency shall be consistent with the design criteria manual used and generally includes quarterly inspections during the first year of establishment following construction and annually thereafter.

The Owner or Designees providing routine inspections shall document all inspections and maintenance and repair needs to ensure compliance with the requirements of the agreement and the plan. The agreement shall allow access to City personnel for inspection and maintenance should the owner default in their responsibilities with the intent to invoice the owner for said work, if needed. Information about inspections and maintenance shall be provided by the owner to the City upon request.

<u>PCSMP Submittal Checklist</u>

A PCSMP checklist shall be submitted with design plans and be recorded by the City with the project record. The PCSMP checklist provided in Appendix A of this document may be used for reference by communities, developers, designers, and builders.

Off-Site Stormwater Mitigation

In some cases it may not be practicable to provide the required treatment within project limits due to various constraints such as site limitations, costs, or other obstacles. If shown by the owner that it is not practicable, off-site mitigation may be allowed at the discretion of the City.

Off site mitigation may be provided by a private land owner in a City-approved stormwater treatment facility or within a City-approved publicly owned stormwater treatment facility provided the proposed mitigation location meets the following minimum criteria;

- A drainage study confirms that the proposed mitigation location provides excess stormwater treatment that is not required to provide treatment for the drainage area.
- The excess treatment capacity in the proposed mitigation location is not already providing mitigation of required stormwater treatment for another development or redevelopment project.
- The owner of the proposed mitigation location maintains or enters into a maintenance agreement that shall be binding on all subsequent owners and includes all required inspection and maintenance requirements for stormwater treatment practices.

Off site mitigation should take place in accordance with the rules and conditions of each individual community. Each community will need to be able to provide the appropriate documentation for tracking all water quality debits and credits for such facilities in the event of an audit. Fees shall be established by the entity funding the stormwater treatment facility.

4.3 Maintenance of Controls

STFs located on private property shall be owned and operated by the owner(s) of the property on which the STF is located; unless the City agrees in writing that a person or entity other than the owner shall own or operate such STF. As a condition of approval of the STF, the owner shall also maintain the STF in perpetuity to its design capacity unless or until the City shall relieve the property owner of that responsibility in writing. The obligation to maintain the STF shall have been memorialized on a subdivision plat, annexation plat, development agreement, subdivision agreement or other form acceptable to the City and recorded by the City with the project records.

The City shall continue to maintain public storm sewer infrastructure including public STFs. Each homeowners association of a subdivision or individual lot owner shall maintain post-construction STFs. When public infrastructure improvements are constructed by the City, such as with the widening of a major arterial or other public improvement, the City shall take responsibility for maintenance of the STF unless otherwise specified in a maintenance agreement.

5.0 Design Guidance

STFs shall be designed using an approved design guidance manual that provides minimum design criteria and considerations. A selection of regional design guides are recommended for design within Nebraska H_2O communities. The most recent versions of the following design guides and manuals are approved for general use in the design of STFs:

- City of Omaha, *"Omaha Regional Stormwater Design Manual – Chapter 8: Stormwater Best Management Practices"*
- City of Lincoln, *"Drainage Criteria Manual - Chapter 8: Stormwater Best Management Practices"*
- NDOR, *"Drainage and Erosion Control Manual – Chapter 3: Stormwater Treatment within MS4 Communities"*
- Urban Drainage and Flood Control District (UDFCD), *"Urban Storm Drainage Criteria Manual, Volume 3: Best Management Practices"*

The designer is encouraged to adopt one design guide/manual for use on a project to the extent practicable. Other approved design guides and manuals may be used if design criteria for the desired STF are not provided in the primary design guide/manual. Any variances from these manuals will require approval of the City Engineer or their Designee. The community may evaluate the suitability of other types of STFs not referenced in the approved design guides and manuals on a case-by-case basis.

The designer shall discuss the use of the alternative design guidance manuals prior to starting design along with any variance in STF design. The designer shall also discuss other requirements for stormwater management within the community including the potential need for stormwater detention. Where one manual conflicts with another, the Engineer shall use sound, cost-effective design practices to resolve the issue. The following minimum design standards are provided to help resolve some conflicts identified.

Stormwater Treatment Facility Selection

Each design guidance manual includes a unique selection of STFs and what is included in one may not be included in another. Furthermore, two manuals may use different names for an STF with the same or similar function. The function, criteria and considerations of a specific STF is what shall be used to determine its use by a design engineer. Table 3 provides a general comparison of the types of STFs included in the approved design guidance manuals.

Table 3. STF Design Guidance for Various Regulatory Agencies

STF Type	Omaha	Lincoln	NDOR	UDFCD
Vegetated Filter Strip	X		X	X
Grass Swale	X		X	X
Infiltration Trench			X	
Infiltration Basin			X	
Bioretention Basin	X	X	X	X
Media Filter			X	
Sand Filter				X
Extended Dry Detention	X	X	X	X
Wet Detention Ponds	X	X	X	X
Stormwater Wetland	X	X	X	X
Underground Detention		X		X
Pervious Pavement	X	X	X	X
Proprietary Structural Treatment Controls	X		X	X
Green Roofs	X	X		X
Soil Conditioning	X			

All design guidance manuals include criteria and considerations for STF selection and should be used for this purpose. The design criteria within these guides shall be adhered to unless the design engineer demonstrates to the City why the criteria do not apply. Stormwater STF suitability will depend on number of factors including, but not limited to, the following:

- Available Space
- Property Access
- Site Topography
- Drainage Basin Size
- Infiltration Rates
- Depth to Groundwater/Bedrock
- Capital Costs/Maintenance

Community Preferences

Each community reserves the right to approve or reject certain STFs based on preferences and/or suitability for their community. Furthermore, certain communities may have regional STFs that they would prefer to use over on-site STFs. It is suggested that the designer discuss these preferences with the community during the pre-application phase of platting or at the beginning of design when considering building on an individual lot.

Collectively, Nebraska H_2O recommends the following preferences and exclusions from the approved manuals for consideration in your design:

Infiltration Rates

Minimum infiltration rate shall be 0.5 in/hr

Maximum infiltration rate shall be 12 in/hr

Infiltration Cells

Infiltration cells should incorporate conditioned soils to reduce the quantity of select material needed to provide treatment in a bioretention garden/basin. This method is described in the Omaha Regional Stormwater Design Manual and NDOR Drainage and Erosion Control Manual.

Drain Time and Control Valves

A design drain time of 24 hours will be used for all STFs that use a water quality control volume to provide treatment and control of runoff. Control valves shall be placed in underdrains to allow for adjustments to the drain time as needed.

Cleanouts

Cleanouts shall be provided on all underdrains to assist with providing needed maintenance.

Pretreatment

Measures shall be incorporated that prevent sediment from depositing in STFs during and after construction. Pretreatment of stormwater runoff through barriers, grass buffers or forebays is recommended on all STFs.

Landscaping

The following resources have been provided to assist in the design of landscaping for a project. It is strongly suggested that a landscape architect or designer assist with plant selection and landscape design.

- UNL Extension, "Stormwater Management: Plant Selection for Rain Gardens in Nebraska" http://www.ianrpubs.unl.edu/epublic/live/g1759/build/g1759.pdf
- UNL Extension, "Nebraska Bioretention and Rain Garden Plants Guide" http://marketplace.unl.edu/extension/ec1261.html
- NDOR, "Plants for the Roadside Environment" https://dot.nebraska.gov/projects/environment/roadside/erosion/
- NDOR, "Establishing Permanent Vegetation after Highway Construction" https://dot.nebraska.gov/media/akkjqps0/road-env-plan-total.pdf
- "The Value of Large Trees", A Publication of the Nebraska Statewide Arboretum, Spring 2007 https://digitalcommons.unl.edu/cgi/viewcontent.cgi?article=1019&context=arboretumpubs

Links were revised on 2023-11-22 by S Riehle, City of Hastings.

These links may contain other references to sources that may be helpful in plant selection and suitability for use with STFs. Keep in mind regional difference in your selection of plants along with differences in soil, light, and moisture within the stormwater STF itself.

<u>APPENDIX A</u>

POST-CONSTRUCTION STORMWATER MANAGEMENT PLAN (PCSMP)

SUBMITTAL CHECKLIST

Post-Construction Stormwater Management Plan (PCSMP) Submittal Checklist

Preliminary submittals required by the City will include preliminary information. Final submittals shall be representative of the intended construction bid package.

PROJECT NAME: ____

PLANS

- ☐ Site topography including existing contours, property lines and easements, utilities, and site features such as existing water bodies, trees and shrubs, pavement and other structures
- ☐ Proposed contours
- ☐ Proposed inlets, storm sewer, culverts, and drainageways
- ☐ Proposed STFs and/or detention facilities
- ☐ Proposed roadways, parking, building footprints, and other structures
- ☐ A table shall be provided in construction drawings that includes, for each Stormwater Treatment Facility (STF) The information shall be provided on drawings in a format that is consistent with the following:

STF Identification Number	STF Type	STF Location (Lat/Long)	Drainage Area (Acres)	Design WQCV (cf) or Q_{WQ} (cfs)	WQCV (cf) or Q_{WQ} (cfs) Provided

CALCULATIONS

- ☐ Water Quality Volume (WQCV) or Water Quality Volume Discharge Rate (Q_{WQ}) for each STF (To be included with a site design or subdivision drainage study)
- ☐ Drainage Study

AGREEMENTS

A maintenance agreement is required for neighborhood level and lot level STFs. If an agreement is made for mitigation off site or other agreements are made, make note and describe below

- ☐ Inspection and Maintenance Agreement
- ☐ Other Agreement

____

CERTIFICATION OF PERMANENT STFs

Unless otherwise indicated by the City, a Hold on the Certificate of Occupancy will be placed on the project until the STF has been certified. If applicable, check “Hold” until certification is received. If not applicable, check N/A.

- ☐ Hold on C.O.
- ☐ N/A

Submitted upon completion of a project; a statement by a professional engineer licensed in the State of Nebraska or person(s) under the direct supervision of a professional engineer licensed in the State of Nebraska attesting that the completed project is in compliance with the approved Final Plan.

- ☐ Certification of Permanent STFs
- ☐ Record Drawings (if required by City)

- ☐ Hold on C.O. Released (if applicable) Released By: ______________________________