CHAPTER 9. WATER QUALITY

CONTENTS

Section Page
WQ-

APPENDICES

TABLES

FIGURES

PHOTOGRAPHS

EXECUTIVE SUMMARY

Purpose of the Chapter

The purpose of this chapter is to provide guidance for selecting, designing, and maintaining stormwater Best Management Practices (BMPs) to minimize potential adverse impacts on stormwater quality caused by urbanization in the City of Rogers. The City, along with many communities around the United States, encourages the widespread use of stormwater BMPs on all development sites.

To comply with the *Federal Clean Water Act*, the Arkansas Department of Energy & Environment Division of Environmental Quality (DEQ) issued Arkansas State Operating Permit ARR040041 to the City of Rogers to authorize discharges from the City's Municipal Separate Storm Sewer System (MS4) to waters of the State. In accordance with the MS4 permit, the City is required to develop and implement a comprehensive Stormwater Management Program that includes controls to identify illicit discharges and reduce the discharge of pollutants from the MS4 to the Maximum Extent Practicable. The design tools provided in this chapter are intended to improve the quality of stormwater runoff from development sites in the City.

Chapter Summary

The historic, traditional approach for managing stormwater was to convey the water away from developed areas as quickly as possible. Today, sound stormwater management programs require new developments to be designed in a manner to reduce runoff volumes, runoff velocities and reduce pollutant loads. This can be achieved with properly designed, implemented, and maintained stormwater BMPs.

The City requirements for stormwater quality protection described in this chapter apply to:

- All development and additions to existing sites that increase the site's impervious area by one tenth (0.1) of an acre or more, including projects that are less than one tenth (0.1) of an acre that are part of a larger common plan of development or sale;
- Sites that are being redeveloped; or
- Other developments, increasing the impervious area by less than one tenth (0.1) of an acre, that have been specifically identified by the City as having a significant potential to adversely impact the quality of stormwater runoff.

To achieve basic objectives related to stormwater quality such as protecting drinking water supplies, protecting human health and the environment, and complying with the federal National Pollutant Discharge Elimination System (NPDES) permit requirements, the City will require new developments to implement several fundamental principles with respect to stormwater management, including:

- Minimizing the amount of runoff from developed areas;

- Minimizing the amount of Directly Connected Impervious Area (DCIA);
- Maximizing the contact of runoff with grass and vegetated soil;
- Maximizing holding and settling times in detention basins;
- Designing BMPs for small, frequent storms;
- Utilizing BMPs in series where feasible;
- Incorporating both flood control and stormwater quality objectives in designs;
- Providing special treatment for runoff from fueling areas and other areas having a high concentration of pollutants; and
- Stabilizing drainageways downstream from developments.

The quantifiable objective of these principles is to capture and manage the Water Quality Capture Volume (WQCV) of each development site. To achieve this objective, specific types of BMPs that can be used are described in this chapter. These include:

- Extended Dry Detention Basin
- Extended Wet Detention Basin
- Constructed Wetland Basin
- Permeable Pavers
- Porous Landscape Detention
- Vegetated Filter Strip/Grass Buffer
- Grass Swale

For each of the BMPs listed above, a description is provided of design considerations, the design procedure and criteria, maintenance considerations, and a design example. Other BMPs are also discussed briefly, such as design considerations for material storage and handling areas, spill containment and control measures, and alternative structural BMPs (e.g., proprietary stormwater treatment units). Low Impact Development (LID), a design approach that incorporates many of the design elements described in this chapter, is also presented.

Other important considerations identified include restrictions imposed by the United States Fish and Wildlife Service (USFWS) on development in the Karst Formation/Cave Springs Recharge Area and regulatory requirements of the United States Army Corps of Engineers (USACE) associated with the development of constructed wetlands.

City Stormwater Protection Requirements

To comply with the City requirements for protection of stormwater quality, new developments or redevelopments must satisfy one of the following two requirements outlined below:

1. The onsite or regional stormwater BMPs must store and treat the calculated Water Quality Capture Volume (WQCV) for the site.

   or

2. A fee must be paid in lieu of implementing the onsite facilities necessary to store and treat the WQCV. The fee-in-lieu option is an alternative only when the development or redevelopment site disturbs between one tenth (0.1) and one half (0.5) of an acre, or the site has not been specifically identified by the City as having a significant potential to adversely impact the quality of stormwater runoff. Fees collected from this option are used for other stormwater quality protection projects throughout the City. Although the fee-in-lieu option eliminates the need to store and treat the WQCV on-site, it does not eliminate the need to provide water quality BMPs on the site upstream of the discharge point to the receiving stream or storm sewer.

   For development sites that have been specifically identified by the City as having a significant potential to adversely impact stormwater quality (e.g., development on steep slopes or highly erosive soils), then the only acceptable option, regardless of the size of the site, is to capture and manage the WQCV calculated for the site. The fee-in-lieu option is not applicable to these sites.

1. INTRODUCTION

1.1. Nature of Pollutants in Stormwater Runoff

Urban stormwater runoff can contain a variety of pollutants that can adversely impact waterbodies. The Nationwide Urban Runoff Program (USEPA 1983) and other studies widely document the types and concentrations of pollutants associated with various land use types. Urban runoff may contain contaminants such as metals, lubricants, solvents, pesticides, herbicides, fertilizers, pet waste, litter and suspended sediments.

The quality of stormwater runoff from the City is of particular importance given its location in the watersheds of Beaver Lake to the east and the Illinois River to the west. This chapter discusses specific engineering measures that can be implemented to improve stormwater quality.

1.2. Historic Engineering Approaches for Stormwater Management

Traditional engineering approaches for stormwater management historically focused on moving water away from people, structures, and transportation systems as quickly and efficiently as feasible. This was accomplished by creating conveyance networks of impervious storm sewers, roof drains, and lined channels, which concentrated runoff discharges to receiving waters.

While the historical focus on stormwater was not on water quality, the potential adverse effects of urban runoff on the physical, chemical, and biological characteristics of receiving waters have been widely documented (e.g., WEF/ASCE 1992, 1998; Debo and Reese 2002; Horner, et al. 1994; Schueler and Holland 2000). Potential water quality implications of the traditional approach to drainage design include the following:

- Introduction of new pollutant sources and types (e.g., sediment from streets and parking lots).
- Increased runoff temperature.
- Habitat damage and ecosystem disruption associated with increased runoff from impervious surfaces, resulting in streambed and bank erosion and associated sediment and pollutant transport.
- Channel widening and instability.
- Destruction of both aquatic and terrestrial physical habitats.
- Increased contaminant transport, leading to increased water quality degradation that often may result in regulatory consequences such as stream segments being listed as impaired on the State 303(d) list and requirements for Total Maximum Daily Load (TMDL) allocations for dischargers to the stream.

- Production of potentially toxic concentrations of contaminants in receiving waters and long-term accumulation of contaminants.

1.3. New Approach and Requirements for Stormwater Management

To comply with the *Federal Clean Water Act*, the Arkansas Department of Energy & Environment Division of Environmental Quality (DEQ) issued Arkansas State Operating Permit ARR040041 to the City of Rogers to authorize discharges from the City's Municipal Separate Storm Sewer System (MS4) to waters of the State. In accordance with the MS4 permit, the City is required to develop and implement a comprehensive Stormwater Management Program that includes controls to identify illicit discharges and reduce the discharge of pollutants from the MS4 to the Maximum Extent Practicable. The design tools provided in this chapter are intended to improve the quality of stormwater runoff from development sites in the City.

To comply with the NPDES requirements and to minimize the potential adverse impacts of urbanization on water quality, the City, along with many communities around the United States, encourages the widespread use of stormwater BMPs on all development sites. The purpose of this chapter is to provide guidance for selecting, designing, and maintaining BMPs. This section is primarily targeted at protecting water quality in conjunction with development and redevelopment of residential and commercial areas. However, BMPs for light industrial areas and other types of land uses are also addressed.

Structural BMPs are constructed facilities designed to passively treat urban stormwater runoff, including practices such as detention basins (both dry basins and wet ponds), wetlands, permeable pavement, and designed vegetated zones, among others. Structural BMPs can be designed to treat small volumes of stormwater on development sites or to serve larger regional drainage areas.

Non-structural BMPs are practices and procedures that minimize or prevent pollution and control it at its source. Examples of non-structural BMPs include proper handling and storage of materials, minimizing directly connected impervious areas to reduce the transport of pollutants in runoff, and implementing public education programs to protect stormwater quality.

The design guidelines in this chapter represent current BMP technology and are anticipated to evolve as BMP technology is evaluated and refined, new BMPs are developed, or as new standards are promulgated by the State. This chapter significantly draws from the Denver Urban Drainage and Flood Control District (UDFCD) *Urban Storm Drainage Criteria Manual (UDFCM), Volume 3, Best Management Practices*, first published in 1992 and regularly updated since then. Volume 3 updates and other information are available from the UDFCD website (www.udfcd.org).

Design requirements are presented for both structural and non-structural water quality BMPs. General BMP descriptions, design considerations and criteria, maintenance considerations, design forms and completed examples are provided for each structural BMP. The discussion in this section is limited to permanent, post-development BMPs. For information on construction-phase erosion and sediment control BMPs, the Chapter 8 – *Construction Site Stormwater Management* shall be referenced.

2. APPLICABILITY

The water quality requirements outlined in this chapter apply to all new developments and redevelopments that add 0.1 acre of impervious area to their site.

For sites that are smaller than 0.5 acre, or for sites that are being redeveloped, the City may allow the property owner to pay a fee in-lieu-of implementing water quality control measures described in this chapter. The fee-in-lieu option is discussed further in Section 3.3.

3. WATER QUALITY DESIGN OBJECTIVES

The primary objectives of the City's stormwater quality requirements are to:

- Protect drinking water supplies.
- Protect public health and safety related to water resources.
- Maximize the quality of water resources to enhance the quality of life.
- Enable recreational opportunities where feasible and beneficial.
- Meet federal National Pollutant Discharge Elimination System (NPDES) program requirements.

To achieve these objectives, the City requires that new developments incorporate specific design features to improve the quality of stormwater runoff. Specifically, new development must implement one or more of the water quality design principles summarized in Section 3.1 as a means to achieve the specific WQCV design requirement(s) for the site, as discussed in Section 3.2.

3.1. Water Quality Design Principles

To achieve the stormwater quality design objectives for a new development, designs shall incorporate one or more of the following principles:

1. **Minimize the amount of runoff.** The total quantity of pollutants transported to receiving waters can be minimized most effectively by minimizing the amount of runoff. Both the quantity of runoff and the amount of pollutant wash-off can be reduced by minimizing the Directly Connected Impervious Area (DCIA) at a site. Impervious areas are considered connected when runoff

travels directly from roofs, driveways, pavement, and other impervious areas to street gutters, closed storm drains, and concrete or other impervious lined channels. Impervious areas are considered disconnected when runoff travels as sheet flow over grass areas or through properly designed BMPs, prior to discharge from the site.

Minimizing DCIA is a land development design philosophy that seeks to reduce paved areas and direct stormwater runoff to landscaped areas, grass buffer strips, and grass-lined swales to slow down the rate of runoff, reduce runoff volumes, attenuate peak flows, and facilitate the infiltration and filtering of stormwater. This approach increases the time of concentration for runoff, in contrast to the historic stormwater engineering approach that resulted in drainage systems with a relatively rapid, large peak runoff rate and increased runoff volumes, even for relatively small storms.

A design approach that minimizes DCIA can be integrated into the landscape and drainage planning for any development. Drainage from rooftop collection systems, sidewalks, and driveways can be directed to landscaped areas, infiltration areas such as porous landscape detention and permeable pavement, grassed buffer strips, or to grass swales. Instead of using traditional solid curbing, curbing can be eliminated in some areas or slotted curbing can be used along with stabilized grass shoulders and swales or can direct flows towards BMPs within street bulb-outs. Residential driveways can use permeable pavement or their runoff can be redirected to the lawn rather than the street. Large parking lots can minimize DCIA by using permeable pavement to capture runoff and encourage local infiltration or storage. Green roofs may also be used as a tool to minimize DCIA.

2. **Maximize contact with grass and vegetated soil.** The opportunity for pollutants to settle can be maximized by providing maximum contact with grass and vegetated soil. Directing runoff over vegetative filter strips and grass swales enhances settling of pollutants as the velocity of flow is reduced. Street bulb-outs must have plantings proposed within them in the design to be utilized as BMPs to capture and treat runoff from the impervious areas within the right-of-way.

3. **Maximize holding and settling time.** The most effective runoff quality controls reduce both the runoff peak and volume. By reducing the rate of outflow and increasing the time of detention storage, settling of pollutants and infiltration of runoff are maximized.

4. **Design for small, frequent storms.** Drainage stormwater systems for flood control are typically designed for large, infrequent storm events. In contrast, water quality controls shall be designed for small, frequent storm events. In Rogers, approximately 90 percent of all rainfall events are 1 inch or less. Studies indicate that many pollutants are frequently washed off in the “first flush,” typically considered the first ½ inch of runoff from directly connected impervious areas.

5. **Utilize BMPs in series where feasible.** Performance monitoring of BMPs throughout the country has shown that the combined effect of several BMPs in series can be more effective in reducing the level of pollutants than just providing a single BMP at the point of discharge. To the extent practical, impervious areas shall be disconnected with runoff directed first to vegetative filter strips, then to grass swales or channels, and then to extended detention basins, etc.

6. **Incorporate both flood control and stormwater quality objectives in designs, where practical.** Incorporating both flood control and water quality enhancement into a single stormwater management facility is encouraged whenever practical. Combining several objectives, such as water quality enhancement and flood control, maximizes the cost-effectiveness of stormwater management facilities.

7. **Provide special care for runoff from fueling areas and other areas having a high concentration of pollutants.** Runoff from areas that pose a specific high hazard to the quality of runoff must be directed to a properly designed BMP that provides both filtration and settling prior to discharge to receiving waters.

3.2. Water Quality Capture Volume

Studies indicate that small-sized, frequently occurring storm events account for the majority of events that result in stormwater runoff from urban drainage basins. Consequently, these frequent storms also account for a significant portion of the annual pollutant loads. Capture and treatment of stormwater from these small and frequently occurring storms is the recommended design approach for water quality enhancement, as opposed to designs for flood control facilities that focus on larger, less frequent storm events. Incorporation of both sets of criteria (i.e., small, frequent storms for water quality purposes and larger storms for flood control) into a single stormwater management facility is encouraged, where practical. However, unless exempt from the requirement, no single BMP shall address more than 50 percent of the site's calculated WQCV.

For sites where the water quality requirements apply, water quality BMPs shall be designed to capture and treat the WQCV of the site. The required WQCV (measured in cubic feet [ft^3]) is a function of the total area tributary to the storage facility and the impervious percentage of the tributary area. The WQCV curves in Figure WQ-1 are calculated for the City of Rogers and are based on approximately the 85th percentile runoff event (i.e., the top 85 percent of storm events in Rogers that generate runoff) (WEF and ASCE, 1998). The required WQCV will need to be dispersed throughout the site. No single BMP can address more than 50 percent of the required WQCV unless a regional water quality BMP is present or if the site is within an industrial zone. The three curves represent the required WQCV for drain times of 12, 24, and 48 hours. Different drain times are required depending on the type of BMP and their relative effectiveness in removing suspended sediments and other contaminants. Storage and treatment of the WQCV can be achieved through the use of five BMPs described in Section 4.0. These BMPs and their respective drain times are:

- Extended dry detention basin — 48 hour drain time
- Constructed wetland basin — 24 hour drain time
- Permeable pavers — 24 hour drain time
- Extended wet detention basin — 12 hour drain time
- Porous landscape detention — 12 hour drain time

**Refer to Chapter 5 – Detention Design for drain times associated with volumetric detention.*

With an understanding of the type of BMP to be employed and the associated drain time, and the impervious percentage of the area tributary to the BMP, Figure WQ-1 graphically shows the WQCV (in cubic feet) per square foot of area tributary to the storage facility. The required WQCV shall be computed using the WQCV Worksheet in the BMP spreadsheet.

The required quantity of the WQCV can be reduced through the use of BMPs that minimize the DCIA at a site. Such BMPs promote infiltration and reduce the runoff volume from a site. These BMPs also serve to filter runoff that does leave the site. Three BMPs that can be used to reduce the necessary WQCV include:

- Permeable pavers
- Vegetated filter strip/grass swale
- Grass swale

As seen above, the use of permeable pavers can potentially store and treat the WQCV as well as reduce the necessary WQCV. The pavers' function would depend on the design of the system. Sites that are increasing the overall impervious area, not including any building's footprint, beyond 2,000 square feet must make at least 10 percent of that impervious area permeable pavement so as to minimize the DCIA. Areas where heavy vehicles or equipment are expected would be exempt of implementing permeable pavement for this purpose. The reduction in the amount of necessary WQCV provided by use of permeable pavement and these BMPs is described in Appendix A.

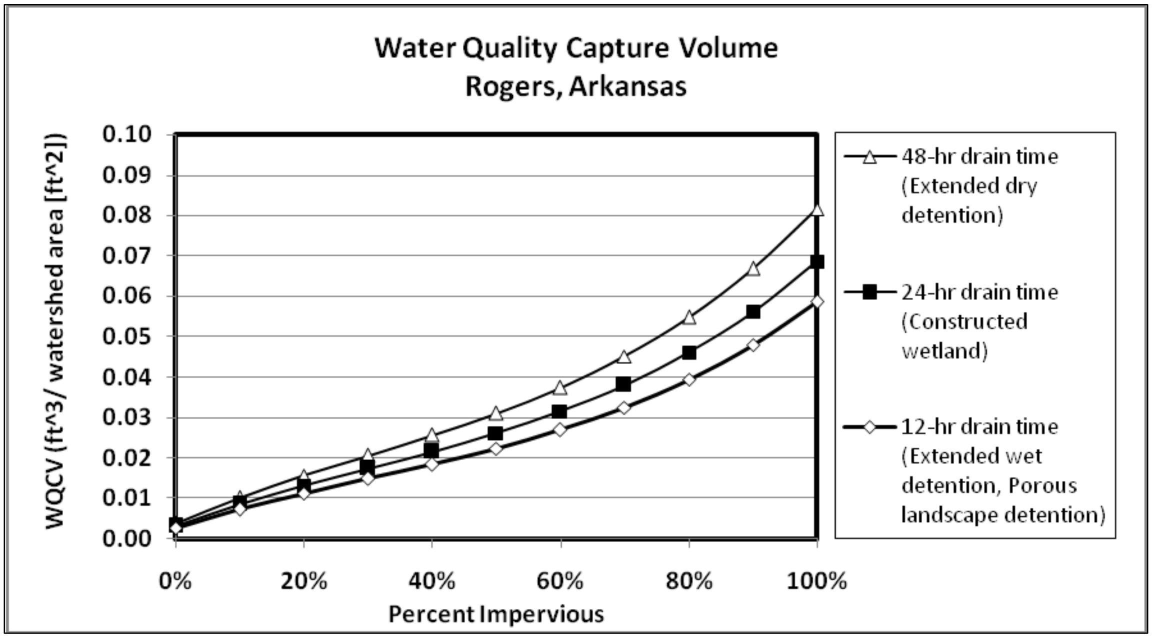


Figure WQ-1
Water Quality Capture Volume for Rogers, Arkansas

3.3. Fee-in-Lieu of Implementing Water Quality Measures

The City may allow the property owner to pay a fee in-lieu-of implementing the water quality control measures described in this section. The fee paid in-lieu-of water quality protection measures is an acceptable alternative only if the development site disturbs less than one half (0.5) an acre and the site has not been specifically identified by the City as having a significant potential to adversely impact the quality of stormwater runoff. Sites that have an existing regional water quality control facility with adequate capacity, as determined by the City, are exempt of having to pay a fee-in-lieu of water quality protection. Proceeds from fees collected from this option will be used by the City to fund regional stormwater facilities or other measures that will benefit the quality of stormwater in the community. The methodology for calculating the in-lieu-of fees is described in Appendix B.

3.4. Other Important Considerations for BMP Selection

In addition to the design considerations above, the following factors shall be considered when selecting BMPs for a site:

- Pollutants Controlled - The BMPs shall effectively control pollutants known to be associated with the tributary land use.
- Reliability/Sustainability - Measures shall be effective over an extended time and be able to be properly maintained over time.

- Public Acceptability - BMP selection shall consider the expected response from the public, particularly neighboring residential properties, if any.

- Agency Acceptability - BMP selection shall consider the expected response of agencies that will oversee the BMPs and their relationship to regulatory requirements.

- Public Safety - Control measures shall be evaluated in terms of public safety and the risks or liabilities that occur during implementation. Public safety is always one of the most important design considerations, not only for “traditional” drainage structures, but also for BMPs.

- Mosquito Control - The potential for mosquito breeding and the spread of mosquito-borne illnesses in stormwater BMPs must be addressed. In general, the biggest concern is the creation of areas with shallow stagnant water and low dissolved oxygen that creates prime mosquito habitat. Other habitat characteristics that may enhance breeding include dense stands of vegetation that may protect larvae from natural predators and soils with high organic content. While stormwater BMPs such as detention ponds and constructed wetlands often include these features, careful design and proper management and maintenance of systems can effectively control mosquito breeding.

  The key to minimizing breeding is to avoid creating, or allowing the formation of, areas of shallow standing water. Studies indicate that pools of deep water (≥ 5 feet) and pools with residence times less than 72 hours are less likely to breed mosquitoes. Stormwater BMPs with permanent pools are generally less of a concern than dry detention basins because of their greater depth. Therefore, dry detention basins must have outlets designed to drain within 48 hours.

Once the BMPs are implemented, it is necessary to ensure that structural BMPs are properly operated and maintained and that the relevant non-structural BMPs are also being implemented. This may involve requiring subdivision covenants, inspecting BMPs, designating individuals responsible for BMPs, and pollution prevention education. Modifications to BMPs over time may also be necessary if land uses or other factors change or if BMPs prove to be ineffective or a nuisance. For permeable paver systems, see the Annual Inspection and Maintenance Checklist.

4. STRUCTURAL BEST MANAGEMENT PRACTICES

Structural BMPs described in this section include vegetated filter strips/grass buffers, grass swales, extended dry detention basins, extended wet detention basins, constructed wetland basins, permeable pavers, porous landscape detention, and proprietary packaged stormwater treatment systems. A brief description of each BMP is provided followed by design procedures and criteria and maintenance considerations. BMPs that capture and treat the WQCV are listed first (Extended Dry Detention Basin, Extended Wet Detention Basin, Constructed Wetland Basin, Porous Landscape Detention, and

Permeable Pavers). These are followed by BMPs that do not store the WQCV but that help to reduce the DCIA (Permeable Pavers, Vegetated Filter Strip/Grass Buffer, and Grass Swale) and which can be used to reduce the required WQCV for a site as described in Appendix A.

Experience with many of the BMPs in Rogers is limited as of 2010 (when this manual was initially published). As experience with BMP design, construction, monitoring, and maintenance builds, the criteria listed below may change.

4.1. Extended Dry Detention Basin

4.1.1. Description

An extended dry detention basin is designed to collect the runoff from smaller, more frequent rainfall events and release the runoff over a longer period of time. An extended dry detention basin collects and treats the "first flush" runoff which frequently has a higher concentration of pollutants typically found in urban runoff. The extended dry detention basin is an adaptation of the more typical detention basin used for flood control. The primary difference is the outlet design. Extended dry detention basins are considered to be "dry" because they are designed to not have a significant permanent pool of water remaining between storm runoff events. An extended dry detention basin can be used for regional or on-site treatment and as follow-up treatment in series with other BMPs.

Photograph WQ-1 – Example of a dry detention basin.
Properly designed and maintained an extended dry detention basin
can be a site amenity.

An extended dry detention basin is typically designed and maintained to pool water for not less than 24 hours and for no more than the design drawdown time of 48 hours. Extended dry detention basins will need to conform to the plantings requirements outlined in Chapter 5 – *Detention Design* for dry detention basins alike. In cases where there is a sufficient distance between the extended dry detention basin and the nearest residential land use (150 feet or more), it may be desirable to allow pools to form and wetland vegetation to grow. These plants generally provide water quality benefits through pollutant uptake, but often generate public complaints when located near a residential area. In addition, the bottom of an extended dry detention basin will be the depository of all the sediment that settles out in the basin and, as a result, can be muddy and may have an undesirable appearance. To mitigate this problem, the designer may provide a small wetland marsh or ponding area in the basin's bottom, which may be incorporated as part of the design to promote biological uptake of certain pollutants.

In addition to reducing peak runoff rates and improving water quality, an extended dry detention basin can be designed to provide other benefits such as recreation, wildlife habitat and open space. Extended dry detention basins may also be used during land development activities to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, must be removed after upstream land disturbances cease and before the basin is placed into final long-term use. As with other BMPs, public safety issues need to be addressed through proper design.

4.1.2. Design Considerations

Major considerations for the design of an extended dry detention basin are summarized below:

Space requirements - It is imperative to plan land use correctly to account for an extended dry detention basin. The land required for an extended dry detention basin is approximately 0.5 to 2.0 percent of the total tributary development area, depending on DCIA and other factors.

Presence of groundwater or baseflow **-** Special consideration must be made when placing an extended dry detention basin in an area of high groundwater, wet weather springs or areas that otherwise have baseflow. Consideration shall be given to constructing an extended wet detention basin or a wetland bottom in those cases. If an extended dry detention basin is constructed, a low flow channel shall be constructed to maintain positive drainage to allow mowing and maintenance. Sites with persistent flow require a special design by a Professional Engineer registered in the State of Arkansas to appropriately address the unique conditions of the site.

Flood control considerations **-** Extended dry detention basins shall be incorporated into the larger flood control basin whenever possible. In all cases, the embankments and spillway shall be designed to safely pass the 100-year flow as described in Chapter 5 – *Detention Design*.

Geology and soils - Soil maps should be consulted, and soil borings may be needed to establish geotechnical design parameters, particularly for cases such as deeper basins or when bedrock or other sensitive geologic features, such as karst formations, are believed to be present. A regular concern with storage basins in Rogers is "puncturing" limestone during the course of excavation, thereby providing a conduit for stormwater into the shallow groundwater system. A map of the Karst Formation/Cave Spring recharge area is provided in Figure WQ-2. Development within the recharge area shall be coordinated with the United States Fish and Wildlife Service (USFWS). The USFWS is responsible for enforcing specific development restrictions to protect resources within the recharge area.

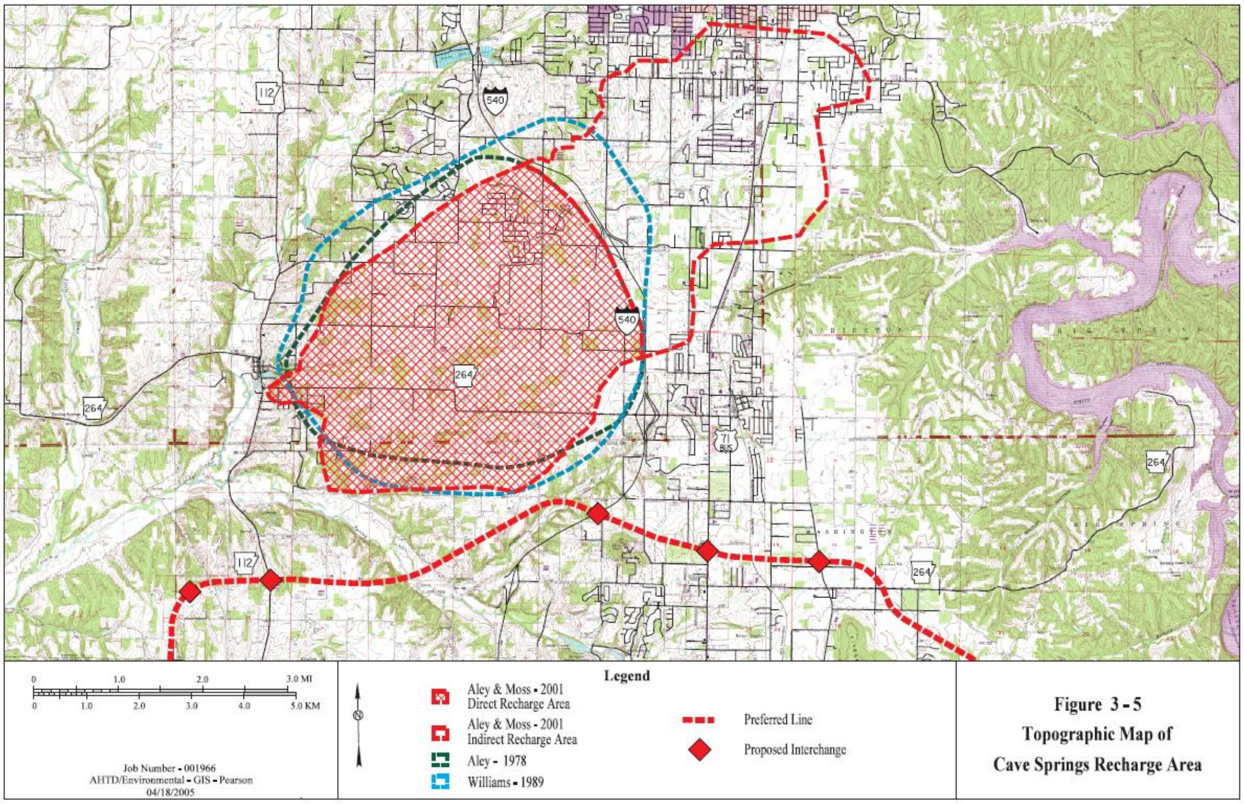


Figure WQ-2
Karst Formation/Cave Springs Recharge Area

Inundation of open space - When multiple uses such as recreation or habitat creation are incorporated into a detention basin, a multiple-stage design shall be used to limit the frequency of inundation of passive recreational areas. Generally, the area within the WQCV is not well suited for active recreation facilities such as ballparks, playing fields, and picnic areas. These are best located above the WQCV pool level as part of the flood control basin.

Maintenance access - Access to critical elements of the pond, such as the inlet, outlet, spillway, and sediment collection areas must be provided for maintenance purposes. The access must have a maximum grade of 10 percent and have an all-weather solid driving surface composed of gravel, crushed rock, concrete, or reinforced turf. An access easement shall be provided if the pond's drainage easement does not adjoin a public right-of-way.

4.1.3. Design Procedure and Criteria

The following steps outline the design procedure and criteria for an extended dry detention basin. Figure WQ-3 shows a representative layout of an extended dry detention basin. The Extended Dry Detention Basin (EDB) Worksheet in the BMP Spreadsheet will aid in the design procedure discussed below.

1. ***Calculate design volume*** - Calculate the design volume, *V*, in ft^3 as follows (a multiplier of 1.25 is applied to account for sediment accumulation):

   $$V = WQCV \cdot 1.25$$ **(Equation WQ-1)**

   In which:

   WQCV = Water Quality Capture Volume, ft^3 (see Section 3.2 for calculation methodology)

   This design volume accounts only for water quality and not for flood control.

2. ***Basin length:width ratio*** - The basin length to width ratio (L:W) shall be between 2:1 and 4:1, and the inlets shall be as far as possible from the outlet. Maximizing the distance between the inlet and the outlet and shaping the pond with a gradual expansion from the inlet, and a gradual contraction toward the outlet will minimize short-circuiting. It the minimum 2:1 ratio cannot be met or the outlet is near the inlet, an alternate means to prevent short-circuiting shall be provided.

3. ***Basin side slopes*** - Basin side slopes shall be a maximum of 3H:1V. The use of flatter slopes is encouraged to facilitate maintenance, access, and safety. In addition, incorporate a flatter upper zone and/or a "safety bench" (a flatter zone near the edge of the pond). The safety bench shall extend outward from the pond edge for a minimum distance of 10 feet, with a maximum slope of 5% and maximum water depth of 18 inches.

4. ***Basin geometry*** - Determine the preliminary basin geometry necessary to provide the design volume. Select the preferred depth of the extended dry detention basin, then solve for the basin bottom width that will provide adequate storage of the design volume. Assume a trapezoidal pond with the selected L:W ratio, side slopes, and basin depth. The EDB Worksheet will assist with this calculation.

5. ***Outlet structure*** - Design the outlet structure to release the WQCV (not the "design volume" [V] from Step 1) over a 48-hour period. Outlet structures shall consist of a perforated plate with a stainless steel well-screen or aluminum bar trash rack. Figure WQ-4 shows details for a perforated plate outlet structure. The EDB Worksheet in the BMP Spreadsheet provides a useful tool for designing the outlet structure and perforation geometry.

Table WQ-1
Requirements for Water Quality Outlet Structures

Parameter	Perforated Plate Requirement
Minimum perforation diameter	1/2 inch
Maximum perforation diameter	4 inches
Minimum number of holes per row	1
Maximum number of holes per row	8
Minimum row spacing	4 to 8 inches [1]
Maximum row spacing	12 inches
Minimum riser pipe diameter	n/a

[1] The minimum row spacing for a perforated plate varies based on the perforation diameter.

For perforated plates, select the perforation diameter, number of holes per row, row spacing and total number of rows to meet the requirements in Table WQ-1. Use the fewest number of columns possible to maximize the perforation diameter. This helps to reduce clogging problems. The EDB Worksheet will calculate the resulting drain time based on the perforation geometry selected. The perforation geometry shall then be modified as necessary to achieve an acceptable drain time.

6. ***Trash rack*** - For perforated plates, provide a trash rack of sufficient size to prevent clogging of the primary water quality outlet. Size the rack so as not to interfere with the hydraulic capacity of the outlet. Using the total outlet area (calculated by multiplying the perforation area per row by the number of rows) and the selected perforation diameter, Figure WQ-5 can be used to determine the minimum open area required for the trash rack. Use one-half of the total outlet area to calculate the trash rack's size. This accounts for the variable inundation of the outlet orifices. The trash rack shall extend 24 inches below the lowest perforation and a micro-pool shall be provided. The micro-pool is a small area of ponded water adjacent to the outlet that provides a flow path for water to discharge when the trash rack becomes clogged with floating trash and debris (see Figure WQ-3). The volume of the micro-pool shall be greater than or equal to 5 percent of the WQCV. The EDB Worksheet provides a useful tool to complete the trash rack design.

7. ***Freeboard*** - A freeboard of at least 12 inches shall be provided above the 100-year water surface elevation for all extended dry detention basins (including facilities that are solely for water quality

purposes and allow larger flows to "pass through") and detention areas in accordance with Chapter 5 – *Detention Design*.

8. ***Low flow channel*** - A low flow channel shall be provided when groundwater or base flow exists in the basin or as required in Chapter 5 – *Detention Design*.

9. ***Vegetation types*** – Plantings will need to be provided as required in Chapter 5 – *Detention Design*. Consideration shall be given to the use of native grasses and plants for pond bottoms, berms, and side slopes. However, the species selected shall be water tolerant in areas where periodic inundation is anticipated. It may be desirable to consult a plant specialist when selecting the appropriate type of vegetation. A list of plant species for different portions of an extended dry detention basin is provided in Table WQ-2.

10. ***Maintenance access*** - Access to the facility shall be provided for maintenance. Grades of the access shall not exceed 10 percent, and a stabilized, all-weather driving surface must be provided.

11. ***Energy dissipation*** The required quantity of the WQCV can be reduced through the use of BMPs that minimize the DCIA at a site. Such BMPs promote infiltration and reduce the runoff volume from a site. These BMPs also serve to filter runoff that does leave the site. Three BMPs that can be used to reduce the necessary WQCV include:

    - Permeable pavers
    - Vegetated filter strip/grass swale
    - Grass swale

    The reduction in the amount of necessary WQCV provided by use of these BMPs is described in Appendix A.

    Energy dissipation and erosion control shall be provided at inlets in accordance with Chapter 5 – *Detention Design*.

12. ***Combination of water quality and flood control facilities*** - Combining the water quality facility with a flood control facility is acceptable. Design of the flood control volume may assume the extended dry detention basin is dry at the beginning of the storm. Additional information can be found in Chapter 5 – *Detention Design*.

13. ***Neighborhood compatibility*** - Plan and design the facility with appearance and neighborhood compatibility as design objectives.

14. ***Forebay*** - A forebay, while optional, should be considered when the design volume exceeds 20,000 ft^3 or a large sediment, trash, or debris load is anticipated due to upstream land use. A

forebay provides an opportunity for larger particles to settle out in the inlet area, which has a solid surface bottom to facilitate mechanical sediment removal. The forebay volume for the extended dry detention basin should be between 3 and 5 percent of the design volume. Outflow from the forebay to the basin shall be through a gravel filter designed to be stable under maximum design flow conditions. The top of the gravel filter shall be set equal to the stage of the design volume. The floor of the forebay shall be concrete and contain a low flow channel to define sediment removal limits. Assure that good, long term access to the perimeter of the forebay is provided, including necessary easements.

Table WQ-2
Suggested Plant List for Extended Dry Detention Basins

Basin Area	Plant Species (Botanical Name)	Plant Species (Common Name)	Planting Guidelines
Micro-pool	Equisetum hyemale	Horsetail/Scouring Rush	1 gal., plant 30" O.C.
	Typha Angustifolia	Narrow-leaved Cattail	1 gal., plant 30" O.C.
	Pontederia cordata	Pickeral Weed	1 gal., plant 30" O.C.
	Scirpus zebrinus	Zebra Rush	1 gal., plant 30" O.C.
Pond Bottom	Juncus effuses	Soft Rush	1 gal., plant 18" O.C.
	Acourus calamus	Sweet Flag	1 gal., plant 18" O.C.
	Carex stricta 'Bowles Golden'	Bowles Golden Sedge	1 gal., plant 24" O.C.
	Caltha palustris	Marsh Marigold	1 gal., plant 24" O.C.
	Peltandra virginica	Arrow Arum	1 gal., plant 24" O.C.
	Equisetum hyemale	Horsetail/Scouring Rush	1 gal., plant 30" O.C.
	Typha Angustifolia	Narrow-leaved Cattail	1 gal., plant 30" O.C.
Interior sideslopes	Juncus effuses	Soft Rush	1 gal., plant 18" O.C.
	Acourus calamus	Sweet Flag	1 gal., plant 18" O.C.
	Carex stricta 'Bowles Golden'	Bowles Golden Sedge	1 gal., plant 24" O.C.
	Caltha palustris	Marsh Marigold	1 gal., plant 24" O.C.
	Iris ensata	Japanese Iris	1 gal., plant 12" O.C.
	Iris fulva	Copper Iris	1 gal., plant 15" O.C.

4.1.4. Maintenance

Maintenance shall be performed regularly to clean out the extended dry detention basin (or forebay if one is present) when sediment accumulates to a depth of 6 inches. A depth gauge shall be installed at the outlet and will help to facilitate determining when sediment removal is necessary. See <u>Chapter 5 – *Detention Design*</u> for depth gauge requirements. Also, appearance may dictate more frequent cleaning.

Maintenance may also be necessary to repair areas of erosion or to remove excessive trash, or debris or sediment clogging the outlet. Design grades must be maintained to ensure shallow ponding does not occur, particularly when within 150 feet or less of residential areas.

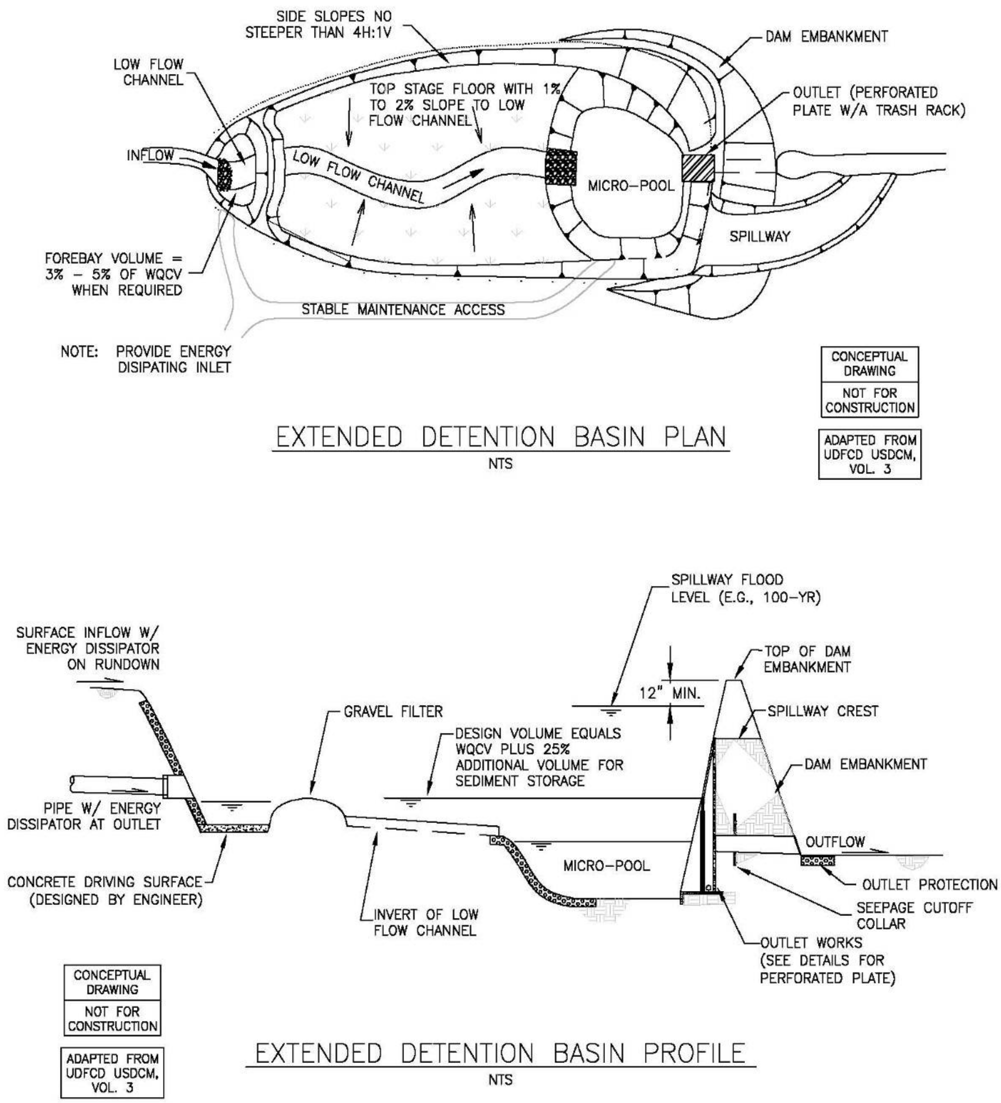
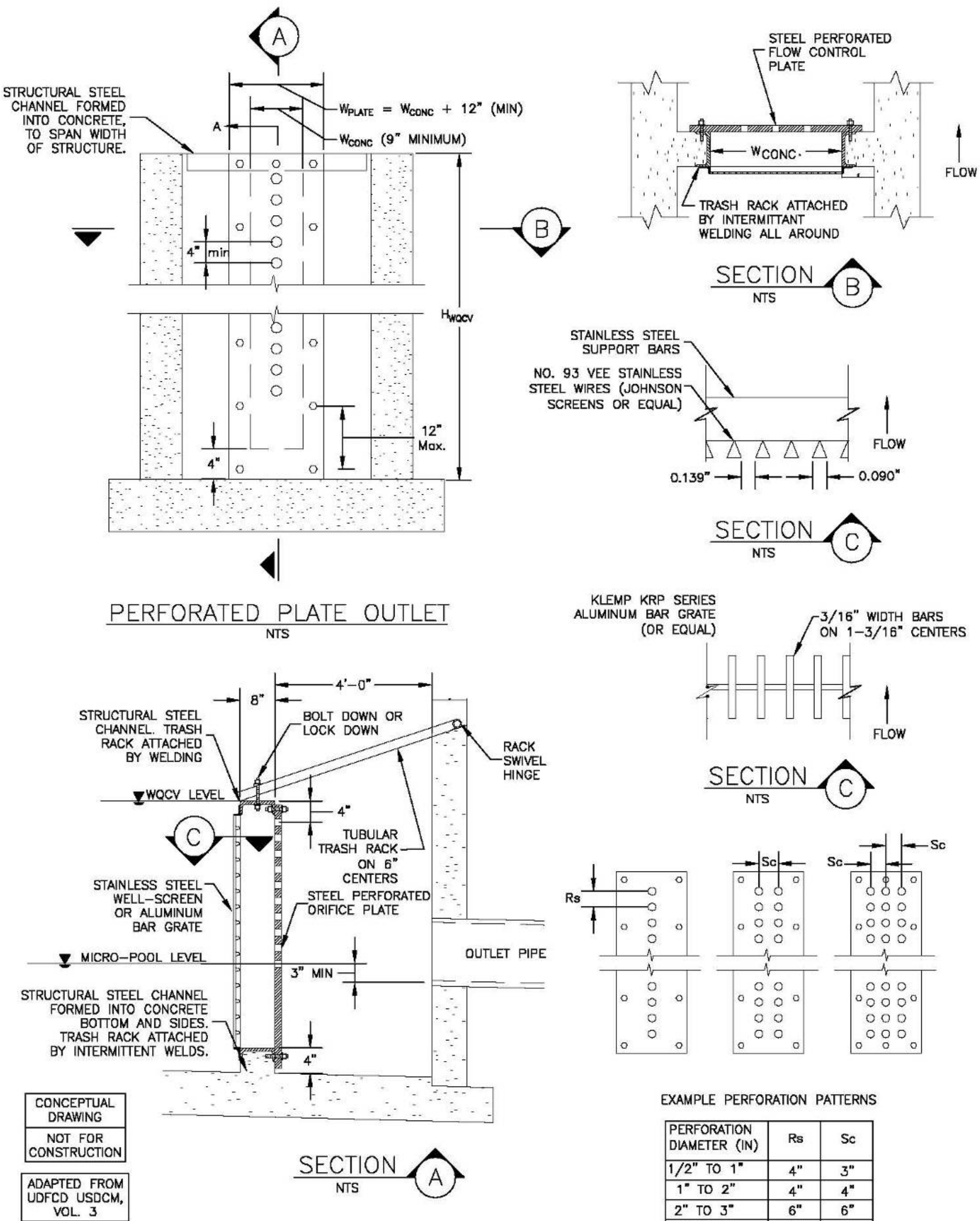


Figure WQ-3
Plan and Profile of an Extended Dry Detention Basin



PERFORATION DIAMETER (IN)	Rs	Sc
1/2" TO 1"	4"	3"
1" TO 2"	4"	4"
2" TO 3"	6"	6"
3" TO 4"	8"	8"

Figure WQ-4
Details for a Perforated Plate and Trash Rack

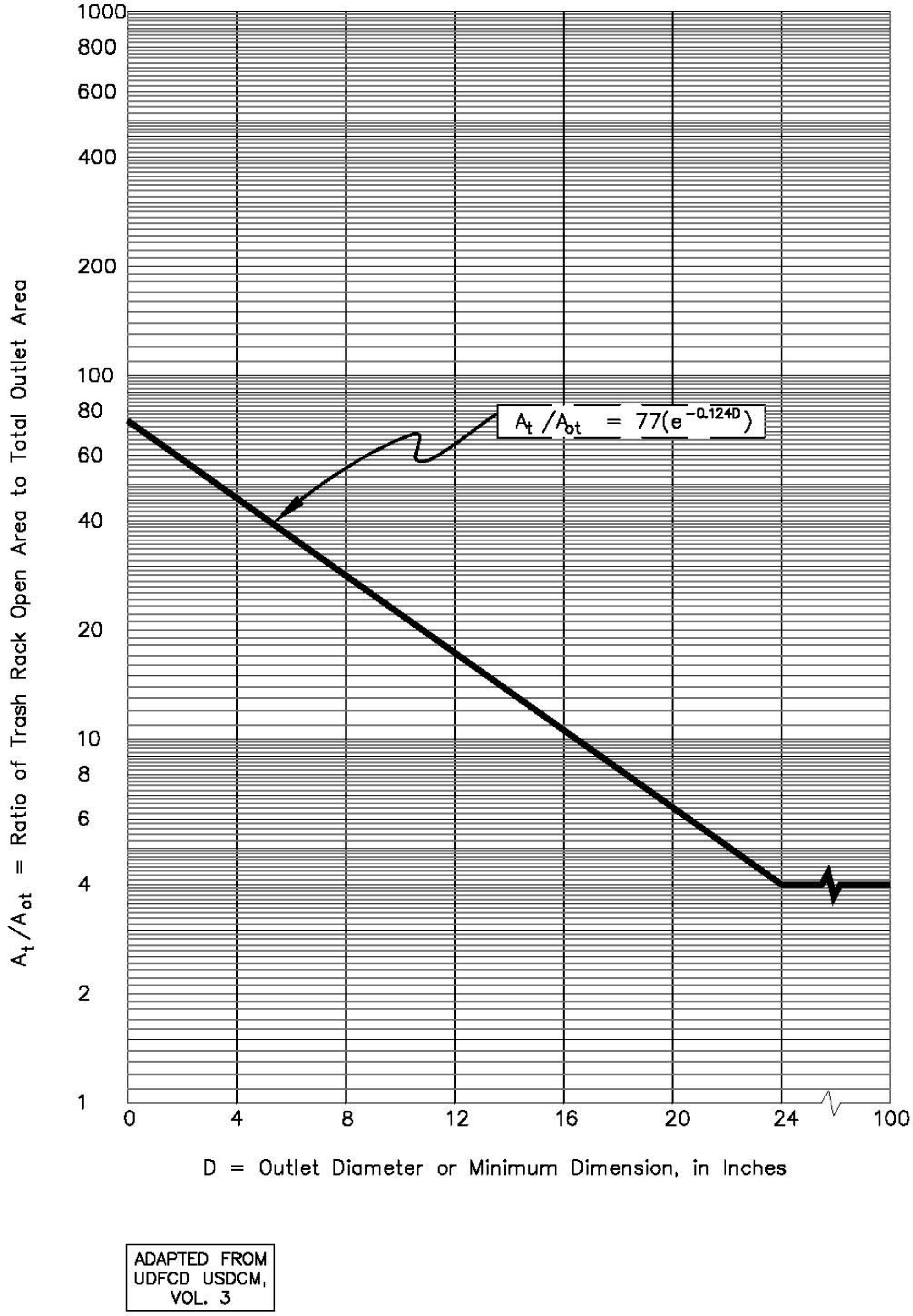


Figure WQ-5

Trash Rack Sizing

4.1.5. Extended Dry Detention Basin Design Example

The following example demonstrates use of the Extended Dry Detention Basin (EDB) Worksheet in the BMP Spreadsheet.

Given: The contributing watershed area is 51.37 acres and the land use type is residential (1/2 acre lot size). Approximately 7.7 acres (15% of the site) are impervious areas.

Determine: Basin volume, basin geometry, outlet structure characteristics, trash rack characteristics and forebay characteristics, if applicable.

Worksheet Data Input

The user selects various input parameters as part of the basin and outlet structure design. Watershed, basin, and outlet characteristics are entered into the input cells in the EDB Worksheet.

Watershed Characteristics – User Inputs

Watershed area = 51.37 acres (given)

The WQCV required is calculated for a facility with a 48 hour drain time using the method described in Section 3.2 of this chapter or using the WQCV Worksheet in the BMP Spreadsheet.

The WQCV value (27,223 ft^3) is used as an input to the worksheet to calculate the minimum design volume for the EDB (Minimum design volume = WQCV * 1.25).

Preliminary Basin Geometry – User Inputs

The preliminary basin geometry consists of a trapezoidal basin with the following characteristics:

Basin length to width ratio, L:W = 3.0

Basin side slope, Z = 4.0 feet/feet (ft/ft)

Basin Depth, D = 2.0 ft

Water Quality Outlet Structure – User Inputs

To determine the perforation geometry of the plate that will drain the WQCV in 24 to 48 hours, it is necessary to use an iterative process that varies the perforation diameter, number of holes per row, and row spacing. It is recommended that the designer use the fewest number of holes per row in order to maximize the perforation diameter and reduce the potential for clogging. The final perforation geometry selected is shown below:

Perforation diameter, $d_{perforation}$ = 1.0 inch

Number of holes per row, $n_{holes\ per\ row}$ = 5

Row spacing, R_s = 4 inches

Pre-sedimentation Forebay Basin – User Inputs

The optional forebay volume should be between 3 and 5 percent of the WQCV. This results in a volume between 1,021 and 1,702 ft^3. For this example, a volume of 1,500 ft^3 was selected and a gravel filter forebay outlet and a concrete floor are included.

Forebay volume = 1,500 ft^3

Results

Results of the analysis are displayed in the EDB Worksheet (see sample worksheet following this design example). The results indicate an extended detention basin with the following characteristics:

- Basin bottom width = 70 ft
- Basin bottom length = 210 ft
- Calculated Design Volume = 34,136 ft^3
- Number of rows = 6 (based on row spacing and depth of WQCV)
- Outlet area per row = 3.93 square inches
- Total outlet area = 23.56 square inches
- Drain time for WQCV = 45.3 hours

Design Procedure Form: Extended Dry Detention Basin (EDB)

Sheet 1 of 2

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2009**
Project:	**Sunny Estates Neighborhood**
Location:	**Rogers, AR**

1. Basin Storage Volume	
A) Contributing Watershed Area (Area)	Area = 51.37 acres
B) Water Quality Capture Volume (WQCV) (Input from WQCV spreadsheet)	WQCV = 27,225 cubic feet
C) Minimum Design Volume: Vol = WQCV * 1.25 A multiplier of 1.25 is applied to account for sediment accumulation	Vol = 34,031 cubic feet
2. Preliminary Basin Geometry (assumes a trapezoidal basin)	
A) Basin Length to Width Ratio (L:W), should be between 2:1 and 4:1	L:W = 3.0
B) Basin Side Slopes, Z (Horizontal:Vertical), should be 3:1 or flatter	Z = 4.0 ft/ft
C) Basin Depth, D	D = 2.00 feet
D) Basin Bottom Width, W	W = 70.00 feet
E) Basin Bottom Length, L	L = 210.00 feet
F) Calculated Design Volume (may be slightly larger than required)	Calc. Vol = 34,136 cubic feet
3. Water Quality Outlet Structure	
A) Outlet Type	X Perforated Plate
B) For a Perforated Plate Select:	
i) Perforation Diameter, $d_{perforation}$ (Min = 0.5", Max = 4.0")	$d_{perforation}$ = 1 inches
ii) Number of Holes per Row, $n_{holes\ per\ row}$ (Min = 1, Max = 8)	$n_{holes\ per\ row}$ = 5
iii) Row Spacing, R_s (Min varies based on $d_{perforation}$, Max = 12")	R_s = 4 inches
C) Results for Perforated Plate	
i) Number of Rows, n_{rows}	n_{rows} = 6
ii) Outlet Area Per Row, A_o	A_o = 3.93 square inches
iii) Total Outlet Area, A_{ot}	A_{ot} = 23.56 square inches
iv) Drain Time for WQCV (should fall between 24 and 48 hours)	Drain Time = 45.3 hours

Design Procedure Form: Extended Dry Detention Basin (EDB)

Sheet 2 of 2

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2008**
Project:	**Sunny Estates Neighborhood**
Location:	**Rogers, AR**

3. Trash Rack for Perforated Plate	
A) Needed Open Area: A_t = 0.5 * (Figure WQ-7 Value) * A_{ot} (Factor of 0.5 accounts for variable innundation of the outlet perforations)	A_t = 801 square inches
B) Height of Trash Rac (Min Height = Dwqcv + 24 inches = 48 inches.)	H_{TR} = ____ inches
C) Width of Concrete Opening: W_{conc} = (A_t / R) / H_{TR} Effective open area, R = 0.6 for wire screens, R = 0.71 for aluminum bar grates	W_{conc} = ____ inches
D) Width of Trash Rack Screen, W_{TR} (Minimum Width = W_{conc} + 6")	W_{TR} = ____ inches
E) Type of Trash Rack Stainless Steel #93 VEE Wire Aluminum Bar Grate	____ S.S. #93 VEE Wire (Johnson Screens) ____ Aluminum Bar Grate (Klemp KRP)
F) Open Space betwee S.S. #93 VEE Wires Aluminum Bearing Bars (Vertical Alignment)	____ #93 VEE Wire Slot Opening ____ Bearing Bar Spacing
G) Spacing of Support Rods (O.C.)	____ On Center Spacing
H) Type and Size of: Support Rods for S.S. #93 VEE Wire Screen Bearing Bars for Aluminum Bar Grate	____ ____
4. Pre-sedimentation Forebay Basin - Enter design values	
A) Volume (3% to 5% of WQCV from 1B) (3% - 5% of Design Volume equals 1021 to 1702 cubic feet.)	1,500 cubic feet
B) Gravel Filter Forebay Outlet (Designed to be stable under maximum design flow conditions)	yes yes/no
C) Concrete Floor in Forebay	yes yes/no

4.2. Extended Wet Detention Basin

4.2.1. Description

An extended wet detention basin differs from and extended dry detention basin because it is designed with a permanent pool, which provides water quality benefits as the influent water mixes with the permanent pool water and most of the sediment deposits remain in the permanent pool zone. Similar to an extended dry detention basin, an extended wet detention basin is designed to collect the runoff from smaller, more frequent rainfall events and release the runoff over a longer period of time. The design collects and treats the “first flush” runoff, which frequently has a higher concentration of most pollutants found in urban runoff. Like an extended dry detention basin, an extended wet detention basin can be used for regional or on-site treatment and as follow-up treatment in series with other BMPs.

An extended wet detention basin provides a similar level of water quality treatment due to the permanent pool compared to an extended dry detention basin, but in less time because the outflow occurs above the bottom of the basin and sedimentation continues after the captured surcharge volume is emptied.

Photograph WQ-2 – Example of an Extended Wet Detention Basin.
This extended wet detention basin is aesthetically pleasing and serves as an amenity to the community, in addition to providing water quality benefits.

An extended wet detention basin shall be designed with the WQCV above the permanent pool, and the outlet structure shall be sized to drain the WQCV in approximately 12 to 15 hours. The reduced drain time (when compared to the extended dry basin) is due to water quality benefits provided by the permanent pool. Flood control volume may also be provided above the permanent pool by including modified outlet controls, a minimum of 1 foot of freeboard above the 100-year water surface, and a 100-year (minimum) overflow spillway.

Extended wet detention basins can be very effective in removing pollutants and, when properly designed and maintained, can satisfy multiple objectives such as the creation of wildlife habitats; provision of recreational, aesthetic, and open space opportunities; and inclusion into a larger, regional flood control basin. An extended wet detention basin must be carefully designed and maintained to address safety concerns, bank erosion, sediment removal, and upstream and downstream impacts to waterways. In addition, extended wet detention basins have the potential for floating litter, debris, algae growth, nuisance odors, and mosquito problems. Aquatic plant growth can be a factor in clogging outlet works, and the permanent pool can attract waterfowl, which can add to the nutrient and bacteria loads entering and leaving the pond. Design considerations for an extended wet detention basin are described below in Section 4.2.2.

Refer to Chapter 5 – *Detention Design* for additional design criteria.

4.2.2. Design Considerations

Major considerations for the design of an extended wet detention basin are summarized below:

Basin volume - The total basin volume of an extended wet detention basin facility consists of: 1) the permanent pool volume, 2) the WQCV above the permanent pool, and 3) the flood control volume above the WQCV (if included). Care shall be taken to assess the complete water budget of the watershed accounting for runoff, baseflow, evaporation, evapotranspiration, seepage, and other losses to assure the permanent pool can be maintained.

Design considerations unique to an extended wet detention basin - In addition to the considerations typically given to an extended dry detention basin, design considerations for an extended wet detention basin include:

- Water balance calculations shall be conducted (including inflow, outflow, evaporation, and subsurface flows in and out of the pond) to assure there is adequate flow to maintain a desirable permanent pool and provide adequate flushing through the basin.

- Edge treatments that will prevent bank erosion must be considered and described in the drainage report as well as shown in the plans.

- To minimize the potential of algae growth, a minimum permanent pool depth of 6 feet must be provided. Aeration shall be provided and other upstream BMPs may also be provided. If algae become a problem, then the property owner or Property Owners Association (POA) must demonstrate that a reasonable effort to remedy the condition has been made within one month of being notified by the City.

- Basin lining must be provided to ensure the basin is watertight and a permanent pool will be maintained. This is particularly important where karst geology exists and the potential for a leaky pond is high. Lining ponds in such areas can be difficult and expensive. A map of the Karst formation/Cave Spring recharge area, which has specific development restrictions enforced by the USFWS, is provided on Figure WQ-2.

- The embankments must be carefully designed to prevent seepage and piping that can lead to loss of the permanent pool or dam failure.

- A shorter detention time of 12 to 15 hours may be used due to the inherent sedimentation that occurs in a wet basin.
- A fence surrounding the pond is required unless the pond design incorporates a safety bench. See Chapter 5 – *Detention Design*.

4.2.3. Design Procedure and Criteria

The following steps outline the design procedure and criteria for an extended wet detention basin. Figure WQ-6 shows a representative layout for an extended wet detention basin. The Extended Wet Detention Basin (EWDB) Worksheet in the BMP Spreadsheet will aid in the design procedure discussed below.

1. ***Residence time*** - For large ponds, if the residence time for the permanent pool volume is 24 hours or greater during a 2-year, 24-hour storm event, the surcharge WQCV is not required above the permanent pool. The residence time, t (hr), is calculated by dividing the permanent pool volume, V_p (ft^3), by the average inflow rate during a 2-year, 24-hour storm event, $Q_{2\text{-}yr\ avg}$ (cfs), as shown in Equation WQ-2. The 2-year, 24 hour average inflow rate is equal to the total event runoff volume divided by the event duration (24 hours). The runoff volume must be calculated using the appropriate hydrologic analysis method presented in Chapter 3 – *Determination of Stormwater Runoff.*

$$t = \frac{V_p}{Q_{2-yr\ avg} \cdot 3600} \qquad \textbf{(Equation WQ-2)}$$

2. ***WQCV (if needed)*** - If the residence time in the permanent pool is less than 24 hours, the WQCV shall be added above the permanent pool and shall be calculated using the method provided in Section 3.2 of this chapter. The WQCV is the surcharge volume above the permanent pool. Generally, an extended wet detention basin shall be located away from any offsite drainage crossing the site to ensure proper function. If offsite area is drained through the facility, that area must be included in all volume calculations.

3. ***Minimum volume required*** - The minimum volume required for the permanent pool is a function of the WQCV and is calculated using Equation WQ-3.

$$V_p = 1.2 \cdot WQCV \qquad \textbf{(Equation WQ-3)}$$

   The permanent pool shall have a depth of at least 6 feet (and preferably deeper) to decrease the likelihood of algae growth. An option to improve water quality treatment and minimize bank erosion is to provide a littoral zone 18 inches deep and 10 feet wide for aquatic plant growth along the perimeter of the permanent pool. This also serves as a safety bench and enhances pond safety.

4. ***Outlet works*** - The outlet works are to be designed in accordance with requirements set forth in Section 4.1.3, Design Procedure and Criteria for an extended dry detention basin, with the exception being that the outlet works must be designed to release the WQCV over a 12- to 15-hour period.

5. ***Trash rack*** -The trash rack is to be designed in accordance with requirements set forth in Section 4.1.3, Design Procedure and Criteria for an extended dry detention basin. The trash rack shall extend at least 24 inches below the permanent pool level.

6. ***Basin length:width ratio*** - The basin length to width ratio shall be between 2:1 and 4:1. Maximizing the distance between the inlet and the outlet will minimize short-circuiting.

7. ***Basin side slopes*** - Basin side slopes above the permanent pool shall be no steeper than 3:1, preferably 5:1 or flatter to limit rill erosion and facilitate maintenance and safety. A “safety bench” shall be constructed around the pond perimeter to promote safety.

8. ***Establishing vegetation*** - A 4- to 6-inch organic topsoil layer, vegetated with aquatic species, shall be provided on the littoral bench, if incorporated. Areas of vegetation above the permanent pool shall include water tolerant species in anticipation of periodic inundation.

9. ***Maintenance access*** - Access to the basin bottom, forebay (if applicable), and outlet area must be provided for maintenance vehicles. Grades of the access shall not exceed 10 percent, and a stabilized, all-weather driving surface must be provided.

10. ***Erosion protection*** - Provide erosion protection at all inlets to the pond.

11. ***Forebay*** - A forebay, while optional, should be considered when the design volume exceeds 20,000 ft^3 or a large sediment, trash, or debris load is anticipated due to upstream land use. Forebays provide an opportunity for larger particles to settle out at a controlled location where sediment and debris can be more easily removed. Install a solid driving surface on the bottom and sides below the permanent water line to facilitate sediment removal. A berm consisting of rock and topsoil mixture shall be part of the littoral bench to create the forebay. The forebay volume within the permanent pool volume shall be between 5 and 10 percent of the design WQCV.

4.2.4. Maintenance

Intermittent maintenance may be necessary to remove floating trash, debris, and algae from the surface of the permanent pool. If algae become a problem, then the property owner or POA must make a reasonable effort to remedy the condition, such as using chemical treatments. It may also be necessary to remove accumulated sediments from the pond bottom on a regular basis. A maintenance plan with these criteria, at a minimum, shall be recorded as part of the subdivision covenants.

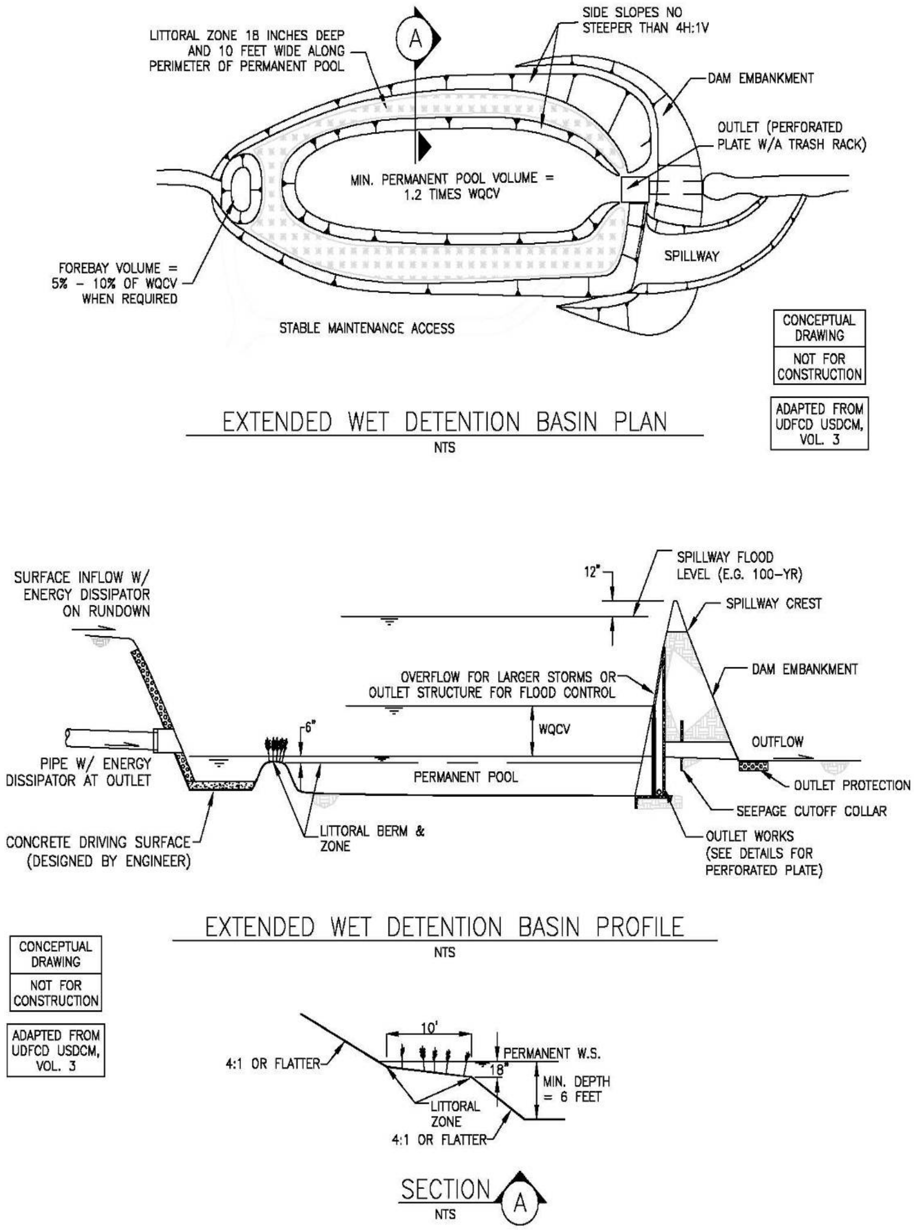


Figure WQ-6
Plan, Profile, and Details of an Extended Wet Detention Basin

4.2.5. Extended Wet Detention Basin Design Example

The following example demonstrates use of the Extended Wet Detention Basin (EWDB) Worksheet in the BMP Spreadsheet.

Given: The contributing watershed area is 46.4 acres, consisting of commercial development (85 percent impervious). All the impervious area on the site is directly connected impervious area (e.g. rooftops, downspouts, paved parking, storm sewer, etc.).

Determine: Basin volume, residence time, basin geometry, outlet structure characteristics, trash rack characteristics, and forebay characteristics.

Worksheet Data Input

Watershed, basin, and outlet characteristics are entered into the input cells in the EWDB Worksheet.

<u>Watershed Characteristics – User Input</u>

Watershed area = 26.4 acres (given, convert to square feet for the worksheet input)
I_a = 85.0% (given)

The WQCV required is calculated in the WQCV worksheet using the method described in Section 3.2 of this chapter for a facility with a 12-hour drain time. For this example, the WQCV calculated is 48,349 ft^3.

This value is automatically carried over to the EWDB worksheet to calculate the minimum design volume for the EWDB (Minimum permanent pool design volume = WQCV * 1.2).

<u>Minimum Permanent Pool Volume – User Input</u>

As described above, the minimum permanent pool volume is based on the WQCV. For this example, a permanent pool volume of 1.35 acre-ft (58,806 ft^3) was selected to ensure the minimum was met.

Permanent Pool Volume, V_p = 58,806 ft^3

<u>Residence Time of Permanent Pool – User Input</u>

The residence time is calculated by dividing the permanent pool volume by the average inflow rate during a 2-year, 24-hour storm event. The average inflow rate is calculated using the appropriate hydrologic analysis method from <u>Chapter 3 – *Determination of Stormwater Runoff*</u>. In this example, the Rational Method is appropriate because of the limited size of the watershed. The average inflow rate is equal to the total runoff volume divided by the event duration. The total runoff volume is a function of the rainfall depth, drainage area and runoff coefficient. The 2-year rainfall depth for the City of Rogers is 4.08 inches in 24 hours. With a drainage area of 26.4 acres and a runoff coefficient of 0.95, the total 2-year runoff volume is approximately 371,445 ft^3. The total runoff volume divided by the event duration (24 hours) results in an average inflow rate to the pond of approximately 4.3 cfs.

Average inflow rate, $Q_{2yr,\ avg}$ = 4.3 cfs

Preliminary Basin Geometry – User Input

The preliminary basin geometry consists of a trapezoidal basin with the following characteristics:

Basin length to width ratio, L:W = 3.0

Basin side slope, Z = 4.0 ft/ft

Basin Depth, D = 6.0 ft

Water Quality Outlet Structure – User Input

To determine the perforation geometry of the plate that will drain the WQCV in 12 to 15 hours, it is necessary to undergo an iterative process of varying the perforation diameter, number of holes per row, and row spacing. It is recommended that the designer use the fewest number of holes per row in order to maximize the perforation diameter and reduce the potential for clogging. Using the EWDB worksheet, the final perforation geometry selected is:

Perforation diameter ($d_{perforation}$) = 3.5 inches

Number of holes per row ($n_{holes\ per\ row}$) = 2

Row spacing (R_s) = 8 inches

Trash Rack Selection – User Input

The trash rack design is based on the size of the perforated plate and the perforation geometry. For this example, the minimum height of the trash rack is based on the depth of the WQCV plus 24 inches. Since the WQCV depth is 36 inches (see Worksheet line 3.G), a height of 60 inches was selected. The minimum width of the trash rack was based on the required width of the concrete opening calculated in the EWDB Worksheet. The minimum width for the trash rack is 91 inches, however a width of 96 inches (8 feet) was selected based on standard material sizes.

Height of trash rack, H_{TR} = 60 inches

Width of trash rack, W_{TR} = 96 inches

Pre-sedimentation Forebay Basin – User Input

The optional forebay volume should be between 5 and 10 percent of the WQCV. This results in a volume between 4,252 and 8,503 ft^3. For this example, a volume of 6,000 ft^3 was selected and a gravel filter forebay outlet and a solid driving surface are included.

Forebay volume = 3,000 ft^3

Results

Results of the analysis are displayed in the EWDB Worksheet (see sample worksheet following this design example). The results indicate:

Volume and Geometry

- Minimum permanent pool volume = 58,019 ft^3
- Selected permanent pool volume = 58,800 ft^3 (2.35 acre-feet)
- Residence time = 3.8 hours (WQCV surcharge is required)
- Basin bottom width = 41 ft
- Basin bottom length = 123 ft
- Calculated permanent pool volume = 60,786 ft^3
- Depth of the WQCV = 2.7 ft
- Calculated WQCV = 85,041 ft^3

Perforated Plate Sizing

- Number of rows = 4 (based on row spacing and depth of WQCV)
- Outlet area per row = 19.24 square inches
- Total outlet area = 76.97 square inches
- Drain time for WQCV = 14.3 hours

Trash Rack Sizing

- Open area required for trash rack = 1,920 square inches
- Type of trash rack = aluminum bar grate (Klemp KRP or equal)
- Selected height of trash rack = 60 inches (equal to minimum required)
- Width of concrete opening = 45 inches
- Selected width of trash rack = 60 inches (rounded up to standard size)
- Open space between aluminum bearing bars = 1 3/16 inches
- Spacing of cross bars (on center) = 2 inches
- Type of bearing bars = 1 1/4 inch by 3/16 inch rectangular bar

Design Procedure Form: Extended Wet Detention Basin (EWDB)

(Sheet 1 of 2)

Designer: J. Smith
Company: A1 Engineering, Inc.
Date: November 15, 2009
Project: Commercial Site #3
Location: Main Street, Rogers, AR

1. Surcharge WQCV and Minimum Permanent Pool Volume	
A) Contributing Watershed Area from WQCV Spreadsheet	Area = 26.4 acres
B) Water Quality Capture Volume ($WQCV_{12}$) (Input from WQCV Spreadsheet, 12 hour drain time)	$WQCV_{12}$ = 48,349.4 cubic feet
C) Minimum Permanent Pool Volume: Vol = WQCV * 1.2	Min. V_p = 58,019.2 cubic feet
2. Check Residence Time of Permanent Pool	
A) Design Permanent Pool Volume, Vp	Design V_p = 58,800 cubic feet
B) Average Inflow Rate to Pond during 2-year Storm Event, $Q_{2yr, avg}$ (Calculated using appropriate hydrologic analysis method in Ch. 5, Runoff)	$Q_{2yr, avg}$ 4.30 cfs
C) Residence Time, t **NOTE: Permanent Pool Residence Time is less than 24 hours. WQCV Surcharge is Required.**	t = 3.8 hours
3. Preliminary Basin Geometry (assumes a trapezoidal basin)	
A) Basin Length to Width Ratio (L:W), should be between 2:1 and 4:1	L:W = 3.0
B) Basin Side Slopes, Z (Horizontal:Vertical), should be 3:1 or flatter	Z = 4.0 ft/ft
C) Permanent Pool Depth, D_p (Min = 6 feet)	D_p = 6.00 feet
D) Basin Bottom Width, W	W = 41.00 feet
E) Basin Bottom Length, L	L = 123.00 feet
F) Calculated Permanent Pool Volume (may be slightly larger than required)	Calc. V_p = 60,786 cubic feet
G) Calculated WQCV Depth, D_{WQCV}	D_{WQCV} = 2.7 feet
H) Calculated WQCV	Calc. WQCV = 49,303 cubic feet
4. Water Quality Outlet Structure	
A) Outlet Type	X Perforated Plate
B) For a Perforated Plate Select: i) Perforation Diameter, $d_{perforation}$ (Min = 0.5", Max = 4.0") ii) Number of Holes per Row, $n_{holes\ per\ row}$ (Min = 1, Max = 8) iii) Row Spacing, R_s (Min varies based on $d_{perforation}$,Max = 12")	 $d_{perforation}$ = 3.5 inches $n_{holes\ per\ row}$ = 2 R_s = 8 inches
C) Results for Perforated Plate i) Number of Rows, n_{rows} ii) Outlet Area Per Row, A_o iii) Total Outlet Area, A_{ot} iv) Drain Time for WQCV (should fall between 12 and 15 hours)	 n_{rows} = 4 A_o = 19.24 square inches A_{ot} = 76.97 square inches Drain Time = 14.3 hours

Design Procedure Form: Extended Wet Detention Basin (EWDB)

(Sheet 2 of 2)

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2009**
Project:	**Commercial Site #3**
Location:	**Main Street, Rogers, AR**

5 Trash Rack for Perforated Plate	
A) Needed Open Area: A_t = 0.5 * (Figure WQ-4 Value) * A_{ot} (Factor of 0.5 accounts for variable innundation of the outlet perforations)	A_t = 1,920 square inches
B) Height of Trash Rack: H_{TR} (Min Height = Dwqcv + 24 inches = 57 inches.)	H_{TR} = 60 inches
C) Width of Concrete Opening: W_{conc} = (A_t / R) / H_{TR} Effective open area, R = 0.6 for wire screens, R = 0.71 for aluminum bar grates	W_{conc} = 45 inches
D) Width of Trash Rack Screen, W_{TR} (Minimum Width = W_{conc} + 6")	W_{TR} = 60 inches
E) Type of Trash Rack Stainless Steel #93 VEE Wire Aluminum Bar Grate	 ___ X Aluminum Bar Grate (Klemp KRP)
F) Open Space between: S.S. #93 VEE Wires Aluminum Bearing Bars (Vertical Alignment)	___ #93 VEE Wire Slot Opening 1 3/16" Bearing Bar Spacing
G) Spacing of Support Rods (O.C.)	2" On Center Spacing
H) Type and Size of: Support Rods for S.S. #93 VEE Wire Screen Bearing Bars for Aluminum Bar Grate	 ___ 1-1/4" x 3/16" rectangular bar
6 Pre-sedimentation Forebay Basin - Enter design values	
A) Volume (5% to 10% of WQCV from 1B) (5% - 10% of Design Volume equals 2417 to 4835 cubic feet.)	3,000 cubic feet
B) Gravel Filter Forebay Outlet	yes yes/no
C) Solid Driving Surface on Bottom and Sides of Forebay	yes yes/no

Notes:

4.3. Constructed Wetland Basin

4.3.1. Description

A constructed wetland basin is a shallow extended wet detention basin that requires a perennial base flow to maintain microorganism habitat and to permit the growth of rushes, willows, cattails, and reeds. The wetland vegetation functions to slow runoff and allow time for sedimentation, filtering, and biological uptake. Existing small wetlands along ephemeral drainageways could be enlarged and incorporated into a constructed wetland system. Such action, however, requires the approval of federal and state regulators.

Photograph WQ-3 – Example of a Constructed Wetland Basin.
These basins can provide multiple benefits, but proper design is essential to avoid development of nuisance conditions, such as excessive algae growth.

When properly designed, a constructed wetland basin can offer several potential advantages, such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. Additionally, the constructed wetland basin can act as part of a multi-use facility by providing flood control storage above the WQCV pool or by providing effective follow-up treatment to other BMPs (such as onsite BMPs or source controls) that rely upon settling of larger sediment particles.

The primary constraint of a constructed wetlands basin is the need for a relatively continuous base flow to ensure viable wetland growth. In addition, silt and algae can accumulate and be flushed out during larger storms, adversely affecting downstream water quality, unless the wetlands are properly designed and built. Also, in order to maintain healthy wetland growth, the surcharge depth for WQCV above the permanent water surface cannot exceed roughly 2 feet. Another potential concern is that a wetland BMP may require a Section 404 permit from the USACE for significant maintenance if the facility is considered a jurisdictional wetland. Jurisdictional wetlands are subject to strict regulatory requirements administered by the USACE. These issues shall be reviewed with the USACE during the design process.

The City will review wetlands projects on a case-by-case basis. The City reserves the right to deny use of a constructed wetland because of these potential concerns.

4.3.2. Design Considerations

Major considerations for the design of a constructed wetland basin are summarized below:

Water budget - Development and analysis of a water budget is needed to show the net inflow of water is sufficient to meet all the projected losses (such as evaporation, evapotranspiration, and seepage for each season of operation) and ensure a perennial baseflow. Insufficient inflow can cause the wetland to become saline or die.

Soils analysis - Loamy soils are needed in a wetland bottom to permit plants to take root. Exfiltration through a wetland bottom cannot be relied upon because the bottom is either covered by soils of low permeability or because the groundwater is higher than the wetland's bottom.

Longitudinal slope - Wetland basins require a nearzero longitudinal slope, which can be provided using embankments.

4.3.3. Design Procedure and Criteria

The following steps outline the design procedure for a constructed wetland basin.

Figure WQ-7 illustrates an idealized constructed wetland basin. The Constructed Wetland Basin (CWB) Worksheet in the BMP Spreadsheet will aid in the design procedure discussed below.

1. ***WQCV*** – Calculate the WQCV in ft^3 using the method described in Section 3.2. The WQCV is the surcharge volume above the permanent wetland pool.

2. ***Permanent pool volume*** – The volume of the permanent wetland pool shall be no less than 75 percent of the WQCV.

3. ***Pool area and depth*** – Proper distribution of wetland habitat is needed to establish a diverse plant community. Distribute pond area in accordance with Table WQ-3.

Table WQ-3
Wetland Pond Water Design Depths

Components	% of Permanent Pool Surface Area	Water Design Depth
Forebay, outlet and free water surface areas	30 to 50%	2 to 4 feet deep
Wetland zones with emergent vegetation	50 to 70%	6 to 12 inches deep*

* One-third to one-half of this zone should be 6 inches deep.

4. ***WQCV surcharge depth*** – The surcharge depth of the WQCV above the permanent pool's water surface shall not exceed 2.0 feet.

5. ***Outlet works*** – The outlet works shall be designed in accordance with requirements set forth for extended dry detention basins in Section 4.1, with the following exceptions:

   a. Design the outlet works to release the WQCV in 22 to 28 hours.

   b. Outlet design shall consider the increased potential for wetland vegetation growth and clogging around the outlet. A micro-pool shall be incorporated into the outlet design to allow sub-surface flow to go under the pool surface (where debris typically accumulates against the trash rack) and through the lower portion of the trash rack.

6. ***Trash rack*** – The trash rack shall be designed in accordance with requirements set forth for extended dry detention basins in Section 4.1. The trash rack shall extend at least 24 inches below the permanent pool level.

7. ***Basin Usage*** – Determine whether flood storage or other uses will be provided and design accordingly for combined uses.

8. ***Basin length:width ratio*** – The basin length to width ratio shall be between 2:1 and 4:1. Maximizing the distance between the inlet and the outlet will minimize short-circuiting.

9. ***Basin side slopes*** – Basin side slopes shall be no steeper than 4:1, preferably 5:1 or flatter to facilitate maintenance, safety, and access.

10. ***Water balance*** – A net influx of water must be available through a perennial base flow and must exceed the losses. A hydrologic balance shall be used to estimate the net quantity of base flow available at a site.

11. ***Energy dissipation at inlets*** – Provide energy dissipation at all inlets to limit sediment resuspension.

12. ***Forebay*** – If a forebay is incorporated into the design, design considerations and criteria for extended wet detention basins (described in Section 4.2) shall be followed.

13. ***Wetland vegetation*** – Cattails, sedges, reeds, and wetland grasses shall be planted in the wetland bottom. Qualified professionals must be utilized to develop the planting plan and to plant the wetland vegetation. Berms and side-slopes shall be sodded with native or turf-forming grasses. Initial establishment of the wetland requires control of the water depth. After planting wetland species, the permanent wetland pool shall be kept at 3 to 4 inches deep at the plant zones to allow growth and to help establish the plants, after which the pool shall be raised to its final operating level. Suggested plant species for constructed wetlands are provided in Table WQ-4. The planting plan for wetlands must be developed by a qualified Wetland Scientist or a Landscape Architect with wetland experience. The wetland plantings must be guaranteed to have a minimum survival rate of three years.

Table WQ-4
Suggested Plant List for Constructed Wetlands

Basin Area	Plant Species (Botanical Name)	Plant Species (Common Name)	Planting Guidelines
Micro-pool	Equisetum hyemale	Horsetail/Scouring Rush	1 gal., plant 30” O.C.
	Typha Angustifolia	Narrow-leaved Cattail	1 gal., plant 30” O.C.
	Pontederia cordata	Pickeral Weed	1 gal., plant 30” O.C.
	Scirpus zebrinus	Zebra Rush	1 gal., plant 30” O.C.
Pond Bottom	Juncus effuses	Soft Rush	1 gal., plant 18” O.C.
	Acourus calamus	Sweet Flag	1 gal., plant 18” O.C.
	Carex stricta ‘Bowles Golden’	Bowles Golden Sedge	1 gal., plant 24” O.C.
	Caltha palustris	Marsh Marigold	1 gal., plant 24” O.C.
	Peltandra virginica	Arrow Arum	1 gal., plant 24” O.C.
	Equisetum hyemale	Horsetail/Scouring Rush	1 gal., plant 30” O.C.
	Typha Angustifolia	Narrow-leaved Cattail	1 gal., plant 30” O.C.
Berms/ Sideslopes	Juncus effuses	Soft Rush	1 gal., plant 18” O.C.
	Acourus calamus	Sweet Flag	1 gal., plant 18” O.C.
	Carex stricta ‘Bowles Golden’	Bowles Golden Sedge	1 gal., plant 24” O.C.
	Caltha palustris	Marsh Marigold	1 gal., plant 24” O.C.
	Iris ensata	Japanese Iris	1 gal., plant 12” O.C.
	Iris fulva	Copper Iris	1 gal., plant 15” O.C.

14. ***Maintenance access*** – Provide vehicle access to the forebay (if applicable) and outlet area for maintenance and removal of bottom sediments. Maximum grades shall not exceed 10 percent, and a stabilized, all-weather driving surface must be provided.

4.3.4. Maintenance

Because proper maintenance of a constructed wetland is necessary to achieve optimal performance, submittal of a maintenance plan for the wetlands will be required for the City to approve a constructed wetlands project. The maintenance plan must include tasks and schedule for both routine and non-routine maintenance, including the following major categories:

- Conduct routine inspections and perform minor maintenance, as needed, for accumulation of litter and debris, burrows, integrity of the outlet, and sediment accumulation (perform semi-annually).

- Perform non-routine maintenance based on the findings from the routine maintenance inspections. Remove accumulated sediment in forebay and main pool basin, as necessary. Removal of sediment from the main pool is required whenever sediment accumulation occupies approximately 20 percent of the WQCV. Periodic sediment removal is also needed if water movement within the wetland is restricted.

As noted in Section 4.3.1, the USACE shall be consulted regarding maintenance of a wetland with respect to Section 404 Permit requirements.

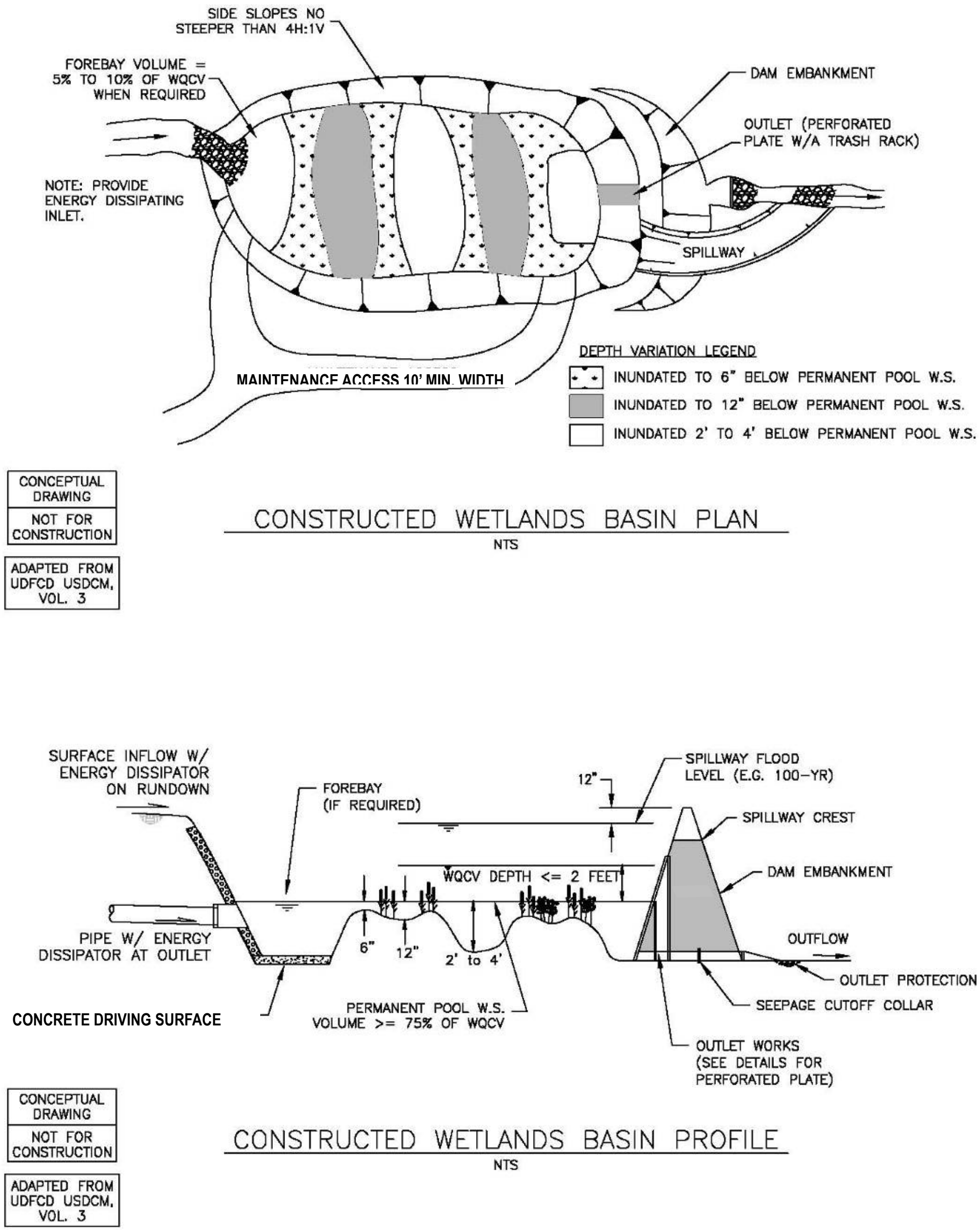


Figure WQ-7
Plan and Profile of an Idealized Constructed Wetland Basin

4.3.5. Design Example

The following example demonstrates use of the Constructed Wetland Basin (CWB) Worksheet in the BMP Spreadsheet.

Given: Assume a contributing watershed area of 86,980 square feet (approximately 2.0 acres), consisting of commercial development for a grocery store (85 percent impervious). All the impervious area on the site is directly connected impervious area (e.g. rooftops connected to downspouts which drain onto paved parking areas that are drained by the local storm sewer).

Determine: Basin volume, basin geometry, outlet structure characteristics, trash rack characteristics and forebay characteristics.

Worksheet Data Input

Watershed, basin, and outlet characteristics are entered into the input cells in the CWB Worksheet as described below:

Watershed Characteristics – User Inputs

Watershed area = 86,980 square feet (approximately 2.0 acres) (given)

The WQCV required is calculated using the method described in Section 3.2 of this chapter.

A WQCV value of 4,387 ft^3 is used to calculate the minimum permanent wetland pool volume for the CWB (Minimum permanent pool design volume = WQCV * 75% = 4,387 x 0.75 = 3290.25 ft^3.

Permanent Wetland Pool Volume – User Inputs

As described above, the minimum permanent wetland pool volume is based on the WQCV. For this example, a permanent wetland pool volume of 3300 ft^3 was selected to ensure the minimum was met.

Permanent wetland pool volume, V_p = 3300 ft^3

Permanent Wetland Pool Surface Area – User Inputs

The permanent wetland pool water surface area is based on an estimated area calculated in the CWB Worksheet. A water surface area of 2,200 ft^2 was selected for this example.

Water surface area = 2,200 ft^2

Permanent Wetland Pool Depth – User Inputs

The depth of the permanent wetland pool varies for different portions of the basin (see Table WQ-3). For this example, a depth of 36 inches was selected for the forebay, outlet and free water surface areas. These areas account for approximately 45 percent (830 ft^2) of the total surface area. A depth of 9 inches was selected for the wetland zones.

Depth of forebay, outlet and free water surfaces = 36 inches

Surface area of forebay, outlet and free water surfaces = 880 ft^2 (40 percent)

Depth of wetland zones with emergent vegetation = 9 inches

Preliminary Basin Geometry – User Inputs

The preliminary basin geometry consists of a trapezoidal basin with the following characteristics:

Basin length to width ratio, L:W = 3.0

Basin side slope, Z = 4.0 ft/ft

Water Quality Outlet Structure – User Inputs

To determine the perforation geometry of the plate that will drain the WQCV in 22 to 28 hours, it is necessary to use an iterative process that varies the perforation diameter, number of holes per row, and row spacing. It is recommended that the designer use the fewest number of holes per row while still providing the necessary area of the openings. Using the fewest number of holes will maximize the diameter of each perforation, thereby reducing their potential for clogging. Using the CWB Worksheet, the final perforation geometry selected is shown below:

Perforation diameter, $d_{perforation}$ = 1.0 inch

Number of holes per row, $n_{holes\ per\ row}$ = 2

Row spacing, R_s = 12 inches

Trash Rack Selection – User Inputs

The trash rack design is based on the size of the perforated plate and the perforation geometry. For this example, the minimum height of the trash rack is based on the depth of the WQCV plus 24 inches. A height of 42 inches was selected. The minimum width of the trash rack was based on the required width of the concrete opening calculated in the CWB Worksheet. The minimum width for the trash rack is 15 inches; however, a width of 18 inches was selected based on standard material sizes. It is noted that the trash rack is larger than required to provide the needed open area. The size is constrained by the required depth (WQCV + 24 inches) and the width of the concrete opening. A conceptual detail of the plate and trash rack is shown on Figure WQ-4.

Height of trash rack, H_{TR} = 43 inches

Width of trash rack, W_{TR} = 18 inches

Pre-sedimentation Forebay Basin – User Inputs

The forebay volume, if used, must be between 5 and 10 percent of the WQCV. This results in a volume between 219 and 439 ft^3. For this example, a volume of 250 ft^3 was selected and a gravel filter forebay outlet and a solid driving surface are included.

Results

Results of the analysis are displayed in the CWB Worksheet (see sample worksheet following this design example). The designer must select actual design values based on the estimated values calculated in the spreadsheet. The results of the CWB Worksheet analysis are shown below:

Volume, Depth and Water Surface Area

- Minimum permanent wetland pool volume = 3,290.5 ft^3
- Selected design permanent wetland pool volume = 3,300 ft^3
- Estimated permanent wetland pool surface area = 2,200 ft^2
- Selected design permanent wetland pool surface area = 2,200 ft^2
- Selected depth of forebay, outlet and free water surface = 36 inches
- Selected surface area of forebay, outlet and free water surface = 880 ft^2 (approximately 40 percent of total surface area)
- Selected depth of wetland zones with emergent vegetation = 9 inches
- Surface area of wetland zones = 1,320 ft^2 (approximately 60 percent of total surface area)
- Depth of the WQCV = 1.51 ft
- Calculated WQCV = 4,420 ft^3

Perforated Plate Sizing

- Number of rows = 2 (based on row spacing and depth of WQCV)
- Outlet area per row = 1.57 square inches
- Total outlet area = 3.14 square inches

- Drain time for WQCV = 27.0 hours

Trash Rack Sizing

- Open area required for trash rack = 107 square inches
- Type of trash rack = stainless steel wire (#93 VEE) screen (Johnson Screens or equal)
- Selected height of trash rack = 43 inches
- Width of concrete opening = 9 inches (required by the perforation size and spacing)
- Selected width of trash rack = 18 inches
- Wire slot opening = 0.139 inches
- Spacing of support rods (on center) = 0.75 inches
- Type of support rods = #156 VEE

Design Procedure Form: Constructed Wetland Basin (CWB)

Sheet 1 of 2

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2009**
Project:	**Commercial Site #7**
Location:	**Main Street, Rogers, AR**

1. Surcharge WQCV and Minimum Permanent Wetland Pool Volume				
A) Contributing Watershed Area (Area) from WQCV Spreadsheet	Area =	2.0	acres	
B) Water Quality Capture Volume ($WQCV_{24}$) (Input from WQCV Spreadsheet, 24 hour drain time)	$WQCV_{24}$ =	4,387	cubic feet	
C) Minimum Permanent Wetland Pool Volume: Vol = 75% * WQCV	Min. V_p =	3,290.5	cubic feet	
2. Permanent Wetland Pool Volume, Depth and Water Surface Area				
A) Design Permanent Wetland Pool Volume, Vp	V_p =	3,300	cubic feet	
B) Estimated Permanent Wetland Pool Water Surface Area (Estimate based on average depth of 18 inches)	Estimated WS Area =	2,200	square feet	
C) Design Permanent Wetland Pool Water Surface Area	WS Area =	2,200	square feet	
D) Forebay, Outlet and Free Water Surface Areas (24" to 48" deep) (Area = 30% to 50% of Design WS Area, or 660 to 1100 square feet.)	Depth= Area=	36.00 880	inches ft^2	% = 40.00%
E) Wetland Zones with Emergent Vegetation (6" to 12" deep) (Area = 50% to 70% of Design WS Area, or 1100 to 1540 square feet.)	Depth= Area=	9.00 1,320	inches ft^2	% = 60.00% 100.00%
3. Basin Geometry for WQCV above Permanent Wetland Pool				
A) Basin Length to Width Ratio (L:W), should be between 2:1 and 4:1	L:W =	3.0		
B) Basin Side Slopes, Z (Horizontal:Vertical), should be 3:1 or flatter	Z =	4.0	ft/ft	
C) Surcharge Depth of WQCV Above Permanent Wetland Pool (Max = 2 feet)	D_{WQCV} =	1.51	feet	
D) Calculated WQCV (may be slightly larger than required)	Calc. WQCV =	4,420	cubic feet	
4. Water Quality Outlet Structure				
A) Outlet Type (Check One)	X	Perforated Riser Pipe		
B) For a Perforated Plate Select:				
i) Perforation Diameter, $d_{perforation}$ (Min = 0.5", Max = 4.0")	$d_{perforation}$ =	1.00	inches	
ii) Number of Holes per Row, $n_{holes\ per\ row}$ (Min = 1, Max = 8)	$n_{holes\ per\ row}$ =	2		
iii) Row Spacing, R_s (Min varies based on $d_{perforation}$,Max = 12")	R_s =	12	inches	
C) Results for Perforated Plate				
i) Number of Rows, n_{rows}	n_{rows} =	2		
ii) Outlet Area Per Row, A_o	A_o =	1.57	square inches	
iii) Total Outlet Area, A_{ot}	A_{ot} =	3.14	square inches	
iv) Drain Time for WQCV (should fall between 22 and 28 hours)	Drain Time =	27	hours	

Design Procedure Form: Constructed Wetland Basin (CWB) - Sedimentation Facility

Sheet 2 of 2

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2009**
Project:	**Commercial Site #7**
Location:	**Main Street, Rogers, AR**

6.	
A) Needed Open Area: $A_t = 0.5 * (\text{Figure WQ-7 Value}) * A_{ot}$	A_t = 107 square inches
B) Height of Trash Rack: H_{TR} (Min Height = Dwqcv + 24 inches = 43 inches.)	H_{TR} = 43 inches
C) Width of Concrete Opening: $W_{conc} = (A_t / R) / H_{TR}$ Effective open area, R = 0.6 for wire screens, R = 0.71 for aluminum bar grates	W_{conc} = 9 inches Minimum width of 9 inches required.
D) Width of Trash Rack Screen, W_{TR} (Minimum Width = W_{conc} + 6")	W_{TR} = 18 inches
E) Type of Trash Rack Stainless Steel #93 VEE Wire Aluminum Bar Grate	 X S.S. #93 VEE Wire (Johnson Screens) __ Aluminum Bar Grate (Klemp KRP)
F) Open Space between: S.S. #93 VEE Wires Aluminum Bearing Bars (Vertical Alignment)	0.139" #93 VEE Wire Slot Opening __
G) Spacing of Support Rods (O.C.)	0.75" On Center Spacing
H) Type and Size of: Support Rods for S.S. #93 VEE Wire Screen Bearing Bars for Aluminum Bar Grate	 #156 VEE __
7. Pre-sedimentation Forebay Basin - Enter design values	
A) Volume (5% to 10% of WQCV from 1B) (5% - 10% of Design Volume equals 219 to 439 cubic feet.)	250 cubic feet
B) Gravel Filter Forebay Outlet	Yes yes/no
C) Solid Driving Surface on Bottom and Sides of Forebay	Yes yes/no

Notes:

4.4. Porous Landscape Detention

4.4.1. Description

Porous landscape detention consists of a low-lying vegetated area underlain by a porous media bed with an underdrain pipe, which gradually dewaters the porous media bed and discharges the runoff to a nearby channel, swale, or drainage system. A shallow surcharge zone exists above the porous landscape detention for temporary storage of the WQCV. During a storm, accumulated runoff ponds in the vegetated zone and gradually infiltrates into the underlying porous media bed.

Photograph WQ-4 – Example of Porous Landscape Detention.
PLD can be integrated into a wide variety of development conditions and can be particularly beneficial for sites with limited green space, such as this parking lot.

Porous landscape detention is ideally suited for small installations such as parking lot islands, street medians, roadside swale features, and site entrance or buffer features. This BMP may also be implemented at a larger scale, serving as an infiltration basin for an entire site, provided the WQCV and average depth requirements contained in this section are met. Vegetation may consist of turfgrass or natural grasses with shrub and tree plantings.

The primary disadvantage of porous landscape detention is the potential for clogging if moderate to high quantities of silts and clays are allowed to flow into the facility. Also, this BMP shall be avoided within 20 feet of building foundations, although an underdrain and impermeable liner can address the concern of saturation, shrink, and swell near a foundation. Additionally, this BMP has a relatively flat surface area and may be difficult to incorporate into steeply sloping terrain.

4.4.2. Example Applications

The photograph below shows an example of a relatively large porous landscape detention facility featuring a dense turfgrass bottom with a putting green.

Photograph WQ-5 – Porous landscape detention facilities can be implemented in many creative ways.

4.4.3. Design Considerations

When implemented using multiple small installations on a site, it is important to accurately account for each upstream drainage area tributary to each porous landscape detention site to make sure that each facility is properly sized for the tributary area.

4.4.4. Design Procedure

The following steps outline the porous landscape detention design procedure and criteria. Figure WQ-8 shows a cross-section for a porous landscape detention. The Porous Landscape Detention (PLD) Worksheet in the BMP Spreadsheet will aid in the design procedure discussed below.

1. ***WQCV*** – Calculate the WQCV in ft^3 based on Section 3.2 of this chapter. The storage volume equals the WQCV.

2. ***Minimum surface area*** – Calculate the minimum required surface area, A_s (ft^2), as follows:

$$A_S = \frac{WQCV}{d_{av}}$$ **(Equation WQ-4)**

In which:

d_{av} = Average depth of the porous landscape detention basin (6-inch minimum, 12-inch maximum)

3. ***Vegetation growth medium*** – To treat stormwater and also serve as a medium for plant growth, provide a well-mixed layer composed of 50% sand (ASTM C-33, no builder's sand), 25% cotton burr or hardwood compost and 25% sandy loam topsoil as shown in Figure WQ-8. The depth of the media should range from a minimum of 18 inches up to a maximum of 3 feet in cases where deeper-rooted plants will be used. The media should have a maximum hydraulic conductivity of approximately 20 inches/hour, with less than 8 inches/hour preferred to sustain plant growth. The top surface should be as flat as possible, with side slopes steeper than 3:1 not recommended. If steeper side-slopes are necessary, use vertical walls to contain the growth medium.

4. ***Sub-base*** – Install an 8-inch layer of granular sub-base with all fractured faces meeting the requirements of AASHTO #3 coarse aggregate specifications. Install 4-inch underdrains at the bottom of the granular layer. Underdrains shall be spaced at a maximum of 20 feet with a minimum slope of 0.2 percent. Underdrains shall connect to an existing drainage system or daylight to an appropriate stormwater drainage channel. Use porous geotextile fabric to line the entire basin bottom and sides. When certified tests show percolation rates of less than 60 minutes per inch of drawdown under the bottom of the basin and infiltration is acceptable, eliminate the gravel layer, underdrains and geotextile fabric.

5. ***Impermeable liner (if needed)*** – When an existing or proposed building is within 20 feet, and/or when land uses pose a risk for groundwater contamination, use an impermeable liner under and on all sides of the porous landscape detention basin.

4.4.5. Maintenance

Periodic maintenance will be necessary for the landscaping in the porous landscape detention. Eventually, a porous landscape detention will require cleanout and replacement of the porous media. If a high level of silts and clays are allowed to flow into the facility, the porous media may become clogged and require replacement more often. The Low Impact Development Center website (www.lowimpactdevelopment.org) provides additional design and maintenance recommendations for bioretention cells, which are comparable to porous landscape detention.

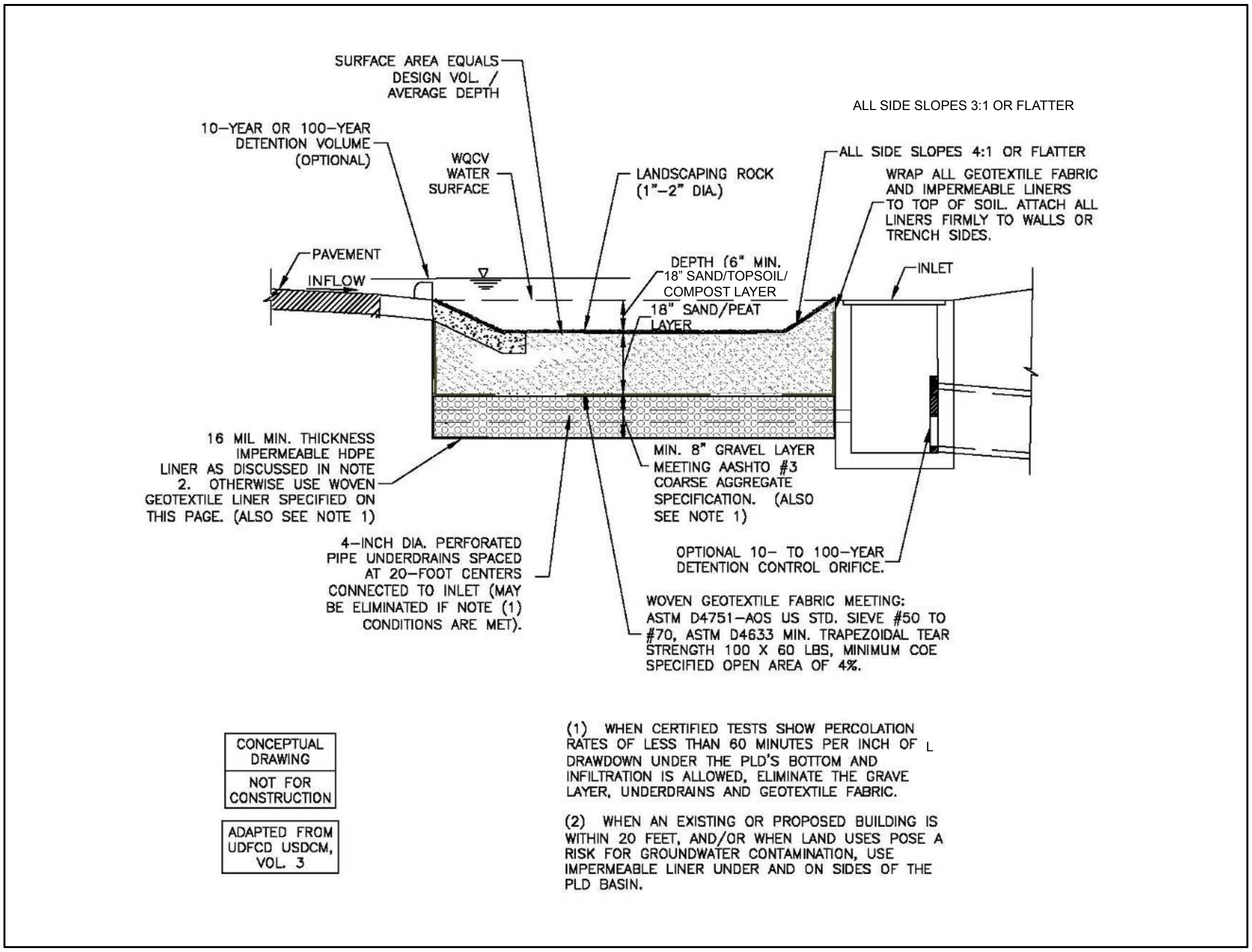


Figure WQ-8
Porous Landscape Detention

4.4.6. Design Example

The following example demonstrates use of the PLD Worksheet in the BMP Spreadsheet.

Given: Assume a tributary drainage area of 50,350 square feet (approximately 1.16 acres) of impervious parking area draining to a parking lot island depression.

Determine: Volume and surface area of a porous landscape detention basin along with other design attributes.

Worksheet Data Input

Porous landscape detention characteristics and design constraints are entered into the input cells of the PLD Worksheet. The WQCV required is calculated using the method described in Section 3.2 of this chapter for a 12 hour drain time.

A WQCV of 2,870 ft^3 was used for further calculations. The average depth of the porous landscape detention basin must fall between 0.5 feet and 1.0 foot. For this example, an average depth of 9 inches (0.75 feet) was selected. Also, assume that the site consists of well-draining soils and that the tributary drainage area does not contain land uses that may have petroleum products, greases or other chemicals.

Porous Landscape Detention Characteristics – User Inputs

- Contributing watershed area = 50,350 ft^2
- Ia = 100%
- Average depth, d_{av} = 0.75 ft
- Subgrade soil characteristics = well-draining
- Land use = no potential for contamination

Results

Results of the analysis are displayed in the PLD Worksheet (see example worksheet on following page). The results indicate:

- The minimum required surface area = 3,827 ft^2.
- The porous landscape detention basin will be drained via infiltration to the subgrade with a woven geotextile fabric.
- A sand-topsoil-compost mix (minimum 18 inch depth) will be used above the woven geotextile fabric. No underdrain is required.

Design Procedure Form: Porous Landscape Detention (PLD)

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2009**
Project:	**Multi-use development parking lot**
Location:	**Rogers, AR**

1. Basin Storage Volume	
A) Contributing Watershed Area (Including the PLD Area)	Area = 50,350 square feet
B) Water Quality Capture Volume (WQCV12) (Input from WQCV Spreadsheet, 12 hour drain time)	$WQCV_{12}$ = 2,870.0 cubic feet
2. PLD Average Depth and Surface Area	
A) Average Depth of PLD, d_{av} (Min = 0.5', Max = 1.0')	d_{av} = 0.75 feet
B) Minimum Required Surface Area, A_s = WQCV / d_{av}	A_s = 3,827 square feet
3. Draining of PLD (Check A, **or** B, **or** C, **answer** D **and** E) Based on answers to 3A through 3E, check the appropriate method	X Infiltration to Sub-grade with Woven Geotextile Fabric 3(C) checked and 3(E) = no
A) Check box if sub-grade is heavy or expansive clay [ ] B) Check box if sub-grade is silty or clayey sand [ ] C) Check box if sub-grade is well-draining soil [X] *Provide a soils report to substantiate.	___ Underdrain with Impermeable liner 3(A) checked or 3(E) = yes ___ Underdrain with Woven Geotextile Fabric (See note 1): 3(B) checked and 3(E) = no
D) Check box if underdrains are not desirable or if underdrains are not feasible at this site. [ ]	___ 16-Mil. Impermeable Membrane with No Underdrain: 3(D) checked - Evapotranspiration only
E) Does tributary catchment contain land uses that may have petroleum products, greases, or other chemicals present, such as gas station, hardware store, restaurant, etc.? yes [ ] no [X]	___ Other:
4. Sand/Peat Mix and Gravel Sub-base (See Figure WQ-7)	
A) Heavy or Expansive Clay Present or Chemical Concerns; Perforated Underdrain Used.	___ 18" Minimum Depth Sand-Peat Mix with 8" Gravel Layer. 16-Mil. Impermeable Liner and a 4" Perforated Underdrain.
B) Silty or Clayey Sand Present; Perforated Underdrain Used.	___ 18" Minimum Depth Sand-Topsoil-Compost Mix with 8" Gravel Layer and a 4" Perforated Underdrain w/ Woven Geotextile Fabric.
C) No Potential for Contamination and Well-Draining Soils are Present; Underdrains Elliminated.	X 18" Minimum Depth Sand-Topsoil-Compost Mix with Woven Geotextile Fabric and No Underdrain (Direct Infiltration).
D) Underdrains are Not Desirable or are Not Feasible at this Site.	___ 18" Minimum Depth Sand-Topsoil-Compost Mix with an Additional 18"Minimum Layer Sand-Topsoil-Compost Mix or Sand-Class 'A' Compost Bottom Layer (Total Sand-Topsoil-Compost Depth of 36"). 16-Mil. Impermeable Liner Used.
E) Other:	___ Other:

Notes: 1) Woven geotextile fabric shall meet ASTM D4751 - AOS U.S. Std. Seive #50 to #70, ASTM D4633 min. trapezoidal tear strength 100 x 60 lbs, min. Corps of Engineers (COE) specified open area of 4%.

4.5. Permeable Pavers

4.5.1. Description

Permeable pavers are intended for use in low vehicle movement areas such as residential driveways and parking pads to accommodate vehicles while simultaneously facilitating stormwater infiltration from precipitation on the porous pavement. Permeable pavers can also be used for residential street parking lanes; maintenance roads and trails; emergency vehicle and fire access lanes in apartment or office complexes; low vehicle movement zones such as parking aprons and maintenance roads; and emergency stopping lanes, crossovers, or parking lanes on divided highways. Some of these options will require City approval and a variance from the City's standard road sections; the developer is strongly urged to discuss these options with the City early in the development process.

Porous asphalt and concrete will be considered on an individual basis and an individual design shall be provided stamped by a licensed engineer. This chapter will provide information and a design process for permeable pavers.

Permeable pavers consist of open void concrete block units laid on a gravel sub-grade. The surface voids are filled with sand or sandy loam turf. An alternate approach is to use reinforced grass porous pavement, consisting of grass turf reinforced with plastic rings and filter fabric underlain by gravel. The permeable pavers shall be mildly sloped, but not completely flat, to decrease the effective imperviousness of a site without creating standing water problems. The permeable pavers can be considered to reduce the imperviousness over the installation area by approximately 25 percent, depending on the exact void ratio of the block.

Photograph WQ-6 – Example of Permeable Pavers.
This pavement helps to reduce imperviousness and promote
Infiltration in low vehicle movement areas.

In addition to serving the function of removing particulate pollutants and other constituents, similar to a sand filter application, permeable pavers can reduce flooding potential by infiltrating or slowing down runoff. Paver block patterns, colors, and materials can serve both functional and aesthetic purposes.

Photograph WQ-7 – A variety of designs are available for porous pavement that can be selected to best fit the site surroundings.

The primary disadvantages of permeable pavers are cost and the lack of performance data in areas that are subject to severe freeze-thaw cycles. However, observations indicate that permeable pavers functions well in freeze-thaw cycles when properly designed and installed. Other potential disadvantages are uneven driving surfaces and potential traps for high-heeled shoes. Also, the cost of restorative maintenance can be relatively high if the system gets plugged with sediment. Maintenance of permeable pavers is the responsibility of the property owner or POA.

4.5.2. Design Considerations

Drainage – Permeable pavers must be installed with a free draining sub-grade or an underdrain system to ensure drainage of the gravel sub-grade. This BMP may not be used at industrial, transportation, or similar sites where chemical or petroleum spills are a possibility unless an impermeable membrane is installed to prevent groundwater contamination. The cumulative drainage area directed to the permeable pavers' surface area must not exceed a 5:1 ratio without consulting and receiving approval from the City Engineer.

Vehicle access lanes - Vehicle movement (i.e., not parking) lanes that lead up to the permeable pavers need to be solid asphalt or concrete pavement.

Void area - Multiple block patterns are acceptable, provided they have at least 20 percent (40 percent preferred) of the surface area as voids. Upon installation, every effort shall be made to assure even flow distribution over the entire porous surface. The pervious area is generally assumed equal to the surface void area of the paver block.

Sedimentation and Debris – Every effort shall be made to prevent sedimentation and debris from entering the void space within the paver blocks during and after construction. A woven geotextile fabric will need to be placed over the base course and/or paver blocks depending on the completion of the system while there are ongoing construction activities adjacent to the permeable paver system or anywhere they would be driven over during construction. Woven geotextile fabric will need to be covered with ply wood to protect the permeable pavers. Additional steps may be required if damage is observed.

Upstream Stabilization – Any area upstream of the permeable paver system will need to be stabilized to prevent sedimentation and debris from entering the system during construction. Any slope 3:1 or greater and adjacent or upstream to the pavers will be required to be sodded.

Adjacent Foundations – Because the permeable paver system promotes infiltration of storm runoff into the sub-base, structural foundations will need to be proposed at least 20-feet away from the edges of the system unless engineered for saturated soil conditions.

Subsurface Detention – The permeable paver system may be utilized as detention to address an increase in runoff. The system will need to be sized to detain for a period of 24 hours.

Pre-Construction Infiltration Testing - The contractor shall conduct pre-construction infiltration testing per Section 103 of the Rogers Standard Specifications after Preparation of Surface and prior to placement of aggregate. The Contractor shall submit pre-construction infiltration test results to the EOR and City Engineer for review and approval prior to installation of other permeable paver system components.

Post-Construction Infiltration Testing - The contractor shall conduct post-construction infiltration testing within 7 days prior to the Final Acceptance Inspection per Section 103 of the Rogers Standard Specifications and submit post-construction infiltration test results to the EOR and City Engineer. Passing post-construction infiltration tests will be required prior to issuance of Certificate(s) of Occupancy.

Manufacturer's Specifications – Permeable pavers shall be installed per manufacturer's specifications. Conflicts between the manufacturer's specifications and City Standard Specifications will be evaluated on a case-by-case basis.

4.5.3. Design Procedure and Criteria

The following steps outline the permeable pavers design procedure and criteria. The Permeable Pavers (PmP) Worksheet in the BMP Spreadsheet will aid in the design procedure. Figure WQ-9 shows cross-sections of paver block installation and its sub-grade.

1. ***Block selection*** - Select appropriate paver blocks that have no less than 20 percent (40 percent preferred) of the surface area open and have a minimum thickness of 3 inches. The manufacturer's installation requirements shall be followed with the exception that Rock Media Pore Volume Inlay Material and Base Course minimum dimensions and requirements in this section shall be followed.

2. ***Void space fill material*** - The permeable pavement openings shall be filled with jointing and bedding aggregates as specified by the paver block manufacturers and shall be placed on a 1-inch-thick leveling course of the aggregate.

3. ***Base course and geotechnical report*** - The base course shall be AASHTO No. 3 coarse aggregate with all fractured surfaces and have a minimum depth of 8 inches. For drainage volume calculations, assume 30 percent of the total base coarse volume to be open pore space. The geotechnical characteristics of the base coarse and sub-grade shall be documented in a report from a geotechnical engineer. A pavement design may be required by the City.

4. ***Geotextile*** - The use of any geotextile material will need to meet the following requirements: ASTM D-4751 – AOS U.S. Std. Sieve #50 to #70 and D-4632 – Trapezoidal tear strength ≥ 100 x 60 lbs; with USACE specified minimum open area ≥ 4 percent.

5. ***Barrier for pollutants (if needed)*** - If the contributing drainage area is a land use with potential activities that store, manufacture, or handle fertilizers, chemical, or petroleum products, install an uninterrupted and puncture free 16-mil polyethylene or PVC impermeable membrane and provide an underdrain system *under* the base course. Otherwise, to permit infiltration, use a geotextile material that meets the ASTM requirements listed under Item 4, above.

6. ***Required porous pavement area*** - The design area ratio of contributing impervious area to porous pavement area shall not exceed 5:1.

7. ***Perimeter wall*** - If a concrete perimeter wall is provided, it should confine the edges of the permeable pavers block area. The wall shall be a minimum of 8-inches wide and 18-inches deep (see Figure WQ-9). If necessary, perimeter walls that are 36 inches in depth or greater shall incorporate rebar in the design to increase the tensile strength of the walls. Perimeter wall designs incorporating rebar will need to include, at a minimum, a #4 horizontal bar offset 3 inches from the bottom of the wall.

8. ***Flow cut-off barrier*** - Provide 16-mil or thicker polyethylene or PVC membrane liner placed vertically or concrete walls to separate individual cells of the porous base course to cut-off horizontal flow of water (see Figure WQ-9).

   Space these cut-off barriers according to the following equation:

$$L_{MAX} = \frac{D}{1.5S_O}$$

(Equation WQ-5)

   in which:

   L_{MAX} = Maximum distance between cut-off membrane normal to the flow (ft)

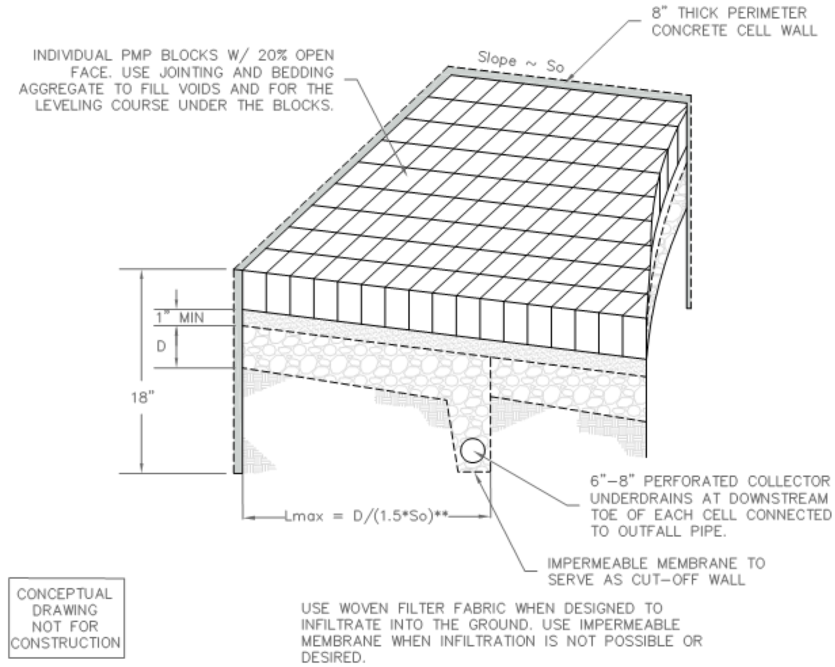
   S_O = Slope of the base course (ft/ft) ($0.0 < S_O < 0.02$)

   D = depth of gravel base course (ft)

9. ***Underdrains and Cleanouts*** – Install 6-inch or 8-inch underdrains at the bottom of the coarse aggregate layer. Underdrains shall connect to an existing storm sewer or daylight to an appropriate stormwater drainage conveyance. Cleanout ports shall be provided with 45º vertical bends at the upstream end and horizontal bends, spaced at a maximum of 200 feet. See *Figure WQ-10.* Provide a soils analysis.

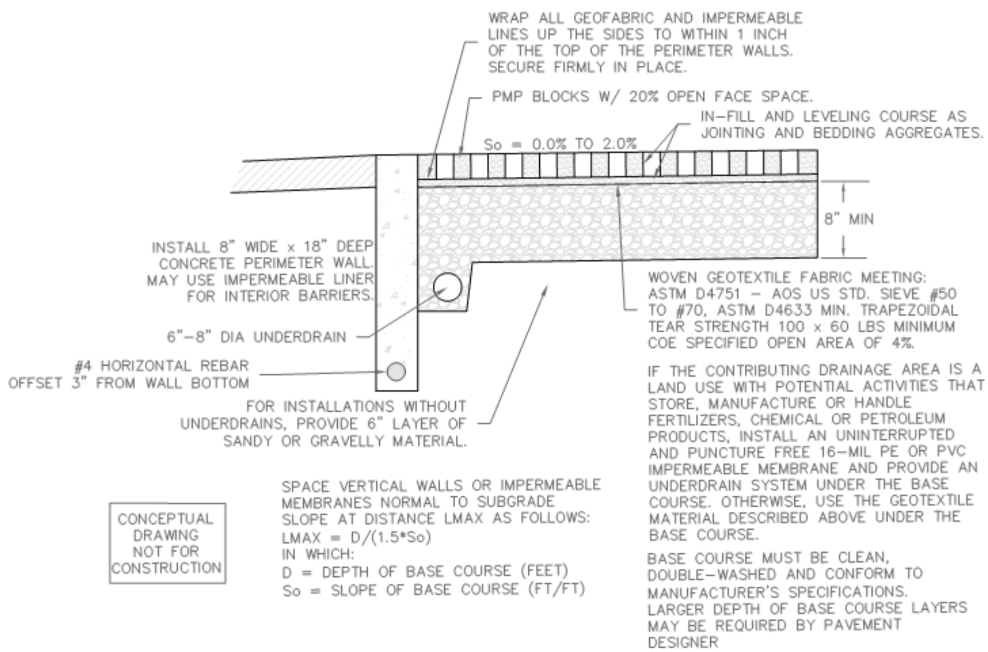
4.5.4. Maintenance

The sand filling the voids within the concrete block pavement will need to be replaced when clogging is evident. Intermittent repairs to the permeable pavers may be necessary due to potential for breakage or displaced blocks caused by heavy machinery or trucks on the permeable pavers. Maintenance of permeable pavers is the responsibility of the property owner or POA. Use of permeable pavers in areas used by the public will be required to be maintained according the maintenance schedule provided by the City. The responsible party must maintain the permeable paver system as directed by the City of Rogers Permeable Paver System Inspection and Maintenance requirements. The responsible party must record maintenance activities and frequencies on City of Rogers Annual Inspection and Maintenance Log. A letter stating the paver system will be perpetually maintained by the owner per the manufacturer's specifications and per the annual maintenance and inspection log will need to be submitted prior to issuance of a Land Disturbance Permit.



PERSPECTIVE VIEW OF SIDE–BY–SIDE PMP CELLS

NTS



SECTION VIEW OF SIDE–BY–SIDE PMP CELLS

NTS

Figure WQ-9

Permeable Pavers

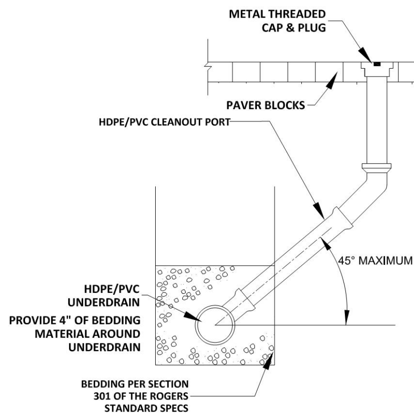


Figure WQ-10
Permeable Paver Cleanout Port

Design Example

The following example demonstrates use of the Permeable Pavers (PmP) Worksheet in the BMP Spreadsheet. The tributary area, porous pavement area, type of modular block, and existing sub-grade soils are given. There are several additional parameters that must be selected by the designer.

Given: Assume a porous pavement area (pedestrian shopping plaza) of approximately 10,000 ft^2 with an additional 14,000 ft^2 of impervious area (surrounding building rooftops) draining onto the porous pavement. The resulting ratio of contributing impervious area to porous pavement area is 1.4. Paver block properties for the selected block (Uni Eco-Stone by Unilock) include an open surface area of 40 percent with a block thickness of 3 1/8 inches. The existing sub-grade consists of silty sands and there is no anticipated potential for groundwater contamination. Open surface area of paver blocks = 40 percent. Minimum thickness of paver blocks = 3.125 inches.

Determine: The materials and layout of a permeable paver system

Worksheet Data Input

Permeable paver characteristics and design constraints are entered into the input cells of the PmP Worksheet.

There are several design parameters that are selected by the designer for materials and layout. The City recommends specific materials and layouts; however, other types may be selected if approved by the City. For this example, criteria set forth by the City are used:

- ASTM C-33 sand for porous pavement infill and leveling course

- A woven geotextile fabric between the sand and gravel layers
- Minimum thickness of gravel layer = 8 inches. (12 inches selected for this example)
- Maximum impervious area to porous pavement area ratio = 2.0 (1.4 for this example)
- A concrete wall (6 inches thick) around the perimeter and to separate interior cells
- Slope of base course = 1 percent (0.01 ft/ft)
- Distance between cutoff walls = 50 ft (selected based on maximum calculated in spreadsheet)

Results

Results of the analysis are displayed in the PmP Worksheet (see sample worksheet on following page).

- Maximum distance between cutoff walls = 67 ft. A distance of 50 feet was selected since the porous pavement area is approximately 200 feet long by 50 feet wide (4 cells with 3 interior walls).

Design Procedure Form: Permeable Pavers (PmP)

Designer: J. Smith
Company: A1 Engineering, Inc.
Date: November 15, 2009
Project: Recreation Center Parking
Location: Rogers, AR

1. Modular Block Properties: Note: Blocks shall have no less than 20% open area - 40% preferred; and shall be no less than 3" thick.	Block Name: Uni Eco-Stone Manufacturer: Uniblock Min. Open Surface Area = 40 % Minimum Thickness = 3.13 inches
2. Porous Pavement Infill (Check the type or describe "Other").	X ASTM C-33 Sand __ Other:
3. Base Course: The following three items are **all** required. A) Sand (ASTM C-33) Leveling Course. B) Woven Geotextile Fabric Between Sand & Gravel - meeting ASTM D4751 - AOS U.S. Std. Seive #50 to #70. ASTM D4632 min. trapezoidal tear strength 100 x 60 lbs, min. Corps of Engineers (COE) specified open area of 4%. C) Thickness of Gravel (AASHTO #3 Coarse Aggregate). 8" minimum thickness required.	X 1" Layer ASTM C-33 Sand Leveling Course __ Other: X Woven Geotextile Fabric per Springfield Water Quality Criteria __ Other: 12 Inches
4. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2):	Ratio = 1.4 (A_{IMP} / A_{POROUS})
5. Perimeter Wall (12" deeper than base course, Min thickness = 6")	X Concrete 6.0 inches thick __ Other:
6. Contained Cells: A) Type: B) Slope of the base course : C) Distance between cutoffs (normal to flow, L): Max. Length L = Gravel Thickness / 1.5 / S = 67 feet.	__ 16-mil. (min.) Impermeable Liner X Concrete Wall S_O = 0.01 ft/ft L = 50 feet, (L_{MAX} = 67)
7. Draining of modular block pavement (Check A, **or** B, **or** C, **answer** D) Based on answers to 7A through 7D, check the appropriate method: A) Check box if sub-grade is heavy or expansive clay [ ] B) Check box if sub-grade is silty or clayey sand [X] C) Check box if sub-grade is well-draining soil [ ] D) Does tributary catchment contain land uses that may have petroleum products, greases, or other chemicals present, such as gas station, hardware store, restaurant, etc.? yes [ ] no [X]	__ Infiltration to Sub-grade with AOS U.S. Std. Seive #50 to #70 Woven Geotextile Fabric (As In 3(B)): 7(C) checked **and** 7(D) = no __ Underdrain with 16-mil. Impermeable Liner 7(A) checked **or** 7(D) = yes X Underdrain with AOS U.S. Std. Seive #50 to #70 Woven Geotextile Fabric (As In 3(B)): 7(B) checked **and** 7(D) = no __ Other:

Notes: Disregard impermeable liner underneath the base material and underdrain unless there is a potential for harmful contaminants to be present

City of Rogers Permeable Paver System Annual Inspection & Maintenance Log

Project Name: ______________________ **Inspectors/Operators:** ______________________

Project Location: ______________________ **Paver Manufacturer:** ______________________

Agency/Party: ______________________ **Brick Description (type/color/dimensions/etc.):** ______________________

Component	Task	Frequency (Month)	Mark if Task is Completed											
			Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Nov	Dec
Permeable Pavers	Inspect for sediment, debris, clogging, and check functionality.	Quarterly (Feb/May/Aug/Nov)											
	Remove surface sediment, debris, and trash.	Monthly											
	Remove weeds or vegetation.	Quarterly (Feb/May/Aug/Nov)											
	Remove stains and other markings.	Quarterly (Feb/May/Aug/Nov)											
	Vacuum with walk-behind unit. [1]	Semi-Annually (May/Nov)											
	Measure infiltration rate per ASTM C1781.	Annually (May)											
	Deep clean with vacuum and pressure wash combination.	As Needed											
	Replace damaged pavers.	As Needed											
	Dress paver joints with aggregate, as applicable. [2]	As Needed											
Underdrain Piping [3]	Inspect for standing water, structural integrity, secure access points, record debris depth.	Monthly											
	Remove sediment, debris, trash, blockages.	Monthly											
	Repair damage.	As Needed											
Outlet [3]	Inspect for sediment, trash, debris, blockages, structural integrity, and outlet control mechanism.	Monthly											
	Clear flow paths and remove sediment, trash, debris, and blockages.	Monthly											
	Repair damage.	As Needed											

Notes:

1) If maintenance is neglected and City of Rogers enters to perform maintenance, a walk-behind vacuum and pressure wash combination unit will be used to perform maintenance. Any damage caused to permeable paver system and the cost of maintenance is at the expense of the owner.

2) Replace jointing aggregate material when greater than 1/4-inch below the surface of the permeable pavers.

3) Maintenance activities for Underdrain Piping and Outlet components not applicable in systems with subsurface detention. Permeable paver maintenance activities still apply; alternate maintenance activities required for subsurface detention per manufacturer recommendations.

Owner's Name (Print): ______________________

Owner's Signature*: ______________________

*By signing the line above, the owner is verifying that maintenance was performed by a qualified party, that the information provided is correct, and the system is functioning as designed to the best of their knowledge. A copy of this signed form will need to be submitted by February 1st of each year to the responsible official within the Rogers Department of Community Development's Engineering Division.

Figure WQ-11
Permeable Paver System Annual Inspection & Maintenance Log

4.6. Vegetated Filter Strip/Grass Buffer

4.6.1. Description

Vegetated filter strips/grass buffer strips are uniformly graded and densely vegetated areas of turfgrass, planted native grasses, or adequate existing grass. They require sheet flow to promote filtration, infiltration, and settling of runoff pollutants. Grass buffers differ from grass swales since they are designed to accommodate overland sheet flow rather than concentrated or channelized flow. Grass and other vegetation provide aesthetically pleasing green space, which can be incorporated into a landscaping and bufferyard plan. In addition, their use typically adds little cost to a development when incorporated into the existing green space requirements, and their maintenance requirements are comparable to routine maintenance of onsite landscaping.

Grass buffers can be utilized for a variety of land uses and are typically located adjacent to impervious areas. Because of the large amount of space required for grass buffers to satisfy complete water quality requirements, additional BMPs are often required. Grass buffers can be used on many sites and are strongly encouraged to provide first flush pollutant removal and infiltration for small rainfall events.

Because the effectiveness of grass buffers depends on having an evenly distributed sheet flow over their surface, the size of the contributing area and the associated volume of runoff must be limited. Whenever concentrated runoff occurs, it shall be evenly distributed across the width of the buffer via a flow spreader or other type of structure used to achieve uniform sheet-flow conditions.

Photograph WQ-8 – Example of a Grass Buffer.

Healthy, dense vegetation helps filter runoff from an adjacent road and parking lot.

4.6.2. Design Considerations

Major considerations for the design of a vegetated filter strip/grass buffer are summarized below:

Preservation of sheet flow – Design of a grass buffer is largely based on maintaining sheet-flow conditions across a uniformly graded area with a gentle slope and a dense grass cover. When a grass buffer is used in areas with unstable slopes, soils or vegetation, formation of rills and gullies that disrupt sheet flow will occur. The resultant short-circuiting will eliminate the intended water quality benefits and must be corrected through maintenance.

Shape of grass buffer area – The preferred shape for a grass buffer is a rectangular strip. The strip shall be free of gullies or rills that concentrate the flow over it. Concentrated runoff shall be evenly distributed across the width of the grass buffer via a flow spreader.

Protection of vegetation – Grass buffers shall be protected from excessive pedestrian or vehicular traffic that can damage the grass cover and affect uniform sheet-flow distribution. A 4-inch topsoil layer that is free of rocks and debris must, prior to vegetation, be spread over the grass buffer area to promote a healthy stand of grass. A mixture of grass and trees may offer benefits for slope stability and improved aesthetics.

4.6.3. Design Procedure and Criteria

The following steps outline the grass buffer design procedure and criteria. Figure WQ-10 is a schematic of a grass buffer facility and its components. The Grass Buffer (GB) Worksheet in the BMP Spreadsheet will aid in the design procedure using the steps described below.

1. ***Peak flow rate*** – Calculate the 2-year peak flow rate, $Q_{2\text{-}year}$ of the area draining to the grass buffer (in cubic feet per second [cfs]), as described in Chapter 3 – *Determination of Stormwater Runoff*.

2. ***Minimum design width*** – The minimum design width, W_G (ft), (perpendicular to flow) is calculated as:

$$W_G = \frac{Q_{2-year}}{0.05} \quad \textbf{(Equation WQ-6)}$$

3. ***Minimum design length*** – The minimum design length, L_G (ft), along the sheet flow direction is dependent on the upstream flow conditions.

   For sheet flow conditions, L_G (ft) is calculated as the greater of the following:

$$L_G = 0.2L_t \text{ or 6 feet} \quad \textbf{(Equation WQ-7)}$$

   In which:

   L_t = Flow path length (ft) of sheet flow over the tributary impervious surface

   For concentrated flow conditions, L_G is calculated as the greater of the following:

$$L_G = 0.15(A_t/W_t) \quad \textbf{(Equation WQ-8)}$$

   or

   6 feet

   In which:

   W_t = Width of the tributary inflow normal to the flowspreader (i.e., width of flowspreader) (ft)

   A_t = Tributary area (ft^2)

4. ***Longitudinal slope*** – The slope in the direction of flow, *S*, shall not exceed 4 percent.

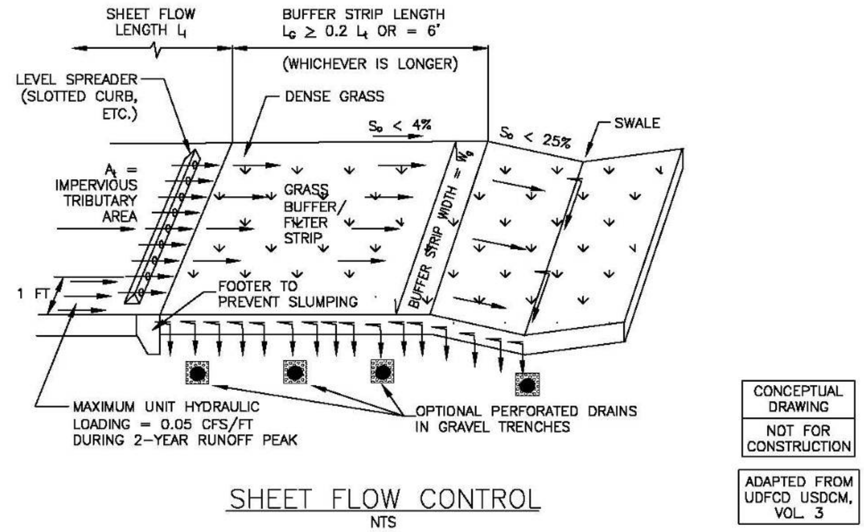
5. ***Flow dispersal*** – Incorporate a device on the upstream end of the buffer to evenly distribute flows along the design length when runoff is concentrated.

6. ***Establishment of vegetation*** – Sod the grass buffer, or plant an alternative vegetation cover approved by the City, and cover with suitable erosion control measures until vegetation is established.

7. ***Collection of outflow*** – Provide a means for outflow collection. The buffer can drain to a grass swale, storm sewer, or street gutter in accordance with design criteria for those facilities. In some cases, the use of underdrains can maintain better infiltration rates as the soils saturate. This will help dry out the buffer after storms or periods of irrigation.

4.6.4. Maintenance

If the grass buffer is located adjacent to urban activity, routine mowing of the strip may be necessary for aesthetic purposes. Eventually, the grass strip next to the spreader or the pavement will accumulate a sufficient amount of sediment to block runoff. At that time, a portion of the grass buffer strip will need to be removed and replaced.



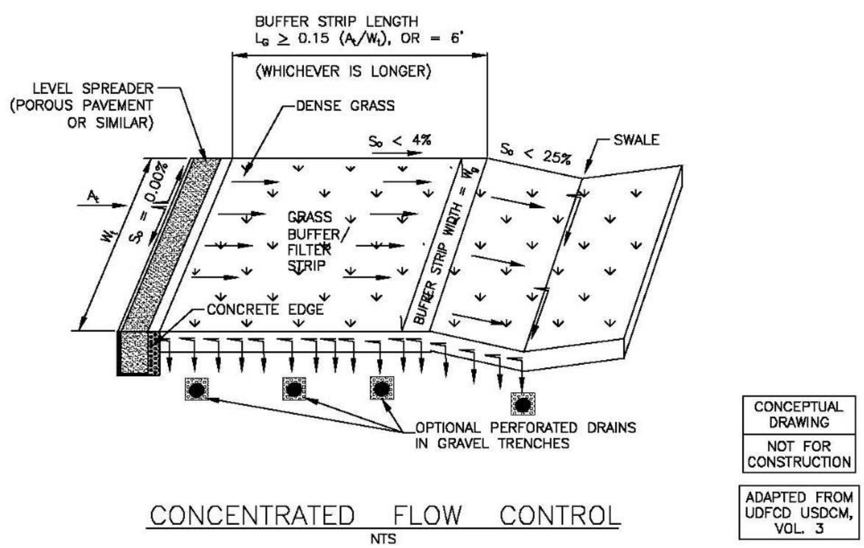


Figure WQ-12
Application of Grass Buffers (Filter Strips)

4.6.5. Grass Buffer Design Example

The following example demonstrates use of the GB Worksheet in the BMP Spreadsheet.

Given: A tributary drainage area of 30,000 square feet (ft^2) of impervious parking area that results in a 2-year peak flow rate of 3.7 cfs (the peak flow rate is calculated using the Rational Method as described in Chapter 3 – *Determination of Stormwater Runoff*. The tributary flow path is approximately 100 feet long, and the runoff from the parking area is sheet flow.

Determine: Minimum width and length of a grass buffer along with other design attributes.

Worksheet Data Input

The GB Worksheet requires input for the grass buffer characteristics and design constraints as described below:

Grass Buffer Characteristics - User Inputs

Q_2 = 2-year peak flow rate = 3.7 cfs

A_t = Tributary area = 30,000 ft^2

L_t = Length of flow path over tributary impervious surface = 100 ft

S = Slope = 3.0 percent

Additional User Inputs

A flow distribution method is not required since the parking area runoff exhibits sheet flow.

Sod was selected as the vegetation method for the grass buffer.

A grass swale will be used for outflow collection.

Results

Results of the analysis are displayed in the GB Worksheet (see sample worksheet on following page). The results indicate:

- Minimum width of grass buffer (W_G)(normal to runoff flow path) = 74 ft
- Design length of grass buffer (L_G)(along direction of flow) = 20 ft

Design Procedure Form: Grass Buffer (GB)

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2009**
Project:	**Store #2**
Location:	**Main Street Commercial Site - Rogers, AR**

1. 2-Year Design Discharge	Q_2 = 3.7 cfs
2. Tributary Catchment Flow A) Min. Width of GB (Normal to runoff flow path): $W_G = Q_2 / 0.05$ B) Tributary Area in Square Feet (A_t)	 W_G = 74 feet (Longer widths may be used) A_t = 30,000 square feet
3. Design Length Along Direction of Flow (Use A **or** B) A) Sheet Flow Conditions Upstream i) Length of Flow Path Over Tributary Impervious Surface ii) Design Length of Buffer: $L_G = 0.2 * L_t$ (6' minimum) B) Concentrated (Non-Sheet) Flow Conditions Upstream i) Width of Flow Level Spreader ii) Design Length of Buffer: $L_G = 0.15 * A_t / W_t$ (6' minimum)	 L_t = 100 feet L_G = 20.0 feet W_t = ____ feet L_G = ____ feet
4. Design Slope (not to exceed 4%)	S = 3.00 %
5. Flow Distribution (Check the type used or describe "Other") (Required when upstream flow is concentrated.)	____ Slotted Curbing ____ Modular Block Porous Pavement ____ Level Spreader ____ Other: ____
6. Vegetation (Check the type used or describe "Other") Note: Seeding and mulching alone is not an acceptable method of erosion control.	X Sod ____ Seed covered with suitable erosion control ____ Other: ____
7. Outflow Collection (Check the type used or describe "Other")	X Grass Swale ____ Street Gutter ____ Storm Sewer Inlet ____ Underdrain Used ____ Other: ____

Notes: ____

4.7. Grass Swale

4.7.1. Description

A grass swale is a densely vegetated drainageway with gentle side slopes that collects and slowly conveys runoff. A grass swale can be located to collect overland flows from areas such as parking lots, buildings, residential yards, roadways, and vegetative filter strips/grass buffers. A grass swale is set below adjacent ground level and runoff enters the swale over grassy banks. Swales in residential and commercial settings can also minimize DCIA by using them as an alternative to a curb-and-gutter system. A grass swale is generally less expensive to construct than a concrete or rock-lined drainage system, and via infiltration can also provide some reduction in runoff volumes from small storms. The grass swale shall be vegetated with dense grasses that can reduce flow velocities and protect against erosion during larger storm events.

Photograph WQ-9 – Example of a Grass Swale.
This grass swale filters runoff from a road and helps reduce flow velocities.

4.7.2. Design Considerations

Major considerations for the design of a grass swale are summarized below:

Swale slope – A grass swale is sized to maintain a low velocity during small storms and to collect and convey larger runoff events. A grass swale generally shall not be used where site slopes exceed 5 percent. The longitudinal slope of a grass swale shall be 0.5 to 1 percent, which often necessitates the use of grade control checks or drop structures. Figure WQ-11 shows trapezoidal and triangular swale configurations.

Use of a swale as a grass buffer – If one or both sides of the grass swale are also to be used as a grass buffer, the design of the grass buffer must incorporate the requirements of Section 4.6.

4.7.3. Design Procedure and Criteria

The following steps outline the grass swale design procedure and criteria. Figure WQ-11 is a schematic of a grass swale facility and its components. The Grass Swale (GS) Worksheet in the BMP Spreadsheet will aid in the design procedure using the steps described below.

1. ***Peak flow rate*** – Calculate the 2-year peak flow rate, $Q_{2\text{-}year}$ (cfs), to be conveyed in the grass swale using a method described in Chapter 3 – *Determination of Stormwater Runoff*. For public improvements, the grass swale must meet the criteria provided in Chapter 6 – *Open Channel Flow Design*. For all developments with detention, it must be shown that the channel can convey the maximum design flow to the detention basin and that bypass will not occur.

2. ***Swale cross-section geometry*** – The geometry of the cross-section shall be either trapezoidal or triangular with side slopes of 3H:1V or, preferably, flatter.

3. ***Longitudinal slope*** – The longitudinal slope, S_o, of the grass swale shall be 0.5 to 1 percent. If the longitudinal slope requirements cannot be met with the available terrain, grade-control checks or small drop structures must be incorporated to maintain the required longitudinal slope. (See Chapter 6 – *Open Channel Flow Design*)

4. ***Maximum velocity*** – To promote sedimentation and enhanced water quality, the maximum velocity of the 2-year peak flow shall not exceed 2 feet per second (ft/s) and the maximum flow depth of the same flow shall not exceed 1 foot.

5. ***Vegetation*** – Sod the grass swale and cover with a suitable erosion control measure until vegetation is established.

4.7.4. Maintenance

Dense turfgrass must be maintained within a grass swale to retain optimal performance as a water quality BMP. The grass swale must be mowed in accordance with City ordinance unless a maintenance plan for other maintenance methods has been approved by the City Department of Planning and Transportation. If check dams are installed in the grass swale, sediment may accumulate up-gradient of the dams. Accumulated sediment shall be removed when sediment depth exceeds 6 inches, or as necessary to prevent the deposition of sediment downstream.

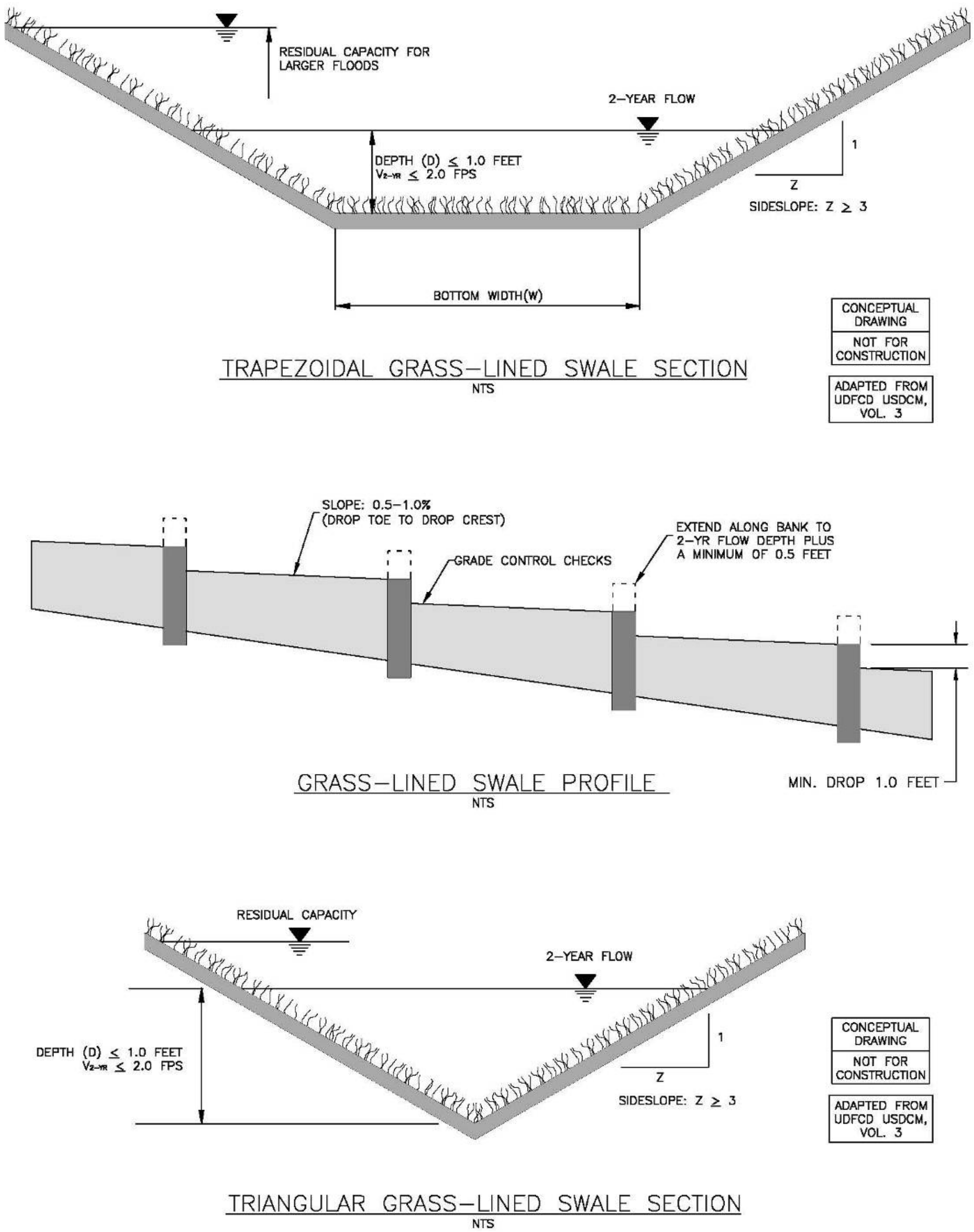


Figure WQ-13
Profile and Sections of a Grass Swale

4.7.5. Grass Swale Design Example

The following example demonstrates use of the GS Worksheet in the BMP Spreadsheet.

Given: Assume a portion of the drainage from a residential neighborhood discharges to a grass swale. The 2-year peak flow rate in the grass swale is 18.0 cfs. For water quality purposes, the swale velocity shall not exceed 2.0 ft/s. The design velocity is set at 1.8 ft/s and a side slope of 3:1 horizontal:vertical is selected.

Determine: Swale geometry and longitudinal slope for a given 2-year peak flow rate and design velocity.

Worksheet Data Input

The GS Worksheet requires input for the grass swale characteristics and design constraints as described below:

Grass Swale Characteristics - User Inputs

Q_2 = 2-year peak flow rate = 18.0 cfs

V_2 = 2-year design flow velocity = 1.8 ft/s

Z = side slope = 3

Additional User Inputs

Sod was selected as the method of achieving stabilized vegetation.

A detention basin is located at the downstream end of the grass swale to provide additional water quality treatment and flood control.

Results

Results of the analysis are displayed in the GS Worksheet (see sample worksheet on following page). The results indicate:

- Design flow depth = 1.0 ft (the maximum allowed for water quality purposes)
- Bottom width of grass swale = 6.0 ft (trapezoidal channel)
- Froude number = 0.38
- Design slope = 0.0058 ft/ft (0.6%)

Design Procedure Form: Grass Swale (GS)

Designer:	**J. Smith**
Company:	**A1 Engineering, Inc.**
Date:	**November 15, 2009**
Project:	**Sunny Estates**
Location:	**Rogers, AR**

1. 2-Year Design Discharge	Q_2 =	18.0	cfs
2-Year Design Flow Velocity (V_2, 2.0 fps Maximum)	V_2 =	1.80	fps
2. Swale Geometry			
A) Channel Side Slope, Z (Horizontal:Vertical) should be 4:1 or flatter	Z =	4.00	(horizontal/vertical)
B) 2-Year Design Flow Depth (D_2, 1 foot maximum)	D_2 =	1.00	feet
C) Bottom Width of Channel (B)	B =	6.0	feet
3. Longitudinal Slope			
A) Froude Number (F, 0.50 maximum, reduce V_2 until F $\le$ 0.50)	F =	0.38	
B) Design Slope, S (Min = 0.002, Max = 0.01) (Based on Manning's n = 0.05)	S =	0.0058	feet/feet

4. Vegetation (Check the type used or describe "Other") Note: Seeding and mulching alone is not an acceptable method of erosion control.		Sod
	X	Seed covered with suitable erosion control
		Other:
6. Outlet (Check the type used or describe "Other")		Grated Inlet
	X	Detention Basin
		Underdrain Used
		Other:

Notes:

4.8. Covering of Storage/Handling Areas

Covering of storage and handling facilities and proper handling of potential industrial or commercial pollutants, such as salt piles, oil products, pesticides, fertilizers, etc., is a requirement under the City's Municipal Separate Storm Sewer System (MS4) discharge permit. A copy of the City's MS4 discharge permit can be provided upon request. In addition, these practices reduce the likelihood of stormwater contamination and help prevent loss of material from wind or rainfall erosion. Development plans for these facilities must specify how potential pollutants will be covered and handled to prevent discharge of the pollutant into the City's MS4. Covering is appropriate for areas where solids (e.g., gravel, salt, compost, building materials, etc.) or liquids (e.g., oil, gas, tar, etc.) are stored, prepared, or transferred. Coverings shall be permanent in nature and handling procedures must be carried through plans and policies in place at the operating facility.

Photograph WQ-10 – Example of Covered Storage/Handling Area. This industrial loading dock is covered to prevent loss of material during transfer.

4.9. Spill Containment and Control

Spill containment within industrial and some commercial sites includes berms, walls, and gates that control spilled material. Berms consist of temporary or permanent curbs or dikes that surround a potential spill site, preventing spilled material from entering surface waters or storm sewer systems. The berm or wall may be made of concrete, earthen material, metal, synthetic liners, or any material that will safely contain the spill. The containment area must have an impermeable floor (asphalt or concrete) or liner so that contamination of groundwater does not occur.

Two methods of berming can be used: 1) containment berming that contains an entire spill, or 2) curbing that routes spill material to a collection basin. Both methods shall be sized to safely contain a spill from the largest storage tank, rail car, tank truck, or other containment device located inside the possible spill area. A collection basin shall be provided to hold stormwater and spills until removal is possible.

Photograph WQ-11 – Spill containment structure with valve control.

4.10. Alternative Structural BMPs

Site conditions may be conducive to the use of alternative BMPs such as proprietary packaged stormwater treatment units. Site conditions may include limited space in an ultra-urban or redevelopment setting, a sensitive receiving water or feature, a site with a high pollutant discharge potential, etc. All proposed units of this type must be reviewed and accepted by the City prior to installation.

5. LOW IMPACT DEVELOPMENT

Low Impact Development (LID) is an overall development approach that is designed to mimic a site's predevelopment hydrology. The major components of LID include:

1. Conservation and protection of site features such as streams, wetlands, and valuable habitat areas and avoidance of potential problem areas such as steep slopes.

2. Minimization of site impacts by minimizing clearing and grading, preserving soils with high infiltration capacities (Hydrologic Soil Group A and B soils), limiting lot disturbance, incorporating soil amendments, disconnecting impervious surfaces, and reducing impervious surfaces.

3. Maintaining the natural time of concentration to the extent practicable through using open drainages, incorporating green spaces, flattening slopes, dispersing drainage, lengthening flow paths, using vegetative swales, maintaining natural flow paths, maximizing stream setbacks, and maximizing sheet flow.

4. Implementing LID integrated management practices (IMPs) that address runoff at its source by using design techniques that infiltrate, filter, store, evaporate, and detain runoff close to its source. Instead of conveying and treating stormwater in facilities located at the bottom of drainage areas, LID relies on practices such as open drainage swales, bioretention cells (similar to porous landscape detention), rain gardens, rain barrels, rooftop storage, depression storage, soil amendments, infiltration swales and other similar features. A typical LID site will have multiple dispersed IMPs, rather than a single BMP at the low corner of a development.

5. Implementing pollution prevention practices that focus on maintenance practices and proper use, handling and storage of materials such as pesticides, fertilizers, household hazardous waste, etc.

Photograph WQ-12 – Example of a Rain Garden.
This rain garden is a low impact development technique that serves as a landscape amenity while also helping to reduce runoff volumes and pollutant loading.

Many of the components of the LID approach have been previously discussed in this chapter. The difference with LID is the overall site design process that incorporates all of the steps described above, resulting in a multi-faceted site design approach.

Because many LID features are natural in appearance and may rely on natural site features (e.g., preservation of soils with high infiltration capacities), it is imperative that the soil structure in these areas not be modified or compacted during construction, thereby reducing the natural infiltration capacity of the soil. This will require careful restriction on the routing of construction equipment, verification that infiltration capacities have been maintained, and possibly the addition of soil amendments.

Another critical requirement for a successful LID site is assuring that regular and proper maintenance is conducted. If the dispersed LID components are not regularly maintained by a qualified landscape professional, the LID site will likely not function as intended. Maintenance costs must be borne by the property owner or POA and maintenance easements must be provided to allow for proper access.

When designing a LID site, it is important to ensure that the landscape practices (such as rain gardens) are attractive and perceived by the property owner as adding value to the property. If these LID practices are viewed as assets, the primary motivation for their long-term maintenance is that of property owners protecting their vested economic interests.

Photograph WQ-13 – Example of a Porous Detention Island.
This porous detention island is designed to reduce runoff rates and volumes and pollutant loading.

Additional design guidance may be incorporated into this Manual in the future regarding LID. In the interim, the Low Impact Development Center website (www.lowimpactdevelopment.org/) provides a good reference for more detailed design guidance, design drawings, and specifications. For example, specifications for engineered soils can be downloaded from the LID website for bioretention cells and swales. LID site designs must be approved by the Department of Planning and Transportation and must be discussed early in the site planning process.

6. REFERENCES

American Society of Civil Engineers and Water Environment Federation. 1992. *Design and Construction of Urban Stormwater Management Systems.* ASCE Manual and Report on Engineering Practice No. 77 and WEF Manual of Practice FD-20. Alexandria,VA: Water Environment Federation.

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Schueler, T. and H. Holland. 2000. *The Practice of Watershed Protection*. Ellicott City, MD: The Center for Watershed Protection.

Urban Drainage and Flood Control District. 1999. *Urban Storm Drainage Criteria Manual, Volume 3*. Denver, CO: Urban Drainage and Flood Control District.

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Appendix A – Adjustment to the Water Quality Capture Volume

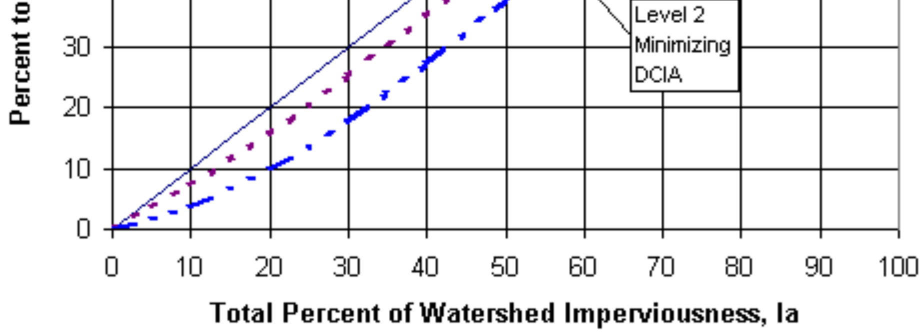
The required Water Quality Capture Volume (WQCV) for a site can be reduced if measures are implemented to reduce the Directly Connected Impervious Area (DCIA) at the site. A DCIA is an impermeable area that drains directly to the improved storm drainage system without an opportunity to infiltrate into the ground. Minimizing DCIA is a land development design approach that reduces paved areas and directs storm water runoff to landscaped areas, grass buffer strips, and grass-lined swales. The purpose is to slow down the rate of runoff, reduce runoff volumes, attenuate peak flows, and facilitate the infiltration and filtering of storm water. Minimizing DCIA can also reduce pollutant loads to the storm water treatment system because of increased infiltration of runoff near the point where the runoff begins.

To reduce the amount of DCIA, slopes on a site should be designed to direct storm water runoff as sheet flow away from buildings, roads, and parking lots toward grass-covered or other pervious areas prior to reaching the storm water conveyance systems or other BMPs. In areas with high permeability soils (Hydrologic Soil Groups A and B), surface runoff may be successfully infiltrated, whereas areas with less permeable soils may require underdrain systems to reduce surface runoff. Sites with average slopes that exceed 5 percent may not be well suited to implementing some aspects of these BMPs because of the reduced potential for infiltration. Steep sites can be addressed by using terracing or retaining walls.

Minimizing DCIA can be implemented in varying degrees. UDFCD (1999) characterizes two general levels associated with minimizing DCIA as follows:

- Level 1 DCIA – Level 1 DCIA involves minimizing DCIA at the individual site development level. This approach generally involves directing runoff from impervious surfaces to flow over grass-covered areas (e.g., filter strips or swales) and providing sufficient travel time to encourage the removal of suspended solids before runoff leaves the site and enters the City storm water collection system. To gain credit for using Level 1 DCIA, *all* impervious surfaces must be designed to drain over grass buffer strips or swales before reaching a storm water conveyance system.

- Level 2 DCIA - A more advanced approach for minimizing DCIA involves minimizing DCIA at the subdivision level (in addition to the individual site development level of Level 1). In addition to the measures taken in Level 1, Level 2 involves replacing solid street curb and gutter systems with no curb or slotted curbing and low-velocity grass-lined swales and pervious street shoulders. Conveyance systems and storm sewer inlets are still necessary to collect runoff at downstream intersections and crossings where storm water flow rates exceed the capacity of the swales. Small culverts will be needed at street crossings and at individual driveways unless inlets are provided to convey the flow to a storm sewer. Implementing Level 2 DCIA involves a public street design differing from public improvement standards and will therefore require early planning with City staff and subdivision variances in accordance with subdivision regulations.



Based on the extent of measures used to minimize DCIA (i.e., Level 1 versus Level 2), Figure A-1 can be used to convert the actual impervious area of a site (horizontal scale) to an effective impervious area (vertical scale) for use in calculating the WQCV. The effective impervious area adjustment for Level 1 and Level 2 DCIA is incorporated into the WQCV Worksheet in the BMP spreadsheet.

Figure A-1
Imperviousness Adjustments for Levels 1 and 2 of Minimizing DCIA

(Source: *Urban Storm Drainage Criteria Manual, Volume 3, Best Management Practices*, UDFCD, 1999)

Appendix B – Fee In-Lieu-of Calculation Methodology

The City may allow the property owner to pay a fee in-lieu-of implementing water quality control measures. The fee paid in-lieu-of water quality protection measures is acceptable only if the development site disturbs less than one half (0.5) an acre and the site has not been specifically identified by the City as having a significant potential to adversely impact the quality of stormwater runoff. Sites that have an existing regional water quality control facility with adequate capacity, as determined by the City, are exempt of having to pay a fee-in-lieu of water quality protection. Proceeds from fees collected from this option will be used by the City to fund regional stormwater facilities or other measures that will benefit the quality of stormwater in the community.

The following method is used to calculate the fee paid in-lieu-of implementing stormwater BMPs:

Base fee - A base fee is calculated from the impervious surface area.

The base fee is $0.50 per square foot of Impervious Surface Area.

Base fee reductions – The amount of impervious surface area used to calculate the base fee for a site can be reduced if BMPs are implemented to reduce the amount of Directly Connected Impervious Area (DCIA) at the site. The reduction to the impervious area is dependent on the extent of BMPs implemented. Refer to Appendix A, Figure A-1 to determine the adjustment to the impervious area based on the type of BMPs employed (i.e., Level 1 DCIA versus Level 2 DCIA). Multiply the impervious area adjustment by the Impervious Area. The reduced Impervious Area is used to calculate the fee to be paid in-lieu-of implementing water quality BMPs.

Example: The impervious percentage of a 2-acre commercial site is 50%. If Level 2 DCIA measures are employed at the site, using Figure A-1 (see Appendix A), the effective impervious area is 38%. The adjustment factor is 0.38/0.5 = 0.76. Multiplying the total impervious area of the site (2 acres x 43560 sq. ft/acre x 50% impervious area = 43560 sq. ft.) by the adjustment factor (0.76) yields an effective impervious area of 33106 sq. ft., which equates to an ISU for the site of 33.1. Therefore, the adjusted fee for the in-lieu-of payment is $16,553 (based on a rate of $0.50 per square foot of Impervious Surface Area).