Chapter 7: Water Quality

Contents

1.0 Overview

The focus of this Chapter is on the frequently occurring rainfall events, those which have the greatest overall impact on the quality of receiving waters. The contents of this Chapter include design guidance for Design Engineers in selecting, maintaining and implementing permanent best management practices (BMPs) for development sites that minimize water quality impacts from stormwater runoff.

The physical and chemical characteristics of stormwater runoff changes as urbanization occurs, requiring comprehensive planning and management to reduce adverse effects on receiving waters. As stormwater flows across roads, rooftops and other hard surfaces, pollutants are picked up and then discharged to streams and lakes. Additionally, the increased frequency, flow rate, duration and volume of stormwater discharges due to urbanization can result in the scouring of rivers and streams, degrading the physical integrity of aquatic habitats, stream function, and overall water quality (EPA, 2009)

FCU suggests that the Design Engineer begins the development process with a clear understanding of the seriousness of stormwater quality management from regulatory and environmental perspectives, and implement a holistic planning process that incorporates water quality up front in the overall site development process. FCU requires that water quality treatment systems for stormwater are installed for all applicable development sites, including the incorporation of enhanced water quality treatment for stormwater, which has been required since 2013.

Generally, standard water quality treatment is required for all portions of development sites that are not treated through LID systems.

STANDARD WQ TREATMENT
+ LID REQUIREMENTS
100% OF SITE TREATED

Many of the concepts presented in this Chapter are based upon the research and practices developed by UDFCD (e.g. WQCV and the Four Step Process). These practices have become design criteria for many communities throughout the region, including Fort Collins. The UDFCD Manual design criteria and design tools that are utilized by FCU are presented herein; however, FCU has further, sometimes more restrictive design requirements than those presented in the UDFCD Manual, which are also provided in this Chapter.

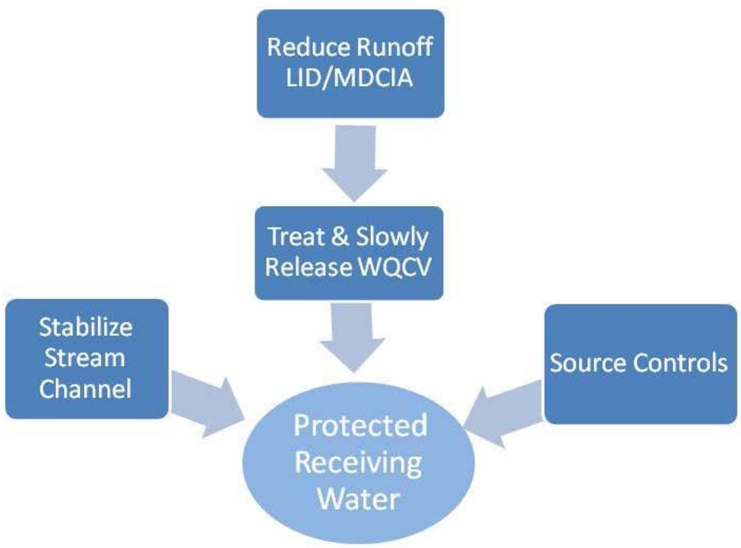
An LID Implementation Manual (provided in Appendix C) is included as a part of this Manual. The LID Implementation Manual is a comprehensive document that includes an LID technique selection matrix, design guidance and construction detailing for all the LID systems commonly accepted by FCU. The LID Implementation Manual is considered a user's guide, whereas, the information presented in this

Chapter focuses on the design criteria for standard and enhanced water quality systems. Designers will find that this Chapter is to be utilized in conjunction with the LID Implementation Manual.

2.0 Four Step Process

UDFCD has long recommended a Four Step Process for receiving water protection that focuses on reducing runoff volumes, treating the water quality capture volume (WQCV), stabilizing streams and implementing long-term source controls. The Four Step Process pertains to management of smaller, frequently occurring events, as opposed to larger storms for which drainage and flood control infrastructure are sized. Implementation of these four steps helps to achieve compliance with stormwater permit requirements (i.e. City's MS4 permit). Added benefits of implementing the complete process can include improved site aesthetics through functional landscaping amenities that also provide stormwater quality benefits.

Figure 2.0-1. The Four Step Process for stormwater quality management



Step 1. Employ Runoff Reduction Practices

To reduce runoff peaks, volumes and pollutant loads from urbanizing areas, implement LID strategies, including Minimizing Directly Connected Impervious Area (MDCIA). For every site, look for opportunities to route runoff through vegetated areas, where possible, by sheet flow. LID practices reduce unnecessary impervious areas and route runoff from impervious surfaces over permeable areas to slow runoff (increase time of concentration) and promote infiltration.

Differences between LID and Conventional Stormwater Quality Management

LID is a comprehensive land planning and engineering design approach to managing stormwater runoff with a goal of replicating the pre-development hydrologic regime of urban and developing watersheds. Given the increased regulatory emphasis on LID, volume reduction and mimicking pre-development hydrology, questions may arise related to the differences between conventional stormwater management and LID. For example, MDCIA is emphasized as the first step in stormwater quality planning and the LID Implementation Manual provides guidance on LID techniques such as linear bioretention, bioretention, permeable pavement systems and pollution prevention (pollutant source controls). Although these practices are all key components of LID, LID is not limited to a set of practices targeted at promoting infiltration. Key components of LID, in addition to individual BMPs, include practices such as:

- An overall site planning approach that promotes conservation design at both the watershed and site levels. This approach to development seeks to “fit” a proposed development to the site, integrating the development with natural features and protecting the site’s natural resources. This includes practices such as preservation of natural areas including open space, wetlands, soil with high infiltration potential and stream buffers. Minimizing unnecessary site disturbances (e.g. grading, compaction) is also emphasized.

- A site design philosophy that emphasizes multiple controls distributed throughout a development, as opposed to a single treatment facility.

- The use of swales and open vegetated conveyances, as opposed to curb and gutter systems.

Even with LID practices in place, most sites will also require centralized flood control facilities. In some cases, site constraints may limit the types of LID techniques that can be implemented, whereas in other cases, developers and engineers may have significant opportunities to integrate LID techniques that may be overlooked due to the routine nature and familiarity of conventional approaches. This Manual provides design criteria and guidance for both LID and conventional stormwater quality management.

Key LID techniques include:

- **Conserve Existing Amenities:** During the planning phase of development, identify portions of the site that add value and should be protected or improved. Such areas may include mature trees, stream corridors, wetlands and Type A/B soils with higher infiltration rates. In order for this step to provide meaningful benefits over the long-term, natural areas must be protected from compaction during the construction phase. Consider temporary construction fence for this purpose. In areas where disturbance cannot practically be avoided, rototilling and soil amendments should be integrated to restore the infiltration capacity of areas that will be restored with vegetation. Additional natural resource protection standards may apply on a particular site, per Section 3.4.1 of the Land Use Code.

- **Minimize Impacts**: Consider how the site lends itself to the desired development. In some cases, creative site layout can reduce the extent of paved areas, thereby saving on initial capital cost of pavement and then saving on pavement maintenance, repair, and replacement over time. Minimize imperviousness, including constructing streets, driveways, sidewalks and parking lot aisles to the minimum widths necessary, while still providing for parking, snow management, public safety and fire access. When soils vary over the site, concentrate new impervious areas over Type C and D soils, while preserving Type A and B soils for landscape areas and other permeable surfaces. Maintaining natural drainage patterns, implementing sheet flow (as opposed to concentrated flow), and increasing the number and lengths of flow paths will all reduce the impact of the development.

- **Permeable pavement** techniques are common LID practices that may reduce the effects of paved areas. The use of various permeable pavement techniques as alternatives to paved areas can significantly reduce site imperviousness.

- **Minimize Directly Connected Impervious Areas (MDCIA):** Impervious areas should drain to pervious areas. Use non-hardened drainage conveyances where appropriate. Route downspouts across pervious areas, and incorporate vegetation in areas that generate and convey runoff. Three key BMPs include:

  - Vegetated Buffers: Sheet flow over a vegetated buffer slows runoff and encourages infiltration, reducing effects of the impervious area.

  - Linear bioretention: Like vegetated buffers, the use of linear bioretention instead of storm sewers slows runoff and promotes infiltration, also reducing the effects of imperviousness.

  - Bioretention (rain gardens): The use of distributed on-site vegetated features such as rain gardens can help maintain natural drainage patterns by allowing more infiltration onsite. Bioretention can also treat the WQCV, as described in the Four Step Process.

Practical Tips for Volume Reduction and Better Integration of Water Quality Facilities
(Adapted from: Denver Water Quality Management Plan, WWE et al. 2004)

- *Consider stormwater quality needs early in the development process. When left to the end of the site development process, stormwater quality facilities will often be shoe-horned into the site, resulting in few options. When included in the initial planning for a project, opportunities to integrate stormwater quality facilities into a site can be fully realized. Dealing with stormwater quality after major site plan decisions have been made is too late and often makes implementation of LID designs more difficult.*

- *Take advantage of the entire site when planning for stormwater quality treatment. Stormwater quality and flood detention is often dealt with only at the low corner of the site, and ignored on the remainder of the site. The focus is on draining runoff quickly through inlets and storm sewers to the detention facility. In this "end-of-pipe" approach, all the runoff volume is concentrated at one point and designers often find it difficult to fit the required detention into the space provided. This can lead to use of underground BMPs that can be difficult to maintain or deep, walled-in basins that detract from a site and are also difficult to maintain. Treating runoff over a larger portion of the site reduces the need for big corner basins and allows implementation of LID principles.*

- *Place stormwater in contact with the landscape and soil. Avoid routing storm runoff from pavement to inlets to storm sewers to offsite pipes or concrete channels. The recommended approach places runoff in contact with landscape areas to slow down the stormwater and promote infiltration. Permeable pavement areas also serve to reduce runoff and encourage infiltration.*

- *Minimize unnecessary imperviousness, while maintaining functionality and safety. Smaller street sections or permeable pavement in fire access lanes, parking lanes, overflow parking, and driveways will reduce the total site imperviousness.*

- *Select treatment areas that promote greater infiltration. Bioretention, permeable pavements, and sand filters promote greater volume reduction than extended detention basins, since runoff tends to be absorbed into the filter media or infiltrate into underlying soils.*

Step 2. Implement BMPs That Provide a WQCV with Slow Release

After runoff has been minimized, the remaining runoff should be treated through capture and slow release of the WQCV. The LID Implementation Manual provides design guidance for BMPs providing treatment of the WQCV, including permeable pavement systems with subsurface water quality treatment or detention, bioretention, extended detention basins, sand filters and constructed wetland ponds. This Chapter also provides the step-by-step procedure to calculate the WQCV.

Step 3. Stabilize Streams

During and following development, natural streams are often subject to bed and bank erosion due to increases in frequency, duration, rate and volume of runoff. Although Steps 1 and 2 help to minimize these effects, some degree of stream stabilization is required. The streams and drainageways within Fort Collins are typically included in Master Drainage Plans which would identify needed channel stabilization measures. These measures not only protect infrastructure such as utilities, roads and trails, but are also important to control sediment loading from erosion of the channel itself, which can be a significant source of sediment and associated constituents, such as phosphorus, metals and other naturally occurring constituents. If stream stabilization is implemented early in the development process, it is far more likely that natural stream characteristics can be maintained with the addition of grade control to accommodate future development. Targeted fortification of a relatively stable stream is typically much less costly than repairing an unraveled channel.

Step 4. Implement Site Specific and Other Source Control BMPs

Site specific needs such as material storage or other site operations require consideration of targeted source control BMPs. This is often the case for new development or significant redevelopment of an industrial or commercial site. Some examples of implementing this practice are:

- To locate trash collection or enclosure areas away from storm drainage or LID facilities so that highly concentrated and polluted runoff from that area has the opportunity to be cleaned prior to runoff into the storm drain.

- To locate dog parks in areas away from detention basins and to educate and enforce pick up practices for dog owners.

- To locate community gardens in areas that are outside of a detention basin to prevent chemical and sediment loading in the detention basin.

- To locate material storage (during construction) away from storm drainage facilities (i.e. stockpiles of backfill or landscape materials)

3.0 BMP Selection

3.1 Storage-Based vs Conveyance-Based BMPs

BMPs in this Manual generally fall into two categories: 1) storage-based and 2) conveyance-based. Storage-based BMPs provide the WQCV and include bioretention/rain gardens, extended detention basins, sand filters, constructed wetland ponds and underground storage, filtration and infiltration systems. Conveyance-based BMPs include linear bioretention (linear bioretention), permeable pavement systems, constructed wetlands, channels and other BMPs that improve quality and reduce volume but only provide incidental storage.

Conveyance-based BMPs can be implemented to help achieve objectives in Step 1 of the Four Step Process. Storage-based BMPs are critical for Step 2 of the Four Step Process. FCU does not require that sites include both storage and conveyance-based BMPs; however, site plans that use a combination of conveyance-based and storage-based BMPs can be used to better mimic pre-development hydrology.

3.2 Treatment Train

Advantages of treatment trains include:

The term "treatment train" refers to multiple BMPs in series (e.g., a roof downspout draining to a bioswale draining to a rain garden draining to an extended detention basin.) Engineering research over the past decade has demonstrated that treatment trains are one of the most effective methods for management of stormwater quality (WERF 2004).

- **Multiple processes for pollutant removal:** There is no "silver bullet" for a BMP that will address all pollutants of concern as a stand-alone practice. Treatment trains that link together complementary processes expand the range of pollutants that can be treated with a water quality system and increase the overall efficiency of the system for pollutant removal.

- **Redundancy:** Given the natural variability of the volume, rate and quality of stormwater runoff and the variability in BMP performance, using multiple practices in a treatment train can provide more consistent treatment of runoff than a single practice and provide redundancy in the event that one component of a treatment train is not functioning as intended.

- **Maintenance:** BMPs that remove trash, debris, coarse sediments and other gross solids are a common first stage of a treatment train. From a maintenance perspective, this is advantageous since this first stage creates a well-defined, relatively small area that can be cleaned out routinely. Downgradient components of the treatment train can be maintained less frequently and will benefit from reduced potential for clogging and accumulation of trash and debris.

3.3 Online vs Offline Facility Locations

The location of WQCV facilities within a development and watershed site requires thought and planning. A key decision involves whether to locate a BMP online or offline. Offline refers to locating a BMP such that all of the runoff from the upstream basin is intercepted and treated by the BMP prior to entering the receiving water. FCU requires that water quality treatment is provided at the site level (offline) before entering receiving waters. FCU will not allow water quality treatment systems to be installed on the receiving waters (online).

3.4 Maintenance and Sustainability

Maintenance needs to be considered early in the planning and design phase. Even when BMPs are thoughtfully designed and properly installed, they can become eyesores, breed mosquitoes, and cease to function if not properly maintained. BMPs are more effectively maintained when they are designed to allow easy access for inspection and maintenance and to take into consideration factors such as property ownership, easements, visibility from easily accessible points, slope, vehicle access, and other factors. FCU requires that design plans adhere to easement dedication requirements and design parameters for access. In addition, FCU requires that maintenance procedures (SOPs) are outlined for each BMP and included in the Development Agreement for each project site.

Sustainability of BMPs is based on a variety of considerations related to how the BMP will perform over time. For example, vegetation choices for BMPs determine the extent of supplemental irrigation required. Choosing native or drought-tolerant plants and seed mixes (as recommended in Chapter 4: Construction Control Measures) helps to minimize irrigation requirements following plant establishment. Other sustainability considerations include large development site conditions. For example, in larger sites with phased and ongoing development, clogging of infiltration BMPs is a concern. In such cases, a decision must be made regarding either how to protect and maintain infiltration BMPs, or whether to allow use of infiltration practices under these conditions.

4.0 Water Quality Detention

Development sites that are required to incorporate water quantity detention into the stormwater management system of the site may also incorporate "extended detention" within the quantity detention basin to meet the City's standard water quality requirements.

Reference: Refer to the BMP Fact Sheet T-5: Extended Detention Basin (EDB) from the 2015 UDFCD Manual, Volume 3, Chapter 4, Section 2.0 for additional design information. This Fact Sheet is included in the Reference section at the end of this Chapter.

An extended detention basin is designed to empty (either completely or almost completely) after stormwater runoff ends. It is an adaptation of a detention basin used for water quantity, with the primary difference being the outlet design. The extended detention basin has a much smaller outlet, which extends the stormwater release time of more frequently occurring runoff events to facilitate pollutant removal. The outlet is designed so that stormwater release for the water quality capture volume (WQCV) is 40 hours.

Combining the water quality facility with the water quantity facility is a common design practice. When detention volume is sized for a site that also incorporates WQCV, the 100-year volume required for quantity detention must be added to the entire WQCV. In addition, the WQCV must account for providing water quality treatment to all stormwater runoff that is not otherwise treated through a Low Impact Development (LID) system. LID systems and requirements are discussed in Section 6.0 of this Chapter.

Soil type at the location of the extended detention basin should be determined during design. However, any exfiltration capacity should be considered a short-term characteristic because exfiltration will decrease over time as the soil is clogged with fine sediment and as the groundwater beneath the basin develops a mound that surfaces into that basin. Therefore, exfiltration rates are not allowed to be accounted for in detention basin volume design.

Other uses may be provided in the detention basin area, such as active or passive recreation. Active recreation facilities include ballparks, playing fields and picnic areas. However, the area within the WQCV is not well-suited for active recreation facilities because of frequent inundation and these facilities must be located outside of the WQCV pool. The area within the WQCV is better suited for passive recreation such as open space and wildlife habitat. See Section 3 of this Chapter for specific examples of facilities that should not be placed in detention areas.

5.0 Hydrologic Basis of the WQCV

5.1 Development of the WQCV

The purpose of designing BMPs based on the WQCV is to improve runoff water quality and reduce hydromodification and the associated impacts on receiving waters. Although some BMPs can help to remove pollutants and achieve modest reductions in runoff volumes for frequently occurring events in a "flow through" mode (e.g., linear bioretention, grass buffers or wetland channels), to address hydrologic effects of urbanization, a BMP must be designed to control the volume of runoff, either through detention, infiltration, evapotranspiration or a combination of these processes (e.g., rain gardens, extended detention basins or other storage-based BMPs). The following insert provides a brief background on the development of the WQCV.

The WQCV is based on an analysis of rainfall and runoff characteristics for 36 years of record at the Denver Stapleton Rain Gage (1948-1984) conducted by Urbonas, Guo, and Tucker (1989) and documented in Sizing a Capture Volume for Stormwater Quality Enhancement (available at www.udfcd.org). This analysis showed that the average storm for the Denver area, based on a 6-hour separation period, has duration of 11 hours and an average time interval between storms of 11.5 days. However, the great majority of storms are less than 11 hours in duration (i.e., median duration is less than average duration). The average is skewed by a small number of storms with long durations.

The data showed that 61% of the 75 storm events that occur on an average annual basis have less than 0.1 inches of precipitation. These storms produce practically no runoff and therefore have little influence in the development of the WQCV. Storm events between 0.1 and 0.5 inches produce runoff and account for 76% of the remaining storm events (22 of the 29 events that would typically produce runoff on an average annual basis). Urbonas et al. (1989) identified the runoff produced from a precipitation event of 0.6 inches as the target for the WQCV, corresponding to the 80th percentile storm event.

The WQCV for a given watershed will vary depending on the imperviousness and the drain time of the BMP, but assuming 0.1 inches of depression storage for impervious areas, the maximum capture volume required is approximately 0.5 inches over the area of the watershed. Urbonas et al. (1989) concluded that if the volume of runoff produced from impervious areas from these storms can be effectively treated and detained, water quality can be significantly improved.

5.2 Optimizing the Capture Volume

Optimizing the capture volume is critical. If the capture volume is too small, the effectiveness of the BMP will be reduced due to the frequency of storms exceeding the capacity of the facility and allowing some volume of runoff to bypass treatment. On the other hand, if the capture volume for a BMP that provides treatment through sedimentation is too large, the smaller runoff events may pass too quickly through the facility, without the residence time needed to provide treatment.

Small, frequently occurring storms account for the predominant number of events that result in stormwater runoff from urban catchments. Consequently, these frequent storms also account for a significant portion of the annual pollutant loads. Capture and treatment of the stormwater from these small and frequently occurring storms is the recommended design approach for water quality enhancement, as opposed to flood control facility designs that focus on less frequent, larger events.

The analysis of precipitation data at the Denver Stapleton Rain Gage revealed a relationship between the percent imperviousness of a watershed and the capture volume needed to significantly reduce stormwater pollutants (Urbonas, Guo, and Tucker, 1990). Subsequent studies (Guo and Urbonas, 1996 and Urbonas, Roesner, and Guo, 1996) of precipitation resulted in a recommendation by the Water Environment Federation and American Society of Civil Engineers (1998) that stormwater quality treatment facilities (i.e., post-construction BMPs) be based on the capture and treatment of runoff from storms ranging in size from "mean" to "maximized" storms. The "mean" and "maximized" storm events represent the 70th and 90th percentile storms, respectively. As a result of these studies, water quality facilities for the Colorado Front Range are recommended to capture and treat the 80th percentile runoff event. Capturing and properly treating this volume should remove between 80 and 90% of the annual TSS load, while doubling the capture volume was estimated to increase the removal rate by only 1 to 2%.

5.3 Attenuation of the WQCV (BMP Drain Time)

The WQCV must be released over an extended period to provide effective pollutant removal for post-construction BMPs that use sedimentation (i.e., extended detention basin and constructed wetland ponds). The extended period generally equates to a 40-hour drain time for the brim-full basin. Constructed wetland basins may have reduced drain times (12 hours or 24 hours) because the hydraulic residence time of the effluent is essentially increased due to the mixing of the inflow with the permanent pool.

When pollutant removal is achieved primarily through filtration such as in a sand filter or rain garden BMP, an extended drain time is still recommended to promote stability of downstream drainageways, but it can be reduced because it is not needed for effective pollutant removal. In addition to counteracting hydromodification, attenuation in filtering BMPs can also improve pollutant removal by increasing contact time, which can aid adsorption/absorption processes depending on the media. The minimum recommended drain time for a post-construction BMP is 12 hours.

5.4 Calculation of the WQCV

The first step in estimating the magnitude of runoff from a site is to estimate the site's total imperviousness. The total imperviousness of a site can be determined taking an area-weighted average of all of the impervious and pervious areas.

STANDARD WATER QUALITY

40-HOUR DRAIN TIME REQUIRED

LID SYSTEMS

12-HOUR DRAIN TIME REQUIRED

The WQCV is calculated as a function of imperviousness and BMP drain time using the following equation and as shown in **Figure 5.4-1**:

WQCV = $a(0.91I^3 - 1.19I^2 + 0.78I)$ **Equation 7-1**

Where: WQCV = Water Quality Capture Volume, watershed inches

a = Coefficient corresponding to WQCV drain time (**Table 5.4-1**)

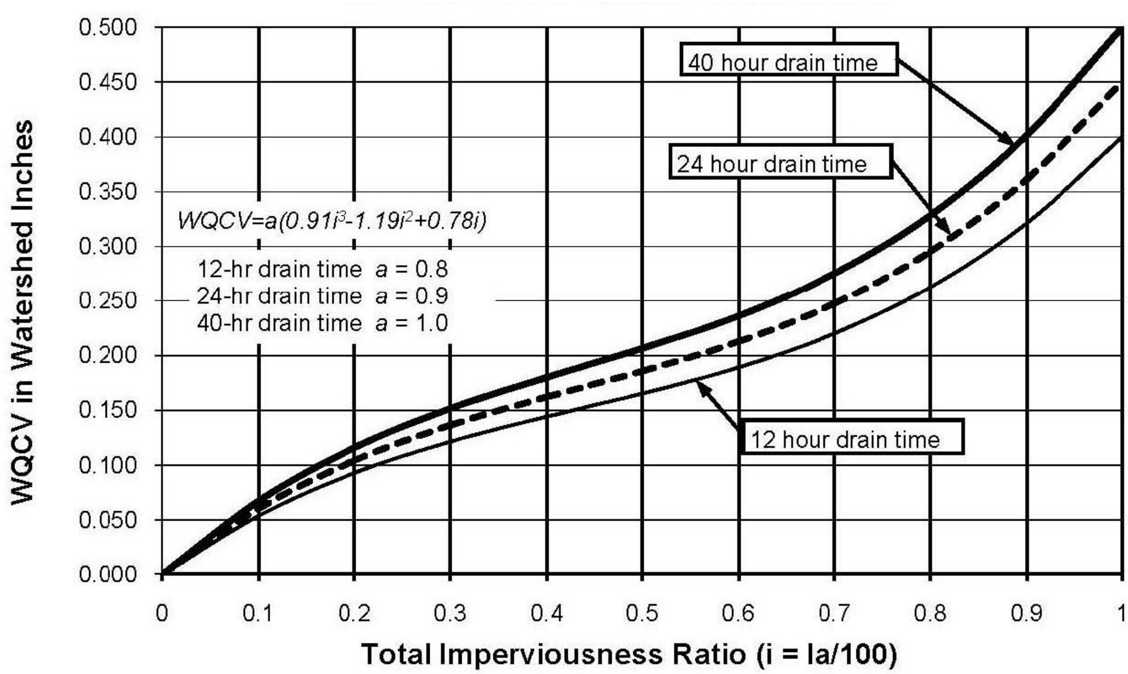
I = Imperviousness (%/100)

Table 5.4-1. Drain Time Coefficients for WQCV Calculations

Drain Time (hrs)	Coefficient (a)
12	0.8
40	1.0

Reference: The UD-BMP excel-based spreadsheet, RG and EDB tabs may be used to aid in calculating WQCV.

Figure 5.4-1 WQCV Based on BMP Drain Time



Once the WQCV in watershed inches is found from Figure 3.2-12 or using Equation 3.2-1, the required BMP volume in acre-feet can be calculated as follows:

$$\mathbf{V} = \left(\frac{\mathbf{WQCV}}{\mathbf{12}}\right)\mathbf{Ax1.2}$$ **Equation 7-2**

Where: V = required volume, acre-ft

A = tributary catchment area upstream, acres

WQCV = Water Quality Capture Volume, watershed inches

1.2 = to account for the additional 20% of required storage for sedimentation accumulation

Reference: Calculating effective imperviousness and quantifying volume reduction as discussed in the 2015 UDFCD Manual, Volume 3, Section 4.0 are not allowed. The City of Fort Collins does not allow for extended detention basins to be designed using the Excess Urban Runoff Volume (EURV) and Full-Spectrum Detention method, as described in the UDFCD Manual.

6.0 Low Impact Development

This Section of this Chapter presents information that is specific to the City of Fort Collins and may be a significant deviation from the information presented in the UDFCD Manuals. Utilizing UDFCD methodologies for Low Impact Development (LID) designs may not be accepted by FCU.

In February 2013, Fort Collins City Council adopted Ordinance No. 152, 2012, to incorporate provisions implementing LID principles; with the goal to declare that the purpose of the City Stormwater Utility is to provide an integrated, sustainable stormwater management program that reflects the community's values of protecting and restoring the City's watersheds. This was subsequently modified and updated in January 2016 with Ordinance No. 007, 2016 to allow for some added flexibility in the implementation of the LID policy.

Reference: Both the initial LID ordinance, Ordinance No. 152, 2012, and the subsequent ordinance, Ordinance No. 007, 2016, can be found on the City of Fort Collins website.

LID is simply defined as an integrated, sustainable stormwater management program that requires a distributed, closer to the source stormwater runoff control that simulates natural processes and relies mainly on filtration and infiltration to locally treat and manage stormwater runoff.

Integration of LID systems into the drainage design is required for all development projects in order to comply with the City's policies on LID, the requirements of this Manual, the City Code and the Land Use Code. LID systems provide a higher degree of stormwater quality treatment than that provided with standard water quality design. The implementation of LID systems requires one of the following two options:

1) 50% of the newly added or modified impervious area must be treated by LID techniques and 25% of new paved (vehicle use) areas must be pervious.

2) 75% of all newly added or modified impervious area must be treated by LID techniques.

Impervious surfaces are defined as hardscape surfaces that do not allow stormwater to infiltrate into the ground. Impervious surfaces include asphalt and concrete surfaces, concrete curbs, gutters, sidewalks, patios and rooftops. (Impervious surface areas must be assumed for single family residential lots when overall impervious areas are being determined for residential developments. The assumed areas must then be included in LID calculations.)

OPTIONS FOR MEETING WATER QUALITY TREATMENT REQUIREMENTS

50% SITE TREATED WITH "STANDARD" WATER QUALITY
\+ 50% SITE TREATED WITH LID (INCLUDING PAVERS)
100% OF SITE TREATED (REQUIREMENTS MET)

OR

25% SITE TREATED WITH "STANDARD" WATER QUALITY
\+ 75% SITE TREATED WITH LID
100% OF SITE TREATED (REQUIREMENTS MET)

"Added" impervious area stated in the two options above is further defined as existing vegetation (or pervious) areas becoming hardscape (or impervious) areas.

"Modified" impervious area stated in the two options above is further defined as existing impervious areas on an existing site being removed and replaced with other impervious surfaces through a redevelopment process (i.e. existing asphalt surface becoming a rooftop surface). Mill and overlay of asphalt areas is not considered a "modified" impervious area.

"Paved" areas, as stated in option 1 above are generally considered to be private vehicle use areas only.

Reference: Refer to the City of Fort Collins LID Implementation Manual in Appendix C for detailed information and requirements on LID systems.

6.1 General Requirements

Included here are some general design requirements applicable for all types of LID system designs in Fort Collins.

- Overall added or modified impervious areas that amount to less than 1000 square feet (< 1000 sf) on a site will not require LID system treatment for water quality.

- For development sites that are adding or modifying 1000 square feet of imperviousness or more (≥ 1000 sf) are required to implement LID system treatment at the site. The LID system is allowed to treat existing imperviousness in exchange for the newly added imperviousness if the surface character is similar (e.g. existing pavement may be treated in lieu of newly added rooftop)

- For single-family residential developments, LID must be placed in tracts or common areas for ownership and maintenance by the HOA. LID systems installed as part of the development requirement shall not be placed on single-family lots.

- LID is not required for private, single-family residential improvement projects that are not a part of a larger subdivision project. (i.e. an existing lot in an older part of Fort Collins that is being re-built)

- LID systems are not allowed to be placed in the public right-of-way to treat runoff from development sites. Stormwater runoff from development must be treated within the confines of the development and therefore cannot be treated and/or placed within a public right-of-way. Stormwater runoff generated within the public right-of-way, however, is still required to be captured and treated for water quality.

- LID systems are generally required to be placed outside of a detention basin area.

- LID systems may only drain to drywells if a gravity outfall for the water quality storm is not available.

- LID systems are required to be sized for the entire area tributary to the LID basin (including any offsite contributing areas)

- LID systems are required to be placed outside of any existing wetlands (jurisdictional and non-jurisdictional), streams or other waters of the U.S.

- LID systems design must comply with the excerpts of the City of Fort Collins Landscape Design Standards and Guidelines for Stormwater and Detention Facilities, dated November 5, 2009 included as Appendix B to this Manual.

6.2 Permeable Pavement

The term “permeable pavement” is a general term to describe any one of several pavement systems that allow infiltration of water into the layers below the pavement through openings within the pavement surface. Use of permeable pavements is an accepted Low Impact Development (LID) practice in Fort Collins and is often used in combination with other BMPs to provide full treatment and slow release of the WQCV. In addition, there are some installations in Fort Collins that have also been designed with an outlet control and increased depth of aggregate material in order to provide quantity detention in excess of the water quality (80th percentile) storm event. Design considerations for permeable pavement systems are presented in the LID Implementation Manual, included in Appendix C. However, there are several design parameters specified below that are also required for all permeable pavement system designs specific to meeting the LID requirements for Fort Collins.

Figure 6.2-1. Design Criteria for Permeable Pavers (FCU)

LOCATION

- Pavers installed within single-family or private driveway areas may not be applied toward the paver requirement of the LID ordinance.
- Pavers along utility corridors is discouraged and will only be allowed on a case-by-case basis
- Paver requirement generally only applies to sites with private vehicle use areas
- For pavers to apply to the paver requirement of the LID ordinance, they must be placed in vehicle use areas. Pavers placed in sidewalks or other areas may be applied toward the LID requirements, but not the specific paver requirement

AREA

- If the project is installing less than 1000 sf of vehicle use area, then the paver requirement does not apply

RUN-ON

- Maximum allowable impervious area "running onto" a paver area is 3x the paver area, or a 3:1 ratio.
- Note that Urban Drainage recommends a maximum 2:1 run-on ratio for tributary impervious areas. FCU allows a maximum of 3:1 run-on ratio.
- Applicable run-on area is from impervious surfaces only (pavements and rooftops). Pervious surfaces are not required to be included in the run-on area calculation.

DETENTION

- Up to 1 acre-foot of detention is allowed in the subsurface media
- Maximum allowable void space is 30% for detention volume calculations

OVERFLOW

- overflow inlet or conveyance is required adjacent to paver areas

SLOPE

- Follow manufactureres recommendations for min and max surface slopes
- Typical min surface slope 0.50%
- Typical max surface slope 2.0%

SUBSURFACE SLOPES

- Follow manufacturers recommendations for min and max subgrade slopes
- Typical min subgrade slope 0.50%

OTHER

- Impermeable liner required along paver subsurface where adjacent to buildings or other infiltration sensitive structures are present as determined by the Design Engineer
- Underdrain piping is required
- Underdrain cleanouts are required for flushing and inspection

6.3 Bioretention (Rain Gardens)

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

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

Design and construction detailing for bioretention systems, alternatively referred to as "rain gardens" are presented in the LID Implementation Manual in Appendix C. Additionally, included in **Figure 6.4-1** below are some key design parameters for rain gardens that are specific to Fort Collins.

NOTES ABOUT DRYWELLS

- DRYWELLS MAY BE UTILIZED AS AN OUTFALL FOR LID FACILITIES ONLY WHEN A GRAVITY OUTFALL TO THE SURFACE OR STORMWATER INFRASTRUCTURE IS NOT AVAILABLE
- DRYWELLS ARE NOT ALLOWED TO BE UTILIZED AS A PRIMARY OUTFALL FOR DETENTION BASINS OR STORM PIPING SYSTEMS
- INCLUSION OF A DRYWELL IN DESIGN PLANS MUST BE ACCOMPANITED BY A GEOTECHNICAL ANALYSIS AND RECOMMENDATIONS
- DRYWELL AGGREGATE MATERIAL MUST EXTEND TO WELL-DRAINING SOILS AS IDENTIFIED IN A GEOTECHNICAL ANALYSIS

6.4 Sand Filter

A sand filter is a filtering or infiltrating BMP that consists of a surcharge zone underlain by a sand bed with an underdrain system. During a storm, accumulated runoff collects in the surcharge zone and gradually infiltrates into the underlying sand bed, filling the void spaces of the sand. The underdrain gradually dewaters the sand bed and discharges the runoff to a nearby channel, swale, storm drain or detention basin. It is similar to a BMP designed for bioretention in that it utilizes filtering, but differs in that it is not specifically designed for vegetative growth. The absence of vegetation in a sand filter allows for active maintenance at the surface of the filter, (i.e., raking for removing a layer of sediment). For this reason, sand filter criteria allows for a larger contributing area and greater depth of storage. Sand filters can also be placed in a vault. Underground sand filters have additional requirements.

Design and construction detailing for sand filters are presented in the LID Implementation Manual. Included in **Figure 6.4-1** below are some key design guides for sand filters.

Figure 6.4-1. Design Criteria for Rain Gardens and Sand Filters

LOCATION	VOLUME	OVERFLOW	UNDERDRAINS
• Generally, Rain Gardens and Sand Filters shall be placed "offline" from the detention basin	• Rain Gardens and Sand Filters are sized for the WQCV • Forebay shall be included and is to be sized for 1% of the WQCV and have a minimum depth of 12" • UD-BMP workbook may be utilized for sizing • Maximum depth is 12" for Rain Gardens	• Area inlet or overflow required at the WQCV depth (12" above the rain garden finished grade surface)	• Underdrain piping is required • Underdrain cleanouts are required for flushing and inspection

6.5 Linear Bioretention

Linear bioretention has low longitudinal slopes and broad cross-sections that convey flow in a slow and shallow manner, thereby facilitating sedimentation and filtering (straining) while limiting erosion. Berms or check dams may be incorporated into the facility to reduce velocities and encourage settling and infiltration. When using berms, an underdrain system should be provided. Linear bioretention is an integral part of the LID concept and may be used as an alternative to a curb and gutter system.

Design and construction detailing for linear bioretention systems are presented in the LID Implementation Manual in Appendix C. Included below are some additional design parameters that are specific to the City of Fort Collins.

Figure 6.5-1. Design Criteria for Linear Bioretention

SLOPES	GEOMETRY	2-YR STORM DESIGN
• Minimum longitudinal slope is 0.5% • Maximum longitudinal slope is 1.0%	• Minimum bottom width is 24" • Maximum side slopes 4:1	• Froude No. ≤ 0.5 • Velocity ≤ 1 fps • Depth ≤ 12"

6.6 Underground Filtration

Underground stormwater BMPs include proprietary and non-proprietary devices installed below ground that provide stormwater quality treatment via sedimentation, screening, filtration and other physical and chemical processes. When surface BMPs are found to be infeasible, underground BMPs may be the only available strategy for satisfying regulatory water quality and/or LID requirements, especially in highly built-up urban areas where water quality measures must be implemented as a part of a retrofit to meet regulatory requirements. The most common sites for underground BMPs are "ultra-urban" environments with significant space constraints. These could include downtown lot-line-to-lot-line development projects, transportation corridors, or small (less than 0.5 acre) redevelopment sites in urban areas.

Included below are some key design requirements for underground systems in Fort Collins. Additionally, design and construction detailing for underground detention and filtration systems are presented in the LID Implementation Manual in Appendix C, and underground detention design requirements are discussed in Chapter 5: Detention of this Manual.

Figure 6.6-1. Design Criteria for Underground LID

LOCATION	VOLUME
• Typically co-located with flood control detention structure • May be allowed within parking garages pending adequate access, maintenance and safety • Never allowed below buildings that include habitable space	• Sized based on the 80th percentile storm using modified FAA method (for the sediment capture chamber) • Release rate is % of infiltration rate through subsurface • Major storm is required to bypass the water quality chamber • Proprietary software may be able to be utilized for volume sizing. This will be determined by FCU on a case-by-case basis. (If proprietary software is allowed, secondary hydraulic calculations may also be required for sizing verifications. • The total system is sized for the WQCV

Reference: See Chapter 6: Detention of this Manual, for discussion and design information on underground detention systems.

Underground detention and filtration basins that are designed using non-proprietary systems will be reviewed by FCU on a case-by-case basis. FCU does not want to discourage unique design ideas for LID systems; however, the designers are typically encouraged to utilize commonly utilized BMPs.

6.7 Vegetated Buffer

Vegetated buffers are densely vegetated strips of grass designed to accept sheet flow from upgradient development. The size of the buffer itself is relatively large compared to the impervious area that is draining onto it. Properly designed vegetated buffers play a key role in LID, enabling infiltration and slowing runoff while also providing filtration (straining) of sediment. Buffers differ from swales in that they are designed to accommodate overland sheet flow rather than concentrated or channelized flow. These are typically employed in a treatment train approach, as part of a larger water quality treatment system.

Figure 6.7-1. Design Criteria for Vegetated Buffers

DESIGN REQUIREMENTS	REQUIREMENTS FOR LID CREDIT
• Appropriate for sheet flow applications only • Level spreaders will be required where point discharges may occur • Minimum cross-slope is 2% and maximum cross-slope is 10% • Requires soil amendment and select vegetation to allow for 80% vegetative cover; does not require weekly maintenance and is not highly manicured with sod or mulch beds • Best suited as part of "treatment train"	• In addition to the design requirements listed to the left, for vegetated buffers to serve as stand-alone LID treatment facility, the following parameters must also be met: • Cross-slopes are no greater than 5% • Buffer must be of an area equal to or greater than the impervious area running onto it (i.e. run-on ratio is 1:1 maximum) • Buffer must be a minimum of 14' wide (in the direction of flow) • Buffer area must be clearly delineated on the plans to eliminate site disturbance and compaction in the buffer area due to construction activities • Soils must be naturally suited for infiltration (i.e. type A or B soils)

Design and construction detailing for vegetated buffers are presented in the LID Implementation Manual in Appendix C.

6.8 Constructed Wetland Channel / Pond

A constructed wetland channel is a conveyance BMP that is built, in part, to enhance stormwater quality. Constructed wetland channels use dense vegetation to slow down runoff and allow time for both biological uptake and settling of sediment.

Constructed wetlands differ from natural wetlands, as they are artificial and are built to enhance stormwater quality. Do not use existing, natural or mitigated area wetlands to treat stormwater runoff. Stormwater must be treated prior to entering natural or existing wetlands and other environmentally sensitive areas. Allowing untreated stormwater to flow into existing wetlands will overload and degrade the quality of the wetland. Sometimes, small wetlands that exist along ephemeral drainageways on Colorado's high plains may be enlarged and incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators. Regulations intended to protect natural wetlands recognize a separate classification of wetlands constructed for water quality treatment. Such wetlands generally are not allowed to be used to mitigate the loss of natural wetlands but are allowed to be disturbed by maintenance activities. Therefore, the legal and regulatory status of maintaining a wetland constructed for the primary purpose of water quality enhancement is separate from the disturbance of a natural wetland. Nevertheless, any activity that disturbs a constructed wetland should be first cleared through the U.S. Army Corps of Engineers to ensure it is covered by some form of an individual, general, or nationwide 404 permit. Any creation of wetlands must also comply with Colorado law, including water rights laws.

Design and construction detailing for constructed wetlands are presented in the LID Implementation Manual in Appendix C.

6.9 Drainage Easements for LID

- Storage-based LID systems (bioretention, sand filters) are required to be placed in a drainage easement that is dedicated to the City

- Permeable pavers are required to be placed in a drainage easement when they are also used for quantity detention

- Extents of drainage easement need to encompass the entire footprint of the LID system

6.9.1 LID Systems in Other Utility Easements

- Generally, LID systems are discouraged from being located within utility easements behind the right-of-way; however, this will be considered on a case-by-case basis

- Conveyance-based LID systems (vegetated buffer) <u>are</u> allowed in utility easements that are located along the back of right-of-way

- Storage-based LID systems (bioretention, sand filters, permeable pavers) <u>are not</u> allowed to be placed in utility easements that are located along the back of right-of-way

- Pre-manufactured planters (for rain gardens) that can be temporarily relocated may be allowed in utility easements. This will be determined on a case-by-case basis by FCU staff.

6.9.2 LID Systems Not Accessible Via Easement

- All LID systems that may not be placed on the ground plane or those that are not accessible via easement or public right-of-way, will still be required to be accessed for inspection. A condition that allows access or entry to an area within the property or building (not accessible via easement) will be included in the Development Agreement for the project.

7.0 References

7.1 Extended Detention Basin (EDB) Fact Sheet T-5 from UDFCD Manual

Description

Photograph EDB-1: This EDB includes a concrete trickle channel and a micropool with a concrete bottom and grouted boulder sideslopes. The vegetation growing in the sediment of the micropool adds to the natural look of this facility and ties into the surrounding landscape.

An extended detention basin (EDB) is a sedimentation basin designed to detain stormwater for many hours after storm runoff ends. This BMP is similar to a detention basin used for flood control, however; the EDB uses a much smaller outlet that extends the emptying time of the more frequently occurring runoff events to facilitate pollutant removal. The EDB's 40-hour drain time for the water quality capture volume (WQCV) is recommended to remove a significant portion of total suspended solids (TSS). Soluble pollutant removal is enhanced by providing a small wetland marsh or "micropool" at the outlet to promote biological uptake. The basins are sometimes called "dry ponds" because they are designed not to have a significant permanent pool of water remaining between storm runoff events.

Site Selection

EDBs are well suited for watersheds with at least five impervious acres up to approximately one square mile of watershed. Smaller watersheds can result in an orifice size prone to clogging. Larger watersheds and watersheds with baseflows can complicate the design and reduce the level of treatment provided. EDBs are also well suited where flood detention is incorporated into the same basin. The depth of groundwater should be investigated. Groundwater depth should be 2 or more feet below the bottom of the basin in order to keep this area dry and maintainable.

Extended Detention Basin	
Functions	
LID/Volume Red.	Somewhat
WQCV Capture	Yes
WQCV+Flood Control	Yes
Fact Sheet Includes EURV Guidance	Yes
Typical Effectiveness for Targeted Pollutants[3]	
Sediment/Solids	Good
Nutrients	Moderate
Total Metals	Moderate
Bacteria	Poor
Other Considerations	
Life-cycle Costs[4]	Moderate

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

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

Designing for Maintenance

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

- Always provide a micropool (see step 7).
- Provide a design slope of at least 3% in the vegetated bottom of the basin (either toward the trickle channel or toward the micropool). This will help maintain the appearance of the turf grass in the bottom of the basin and reduce the possibility of saturated areas that may produce unwanted species of vegetation and mosquito breeding conditions. Verify slopes during construction, prior to vegetation.
- Follow trash rack sizing recommendations to determine the minimum area for the trash rack (see design step 9).
- Provide adequate initial surcharge volume for frequent inundation (see design step 3).
- Provide stabilized access to the forebay, outlet, spillway, and micropool for maintenance purposes.
- Provide access to the well screen. The well screen requires maintenance more often than any other EDB component. Ensure that the screen can be reached from a point outside of the micropool. When the well screen is located inside the outlet structure, provide an access port within the trash rack or use a sloped trash rack that consists of bearing bars (not horizontal) that create openings no more than five inches clear.
- Provide a hard-bottom forebay that allows for removal of sediment.
- Where baseflows are anticipated, consider providing a flow-measuring device (e.g. weir or flume with staff gage and rating curve) at the forebay to assist with future modifications of the water quality plate. Typically, the baseflow will increase as the watershed develops. It is important that the water quality plate continue to function, passing the baseflow while draining the WQCV over approximately 40 hours. Measuring the actual baseflow can be helpful in determining if and when the orifice place should be replaced.

Benefits

- The relatively simple design can make EDBs less expensive to construct than other BMPs, especially for larger basins.
- Maintenance requirements are straightforward.
- The facility can be designed for multiple uses.

Limitations

- Ponding time and depths may generate safety concerns.
- Best suited for tributary areas of 5 impervious acres or more. EDBs are not recommended for sites less than 2 impervious acres.
- Although ponds do not require more total area compared to other BMPs, they typically require a relatively large continuous area.

EDBs providing combined water quality and flood control functions can serve multiple uses such as playing fields or picnic areas. These uses are best located at higher elevation within the basin, above the WQCV pool level.

Design Procedure and Criteria

The following steps outline the design procedure and criteria for an EDB and Figure EDB-3 shows a typical configuration. UD-BMP, available at www.udfcd.org, is an Excel based workbook that can be used to perform some of the below calculations and ensure conformance to these criteria. UD-Detention, another workbook developed by UDFCD can be used to develop and route a storm hydrograph through an EDB and design the outlet structure.

1. **Basin Storage Volume**: Provide a design volume equal to the WQCV or the EURV. This volume begins at the lowest orifice in the outlet structure.

   - Determine the imperviousness of the watershed (or effective imperviousness where LID elements are used upstream).

   - Find the required storage volume. Determine the required WQCV or EURV (watershed inches of runoff) using Figure 3-2 located in Chapter 3 of this manual (for WQCV) or equations provided in the *Storage* chapter of Volume 2 (for EURV).

   - Calculate the design volume as follows:

   For WQCV:

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

   For EURV:

   $$V = \left[\frac{\text{EURV}}{12}\right] A \qquad \text{Equation EDB-2}$$

   Where:

   V = design volume (acre ft)

   A = watershed area tributary to the extended detention basin (acres)

2. **Basin Shape**: Always maximize the distance between the inlet and the outlet. It is best to have a basin length (measured along the flow path from inlet to outlet) to width ratio of at least 2:1. A longer flow path from inlet to outlet will minimize short circuiting and improve reduction of TSS. To achieve this ratio, it may be necessary to modify the inlet and outlet points through the use of pipes or swales.

3. **Basin Side Slopes**: Basin side slopes should be stable and gentle to facilitate maintenance and access. Slopes that are 4:1or flatter should be used to allow for conventional maintenance equipment and for improved safety, maintenance, and aesthetics. Side slopes should be no steeper than 3:1. The use of walls is highly discouraged due to maintenance constraints.

4. **Inlet**: Dissipate flow energy at concentrated points of inflow. This will limit erosion and promote particle sedimentation. Inlets should be designed in accordance with UDFCD drop structure criteria for inlets above the invert of the forebay, impact basin outlet details for at grade inlets, or other types of energy dissipating structures.

5. **Forebay Design**: The forebay provides an opportunity for larger particles to settle out in an area that can be easily maintained. The length of the flow path through the forebay should be maximized, and the slope minimized to encourage settling. The appropriate size of the forebay may be as much a function of the level of development in the tributary area as it is a percentage of the WQCV. When portions of the watershed may remain disturbed for an extended period of time, the forebay size will need to be increased due to the potentially high sediment load. Refer to Table EDB-4 for a design criteria summary. When using this table, the designer should consider increasing the size of the forebay if the watershed is not fully developed.

   The forebay outlet should be sized to release 2% of the undetained peak 100-year discharge. A soil riprap berm with 3:1 sideslopes (or flatter) and a pipe outlet or a concrete wall with a notch outlet should be constructed between the forebay and the main EDB. It is recommended that the berm/pipe configuration be reserved for watersheds in excess of 20 impervious acres to accommodate the minimum recommended pipe diameter of 8 inches. When using the berm/pipe configuration, round up to the nearest standard pipe size and use a minimum diameter of 8 inches. The floor of the forebay should be concrete or lined with grouted boulders to define sediment removal limits. With either configuration, soil riprap should also be provided on the downstream side of the forebay berm or wall if the downstream grade is lower than the top of the berm or wall. The forebay will overtop frequently so this protection is necessary for erosion control. All soil riprap in the area of the forebay should be seeded and erosion control fabric should be placed to retain the seed in this high flow area.

6. **Trickle Channel:** Convey low flows from the forebay to the micropool with a trickle channel. The trickle channel should have a minimum flow capacity equal to the maximum release from the forebay outlet.

   - **Concrete Trickle Channels:** A concrete trickle channel will help to establish the bottom of the basin long-term and may also facilitate regular sediment removal. It can be a "V" shaped concrete drain pan or a concrete channel with curbs. A flat-bottom channel facilitates maintenance. A slope between 0.4% - 1% is recommended to encourage settling while reducing the potential for low points within the pan.

   - **Soft-bottom Trickle Channels**: When designed and maintained properly, soft-bottom trickle channels can allow for an attractive alternative to concrete. They can also improve water quality. However, they are not appropriate for all sites. Be aware, maintenance of soft bottom trickle channels requires mechanical removal of sediment and vegetation. Additionally, this option provides mosquito habitat. For this reason, UDFCD recommends that they be considered on a case-by-case basis and with the approval of the local jurisdiction. It is recommended that soft bottom trickle channels be designed with a consistent longitudinal slope from forebay to micropool and that they not meander. This geometry will allow for reconstruction of the original design when sediment removal in the trickle channel is necessary. The trickle channel may also be located along the toe of the slope if a straight channel is not desired. The recommended minimum depth of a soft bottom trickle channel is 1.5 feet. This depth will help limit potential wetland growth to the trickle channel, preserving the bottom of the basin.

     Riprap and soil riprap lined trickle channels are not recommended due to past maintenance experiences, where the riprap was inadvertently removed along with the sediment during maintenance.

7. **Micropool and Outlet Structure**: Locate the outlet structure in the embankment of the EDB and provide a permanent micropool directly in front of the structure. Submerge the well screen to the bottom of the micropool. This will reduce clogging of the well screen because it allows water to flow though the well screen below the elevation of the lowest orifice even when the screen above the water surface is plugged. This will prevent shallow ponding in front of the structure, which provides a breeding ground for mosquitoes (large shallow puddles tend to produce more mosquitoes than a smaller, deeper permanent pond).

   Micropool side slopes may be vertical walls or stabilized slopes of 3:1 (horizontal:vertical). For watersheds with less than 5 impervious acres, the micropool can be located inside the outlet structure (refer to Figures OS-7 and OS-8 provided in Fact Sheet T-12). The micropool should be at least 2.5 feet in depth with a minimum surface area of 10 square feet. The bottom should be concrete unless a baseflow is present or anticipated or if groundwater is anticipated. Riprap is not recommended because it complicates maintenance operations.

   Basins with micropools have fewer mosquitoes. Micropools reduce shallow wet areas where breeding is most favorable.

   Where possible, place the outlet in an inconspicuous location as shown in Photo EDB-3. This urban EDB utilizes landscaped parking lot islands connected by a series of culverts (shown in Photo EDB-4) to provide the required water quality and flood control volumes.

   The outlet should be designed to release the WQCV over a 40-hour period. Draining a volume of water over a specified time can be done through an orifice plate as detailed in Fact Sheet T-12. Use reservoir routing calculations as discussed in the *Storage* Chapter of Volume 2 to assist in the design. Two workbooks tools have been developed by UDFCD for this purpose, UD-FSD and UD-Detention. Both are available at www.udfcd.org. UD-FSD is recommended for a typical EDB full spectrum detention design. UD-Detention uses the same methodology and can be used for a full spectrum detention basin or a WQCV only design. It also allows for a wider range of outlet controls should the user want to specify something beyond what is shown in Fact Sheet T-12.

   Refer to BMP Fact Sheet T-12 for schematics pertaining to structure geometry, grates, trash racks, orifice plate, and all other necessary components.

   The outlet may have flared or parallel wing walls as shown in Figures EDB-1 and EDB-2, respectively. Either configuration should be recessed into the embankment to minimize its profile. Additionally, the trash rack should be sloped with the basin side-slopes.

8. **Initial Surcharge Volume**: Providing a surcharge volume above the micropool for frequently occurring runoff minimizes standing water and sediment deposition in the remainder of the basin. This is critical to turf maintenance and mosquito abatement in the basin bottom. The initial surcharge volume is not provided in the micropool nor does it include the micropool volume. It is the available storage volume that begins at the water surface elevation of the micropool and extends upward to a grade break within the basin (typically the invert of the trickle channel).

Photograph EDB-2. The initial surcharge volume of this EDB is contained within the boulders that surround the micropool.

Photograph EDB-3. Although walls may complicate maintenance access, this outlet structure is relatively hidden from public view. This photo was taken shortly following a storm event.

Photograph EDB-4. A series of landscape islands connected by culverts provide water quality and flood control for this site.

The area of the initial surcharge volume, when full, is typically the same or slightly larger than that of the micropool. The initial surcharge volume should have a depth of at least 4 inches. For watersheds of at least 5 impervious acres, the initial surcharge volume should also be at least 0.3% of the WQCV. The initial surcharge volume is considered a part of the WQCV and does not need to be provided in addition to the WQCV. It is recommended that this area be shown on the grading plan or in a profile for the EDB. When baseflows are anticipated, it is recommended that the initial surcharge volume be increased. See the inset on page EDB-9 for additional guidelines for designing for baseflows.

9. **Trash Rack**: Provide a trash rack (or screen) of sufficient size at the outlet to provide hydraulic capacity while the rack is partially clogged. Openings should be small enough to limit clogging of the individual orifices. Size any overflow safety grate so it does not interfere with the hydraulic capacity of the outlet pipe. See BMP Fact Sheet T-12 for detailed trash rack and safety grate design guidance.

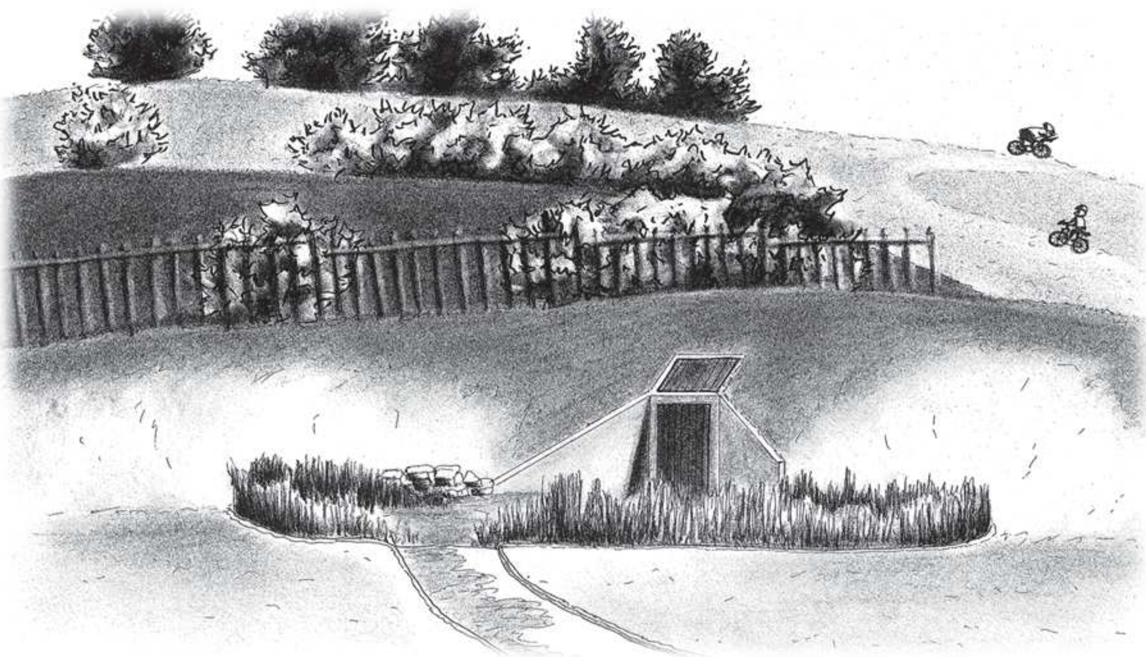


Figure EDB-1. Flared wall outlet structure configuration. Graphic by Adia Davis.

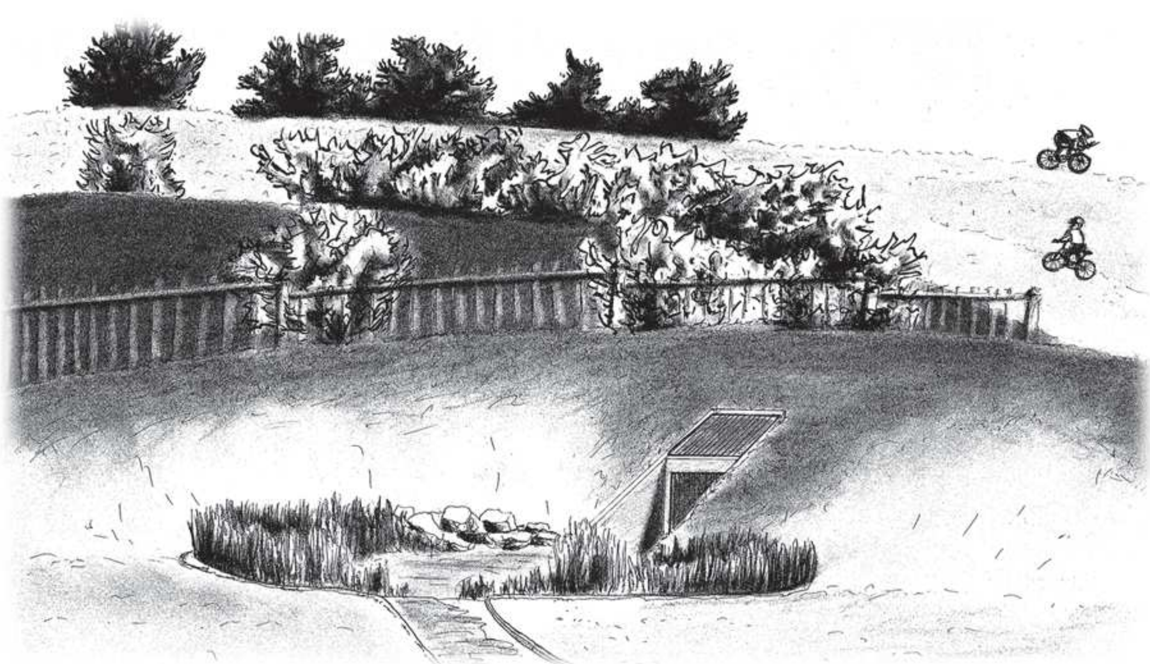


Figure EDB-2. Parallel wall outlet structure configuration. Graphic by Adia Davis.

10. **Overflow Embankment:** Design the embankment to withstand the 100-year storm at a minimum. If the embankment falls under the jurisdiction of the State Engineer's Office, it must be designed to meet the requirements of the State Engineer's Office. The overflow should be located at a point where waters can best be conveyed downstream. Slopes that are 4:1 or flatter should be used to allow for conventional maintenance equipment and for improved safety, maintenance, and aesthetics. Side slopes should be no steeper than 3:1 and should be planted with turf forming grasses. Poorly compacted native soils should be excavated and replaced. Embankment soils should be compacted to 95% of maximum dry density for ASTM D698 (Standard Proctor) or 90% for ASTM D1557 (Modified Proctor). Spillway structures and overflows should be designed in accordance with the *Storage* Chapter of Volume 2 as well as any local drainage criteria. Buried soil riprap or reinforced turf mats installed per manufacturer's recommendations can provide an attractive and less expensive alternative to concrete.

11. **Vegetation:** Vegetation provides erosion control and sediment entrapment. Basin bottom, berms, and side slopes should be planted with turf grass, which is a general term for any grasses that will form a turf or mat, as opposed to bunch grass which will grow in clumplike fashion. Xeric grasses with temporary irrigation are recommended to reduce maintenance requirements, including maintenance of the irrigation system as well as frequency of mowing. Where possible, place irrigation heads outside the basin bottom because irrigation heads in an EDB can become buried with sediment over time.

12. **Access:** Provide appropriate maintenance access to the forebay and outlet works. For larger basins, this means stabilized access for maintenance vehicles. If stabilized access is not provided, the maintenance plan should provide detail, including recommended equipment, on how sediment and trash will be removed from the outlet structure and micropool. Some communities may require

Designing for Baseflows

Baseflows should be anticipated for large tributary areas and can be accommodated in a variety of ways. Consider the following:

- If water rights are available, consider alternate BMPs such as a constructed wetland pond or retention pond.
- Anticipate future modifications to the outlet structure. Following construction, baseflows should be monitored periodically. Intermittent flows can become perennial and perennial flows can increase over time. It may be determined that outlet modifications are necessary long after construction of the BMP is complete.
- Design foundation drains and other groundwater drains to bypass the water quality plate directing these drains to a conveyance element downstream of the EDB. This will reduce baseflows and help preserve storage for the WQCV.
- When the basin is fully developed and an existing baseflow can be approximated prior to design, the water quality orifices should be increased to drain the WQCV in 40 hours while also draining the baseflow. This requires reservoir routing using an inflow hydrograph that includes the baseflow. The *UD-Detention* workbook available at www.udfcd.org may be used for this purpose.
- Increase the initial surcharge volume of the pond to provide some flexibility when baseflows are known or anticipated. Baseflows are difficult to approximate and will continue to increase as the watershed develops. Increasing the initial surcharge volume will accommodate a broader range of flows.

vehicle access to the bottom of the basin regardless of the size of the watershed. Grades should not exceed 10% for haul road surfaces and 20% for skid-loader and backhoe access. Stabilized access includes concrete, articulated concrete block, concrete grid pavement, or reinforced grass pavement. The recommended cross slope is 2%.

Aesthetic Design

Since all land owners and managers wish to use land in the most efficient manner possible, it is important that EDBs become part of a multi-use system. This encourages the design of EDBs as an aesthetic part of a naturalized environment or to include passive and/or active open space. Within each scenario, the EDB can begin to define itself as more than just a drainage facility. When this happens, the basin becomes a public amenity. This combination of public amenity and drainage facility is of much greater value to a landowner. Softened and varied slopes, interspersed irrigated fields, planting areas and wetlands can all be part of an EDB.

The design should be aesthetic whether it is considered to be an architectural or naturalized basin. Architectural basins incorporate design borrowed or reflective of the surrounding architecture or urban forms. An architectural basin is intended to appear as part of the built environment, rather than hiding the cues that identify it as a stormwater structure. A naturalized basin is designed to appear as though it is a natural part of the landscape. This section provides suggestions for designing a naturalized basin. The built environment, in contrast to the natural environment, does not typically contain the randomness of form inherent in nature. Constructed slopes typically remain consistent, as do slope transitions. Even dissipation structures are usually a hard form and have edges seldom seen in nature. If the EDB is to appear as though it is a natural part of the landscape, it is important to minimize shapes that provide visual cues indicating the presence of a drainage structure. For example, the side sides should be shaped more naturally and with varying slopes for a naturalized basin.

Suggested Methods for a Naturalized Basin

- Create a flowing form that looks like it was shaped by water.
- Extend one side of the basin higher than the other. This may require a berm.
- Shape the bottom of the basin differently than the top.
- Slope of one side of the basin more mildly than the opposing side.
- Vary slope transitions both at the top of the bank and at the toe.
- Use a soft-surface trickle channel if appropriate and approved.
- When using rock for energy dissipation, the rock should graduate away from the area of hard edge into the surrounding landscape. Other non-functional matching rock should occur in other areas of the basin to prevent the actual energy dissipation from appearing out of context.
- Design ground cover to reflect the type of water regime expected for their location within the basin.

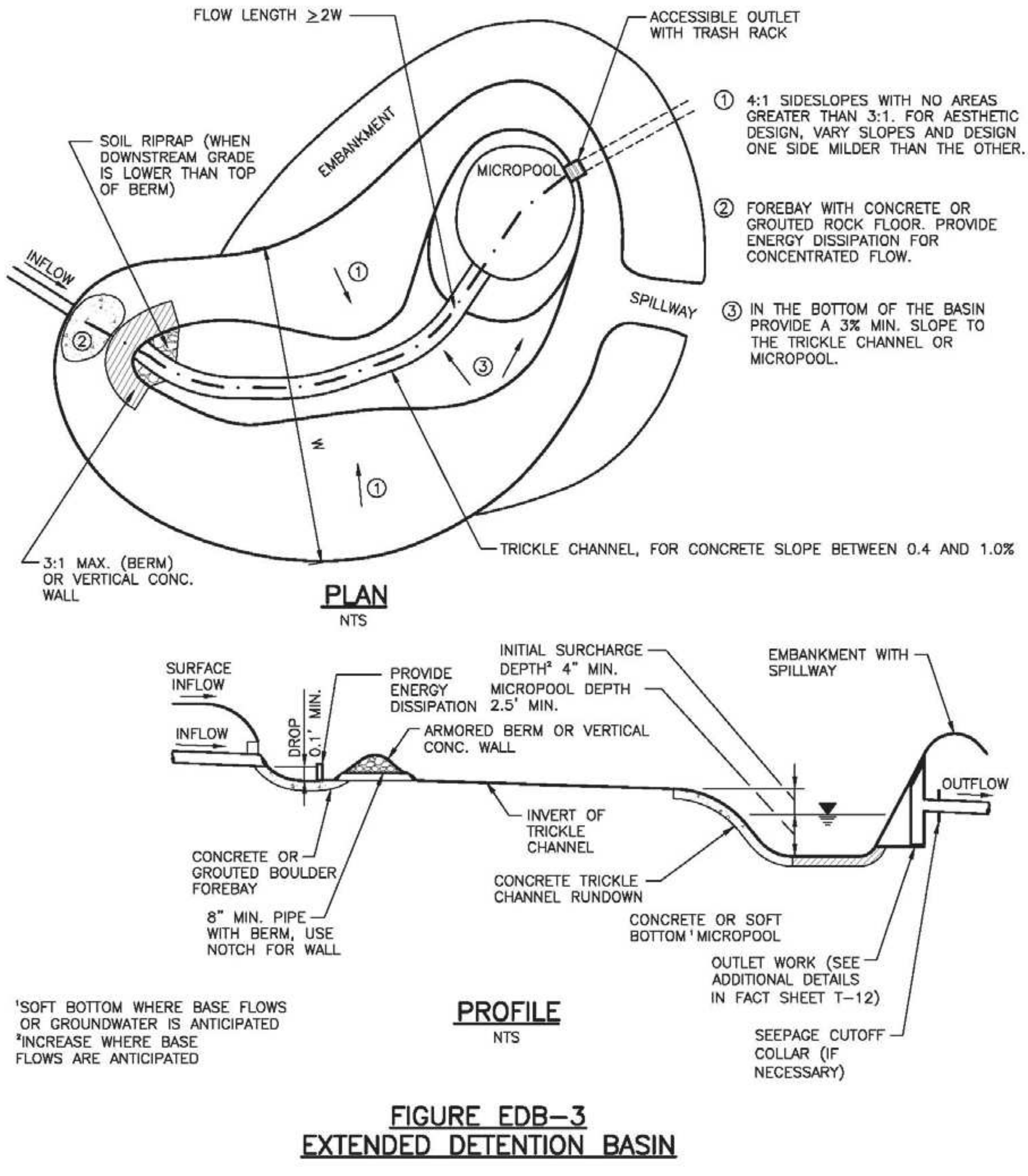


Figure EDB-3. Extended Detention Basin (EDB) Plan and Profile

Additional Details are provided in BMP Fact Sheet T-12. This includes outlet structure details including orifice plates and trash racks.

Table EDB-4. EDB component criteria

	On-Site EDBs for Watersheds up to 1 Impervious Acre[1]	EDBs with Watersheds between 1 and 2 Impervious Acres[1]	EDBs with Watersheds up to 5 Impervious Acres	EDBs with Watersheds over 5 Impervious Acres	EDBs with Watersheds over 20 Impervious Acres
Forebay Release and Configuration	EDBs should not be used for watersheds with less than 1 impervious acre.	Release 2% of the undetained 100-year peak discharge by way of a wall/notch configuration	Release 2% of the undetained 100-year peak discharge by way of a wall/notch configuration	Release 2% of the undetained 100-year peak discharge by way of a wall/notch configuration	Release 2% of the undetained 100-year peak discharge by way of a wall/notch or berm/pipe[2] configuration
Minimum Forebay Volume		1% of the WQCV	2% of the WQCV	3% of the WQCV	3% of the WQCV
Maximum Forebay Depth		12 inches	18 inches	18 inches	30 inches
Trickle Channel Capacity		≥ the maximum possible forebay outlet capacity	≥ the maximum possible forebay outlet capacity	≥ the maximum possible forebay outlet capacity	≥ the maximum possible forebay outlet capacity
Micropool		Area ≥ 10 ft^2	Area ≥ 10 ft^2	Area ≥ 10 ft^2	Area ≥ 10 ft^2
Initial Surcharge Volume		Depth ≥ 4 inches	Depth ≥ 4 inches	Depth ≥ 4 in. Volume ≥ 0.3% WQCV	Depth ≥ 4 in. Volume ≥ 0.3% WQCV

[1] EDBs are not recommended for sites with less than 2 impervious acres. Consider a sand filter or rain garden.

[2] Round up to the first standard pipe size (minimum 8 inches).

7.2 Outlet Structures Fact Sheet T-12 from UDFCD Manual

Description

This section provides guidance and details for outlet structures for the use primarily with BMPs utilizing sedimentation, (i.e., extended detention basins, retention ponds and constructed wetland ponds). The information provided in this section includes guidance for different size watersheds as well as for incorporating full spectrum detention as described in the *Storage* chapter of Volume 2.

The details contained in this Fact Sheet are intended to provide a starting point for design. UDFCD recommends that design details for outlet structures be specific for each site with structural details drawn to scale. The details provided in this Fact Sheet are not intended to be used without modification or additional detail.

Photograph OS-1. Although each site is different, most sedimentation BMPs have similar outlet structures. Each structure should include a partially submerged orifice plate with a screen (or grate) protecting the orifice plate from clogging, and an overflow weir for flows exceeding the WQCV or excess urban runoff volume (EURV), when full spectrum detention is used.

Outlet Design

Large Watershed Considerations

UDFCD recommends that water quality treatment be provided close to the pollutant source. This is a fundamental concept of Low Impact Development (LID). Although flood control facilities, including full spectrum detention facilities, have been shown to be very effective for watersheds exceeding one square mile, this is not the case for water quality facilities. One reason for this is that the baseflow associated with a larger watershed will vary and can be difficult to estimate. The orifice plate should be designed to pass the baseflow while detaining the water quality capture volume (WQCV) for approximately 40 hours. When the baseflow is overestimated, the WQCV is not detained for the recommended time, passing through without treatment. When the baseflow is underestimated, the elevation of the permanent pool will be higher than designed, causing maintenance issues as well as reducing the volume available for detention of the WQCV, which also allows for a portion of this volume to pass through without treatment. For this reason, UDFCD recommends that facilities designed for both water quality and flood control be limited, where possible, to watersheds without a baseflow. The maximum recommended watershed for combined facilities is one square mile. Additional discussion on designing for baseflows is provided in the EDB BMP Fact Sheet (T-5).

Designing for Maintenance

Rather than using the minimum criteria, consider maximizing the width of the trash rack to the geometry of the outlet. This will reduce clogging and frequency of maintenance. Reduced clogging in EDB outlet structures will preserve the initial surcharge volume thus reducing frequency of inundation in the bottom of the basin. This will benefit the grasses and reduce long-term EDB maintenance requirements (including sediment removal in the grassed area) and may reduce the life-cycle cost of the BMP.

Orifice Plates, Trash Racks, and Safety Grates

An orifice plate is used to release the WQCV slowly over 40 hours. For full spectrum detention, the orifice plate is extended to drain a larger volume, the EURV, over approximately 72 hours. The figures and tables in this section provide recommendations for orifice configurations and trash rack type and size. Guidance is provided for plates using both circular and rectangular orifices.

Orifice Sizing

Follow the design steps included in the BMP Fact Sheet for the appropriate BMP. The UD-Detention workbook, available at www.udfcd.org, can be used to route flows and calculate the required orifice sizes. UDFCD recommends a total of three orifices to maximize the orifice size and avoid clogging of the orifice plate. A detail showing the recommended orifice configuration is provided in Figure OS-4.

Photograph OS-2. This trash rack could not be properly

Photograph OS-3. Trash rack after repair.

Trash Rack Sizing

Once the size of the orifice has been determined, this information, along with the total orifice area in the water quality plate, is used to determine the total open area of the grate. See Figure OS-1 and use the dashed line to size the trash rack. Include the portion of the trash rack that is inundated by the micropool in total open area of the grate.

Be aware, Figures OS-5, OS-6, OS-7, and OS-8 dimension the minimum width clear for the trash rack frame. It is also important to provide adequate width for attachment to the outlet structure (see Photos OS-2 and OS-3). Also, consider maximizing the width of the trash rack to the geometry of the outlet. This will reduce clogging and maintenance requirements associated with cleaning the trash rack. This Fact Sheet also includes recommendations for the thickness of the steel water quality plate (see Table OS-2).

Safety Grates

Safety grates are intended to keep people and animals from inadvertently entering a storm drain. They are sometimes required even when debris entering a storm drain is not a concern. The grate on top of the outlet drop box is considered a safety grate and should be designed accordingly. The danger associated with outlet structures is the potential associated with pinning a person or animal to unexposed outlet pipe or grate. See the *Culverts and Bridges* chapter of Volume 2 of this manual for design criteria related to safety grates.

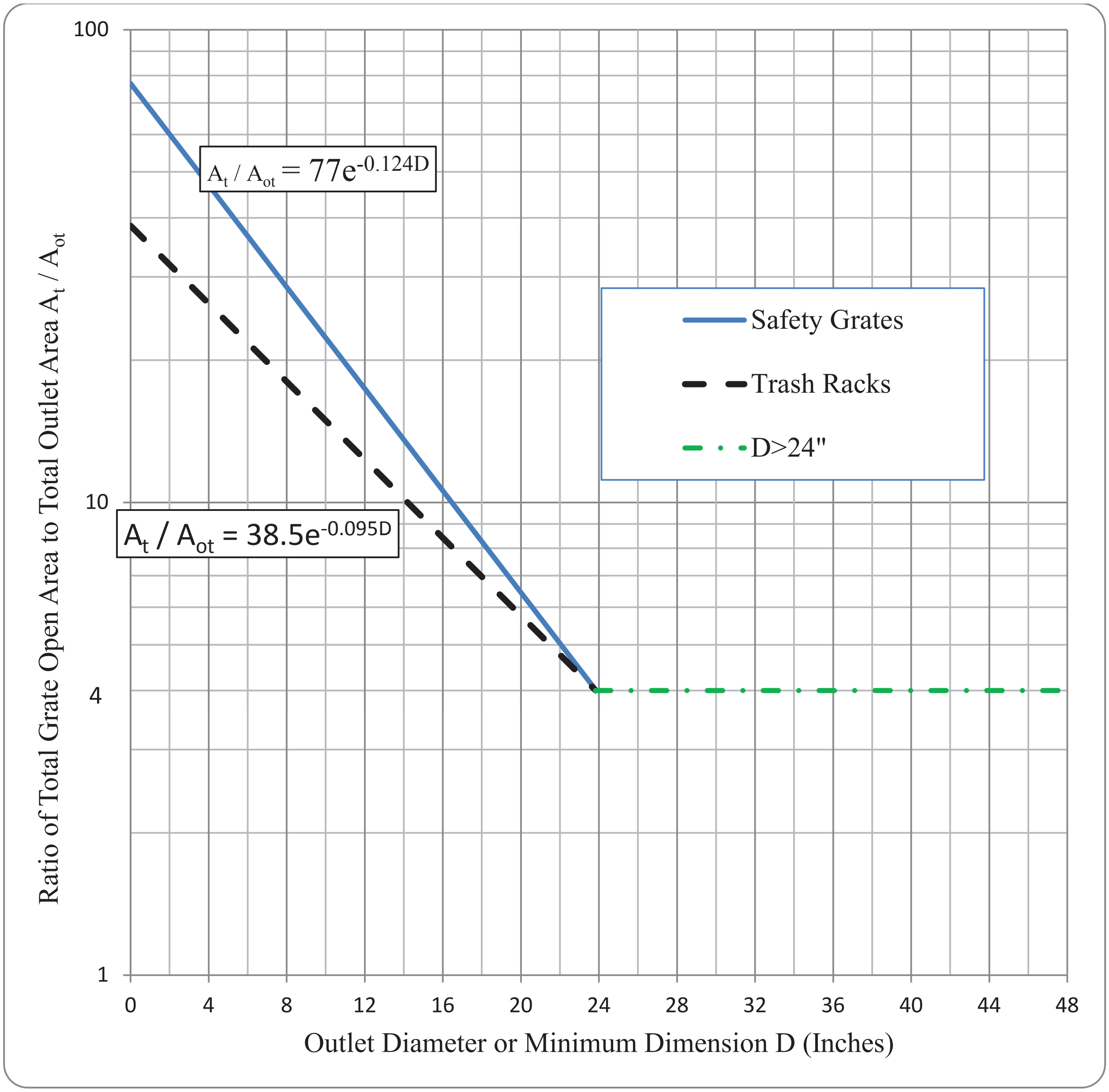


Figure OS-1. Trash Rack Sizing

Outlet Geometry

Outlets for small watersheds will typically be sized for maintenance operations while the geometry of outlets for larger watersheds may be determined based on the required size of the trash rack. For all watershed sizes, the outlet should be set back into the embankment of the pond to better allow access to the structure. This also provides a more attractive BMP. For larger watersheds, this will require wing walls. Wing walls are frequently cast-in-place concrete, although other materials, such as grouted boulders, may be used where appropriate. Consider safety, aesthetics, and maintenance when selecting materials and determining the geometry. A safety rail should be included for vertical drops of 3 feet or more. Depending on the location of the structure in relation to pedestrian trails, safety rails may also be required for lesser drops. Stepped grouted boulders can be used to reduce the height of vertical drops.

As shown in Figures EDB-1 and EDB-2 provided in BMP Fact Sheet T-5, wing walls can be flared or parallel. There are advantages to both configurations. Parallel wing walls may be more aesthetic; however, depending on the geometry of the pond, may limit accessibility to the trash rack. Flared wing walls can call attention to the structure but provide better accessibility and sometimes a vertical barrier from the micropool of an EDB, which can increase safety of the structure. Parallel walls can also be used with a second trash rack that is secured flush with the top of the wall as shown in Photo OS-4. This eliminates the need for a safety rail and may provide additional protection from clogging; however, it creates a maintenance issue by restricting access to the water quality screen. The rack shown in Photo OS-4 was modified after construction due to this problem.

Photograph OS-4. Maintenance access to the water quality trash rack was compromised by the location of a secondary trash rack on this outlet. This may have been included as a safety rack or as additional protection from clogging. The owner modified the structure for better access. A safety rail would have been a better solution.

Photograph OS-5. Interruptions in the horizontal members of this trash rack and the spacing of the vertical members allow easier access to clean the water quality grate. A raking tool can be used to scrape the water quality trash rack.

Micropools within the Outlet Structure

The micropool of an EDB may be placed inside the structure when desired. This is becoming increasingly common for smaller watersheds and near airfields where large bird populations can be problematic. When designing this type of structure, consider maintenance of the water quality trash rack. The secondary trash rack should be designed to allow maintenance of the water quality trash rack similar to that shown in Photo OS-5. This concept can easily be incorporated into smaller outlet structures (see Figures OS-7 and OS-8 for details).

Outlet Structure Details

A number of details are presented in this section to assist designers with detailing outlet structures. Table OS-1 provides a list of details available at www.udfcd.org. These details are not intended to be used in construction plans without proper modifications as indicated in this table.

Table OS-1. Summary of Outlet Structure Details and Use

Figure	Detail	Use of Detail
OS-2	Typical outlet structure for full spectrum detention	Conceptual.
OS-3	Typical outlet structure for WQCV treatment and attenuation	Conceptual.
OS-4	Orifice plate and trash rack detail and notes	Outlet section. Modify per true structure geometry and concrete reinforcement. Modify notes per actual design.
OS-5	Typical outlet structure with well screen trash rack	Outlet sections. Modify per true structure geometry and concrete reinforcement. Add additional sections and detailing as necessary. Modify notes per actual design.
OS-6	Typical outlet structure with bar grate trash rack	Outlet sections. Modify per true structure geometry and concrete reinforcement. Add additional sections and detailing as necessary. Modify notes per actual design.
OS-7	Full spectrum detention outlet structure for 5-acre impervious area or less	Outlet profile and section. Modify per true EURV elevation and concrete reinforcement. Add additional sections and detailing as necessary.
OS-8	WQCV outlet structure for 5-acre impervious area or less	Outlet sections. Modify per true WQCV elevation and concrete reinforcement. Add additional sections and detailing as necessary.

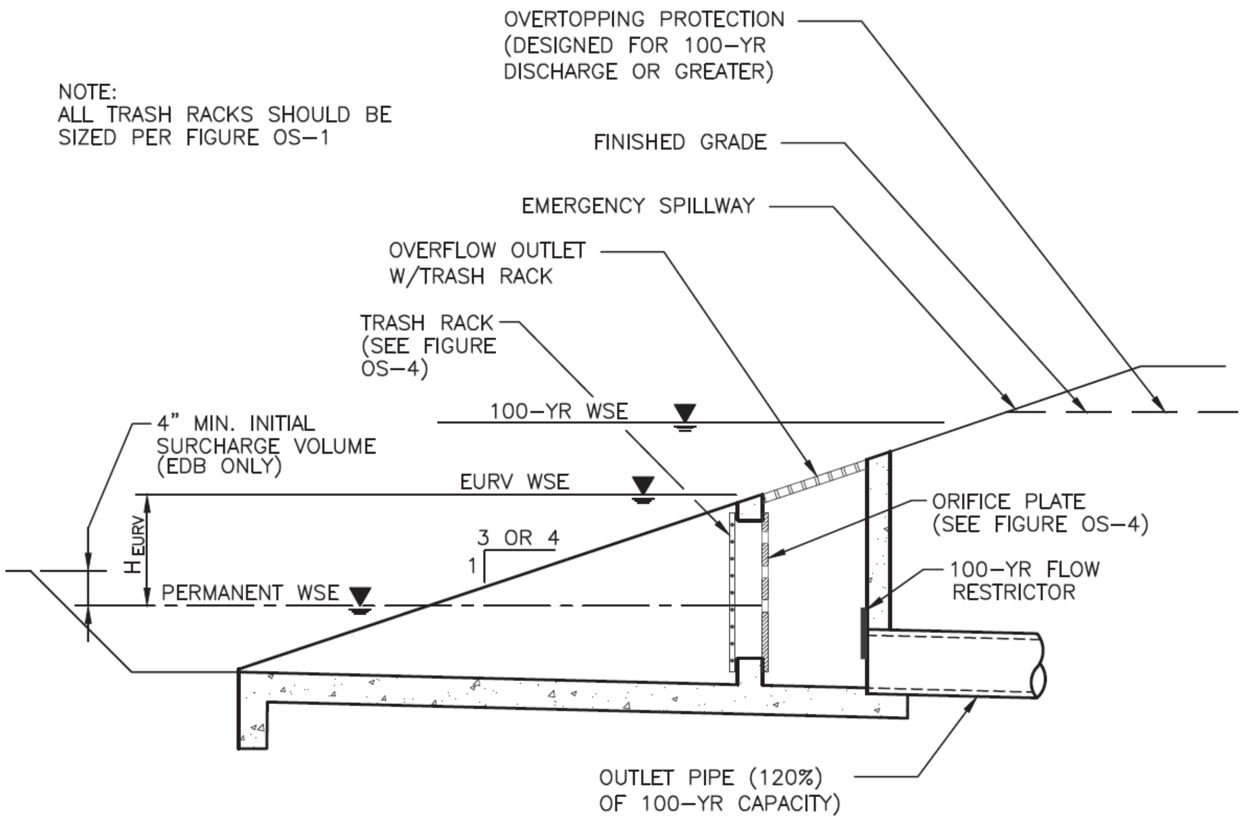


Figure OS-2. Typical outlet structure for full spectrum detention

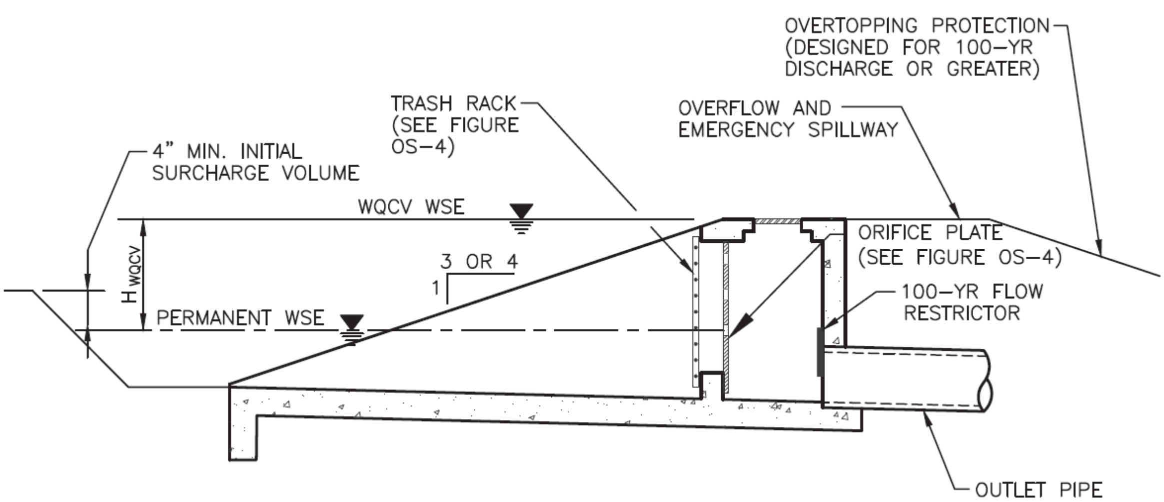
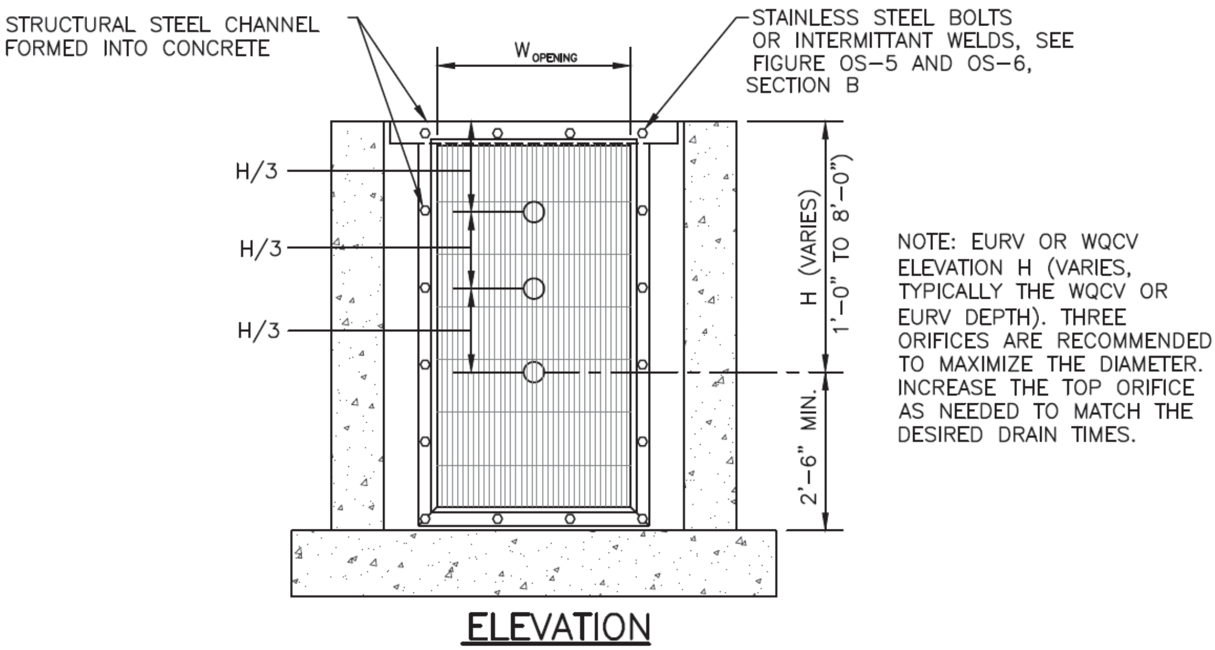


Figure OS-3. Typical outlet structure for WQCV treatment and attenuation



ORIFICE PLATE NOTES:

1. PROVIDE CONTINUOUS NEOPRENE GASKET MATERIAL BETWEEN THE ORIFICE PLATE AND CONCRETE.
2. BOLT PLATE TO CONCRETE 12" MAX. ON CENTER. SEE TABLE OS-2 FOR PLATE THICKNESS.

EURV AND WQCV TRASH RACKS:

1. WELL-SCREEN TRASH RACKS SHALL BE STAINLESS STEEL AND SHALL BE ATTACHED BY INTERMITTENT WELDS ALONG THE EDGE OF THE MOUNTING FRAME.
2. BAR GATE TRASH RACKS SHALL BE ALUMINUM AND SHALL BE BOLTED USING STAINLESS STEEL HARDWARE.
3. TRASH RACK OPEN AREAS ARE FOR SPECIFIED TRASH RACK MATERIALS. TOTAL TRASH RACK SIZE MAY NEED TO BE ADJUSTED FOR MATERIALS HAVING DIFFERENT OPEN AREA/GROSS AREA RATIO (R VALUE).
4. STRUCTURAL DESIGN OF TRASH RACKS SHALL BE BASED ON FULL HYDROSTATIC HEAD WITH ZERO HEAD DOWNSTREAM OF THE RACK.

OVERFLOW SAFETY GRATES:

1. ALL SAFETY GRATES SHALL BE MOUNTED USING STAINLESS STEEL HARDWARE AND PROVIDED WITH HINGED AND LOCKABLE OR BOLTABLE ACCESS PANELS.
2. SAFETY GRATES SHALL BE STAINLESS STEEL, ALUMINUM, OR STEEL. STEEL GRATES SHALL BE HOT DIP GALVANIZED AND MAY BE HOT POWDER COATED AFTER GALVANIZING.
3. SAFETY GRATES SHALL BE DESIGNED SUCH THAT THE DIAGONAL DIMENSION OF EACH OPENING IS SMALLER THAN THE DIAMETER OF THE OUTLET PIPE.
4. STRUCTURAL DESIGN OF SAFETY GRATES SHALL BE BASED ON FULL HYDROSTATIC HEAD WITH ZERO HEAD DOWNSTREAM OF THE RACK.

Figure OS-4. Orifice plate and trash rack detail and notes

Table OS-2. Thickness of steel water quality plate

Steel plate thickness (in inches) based on design depth and span of plate											
		Head (feet)									
		3	4	5	6	7	8	9	10	11	12
Span (feet)	1	0.1875	0.1875	0.1875	0.1875	0.1875	0.1875	0.1875	0.1875	0.1875	0.1875
	2	0.1875	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500	0.2500
	3	0.2500	0.2500	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.3750	0.5000
	4	0.2500	0.3750	0.3750	0.3750	0.3750	0.5000	0.5000	0.5000	0.5000	0.5000

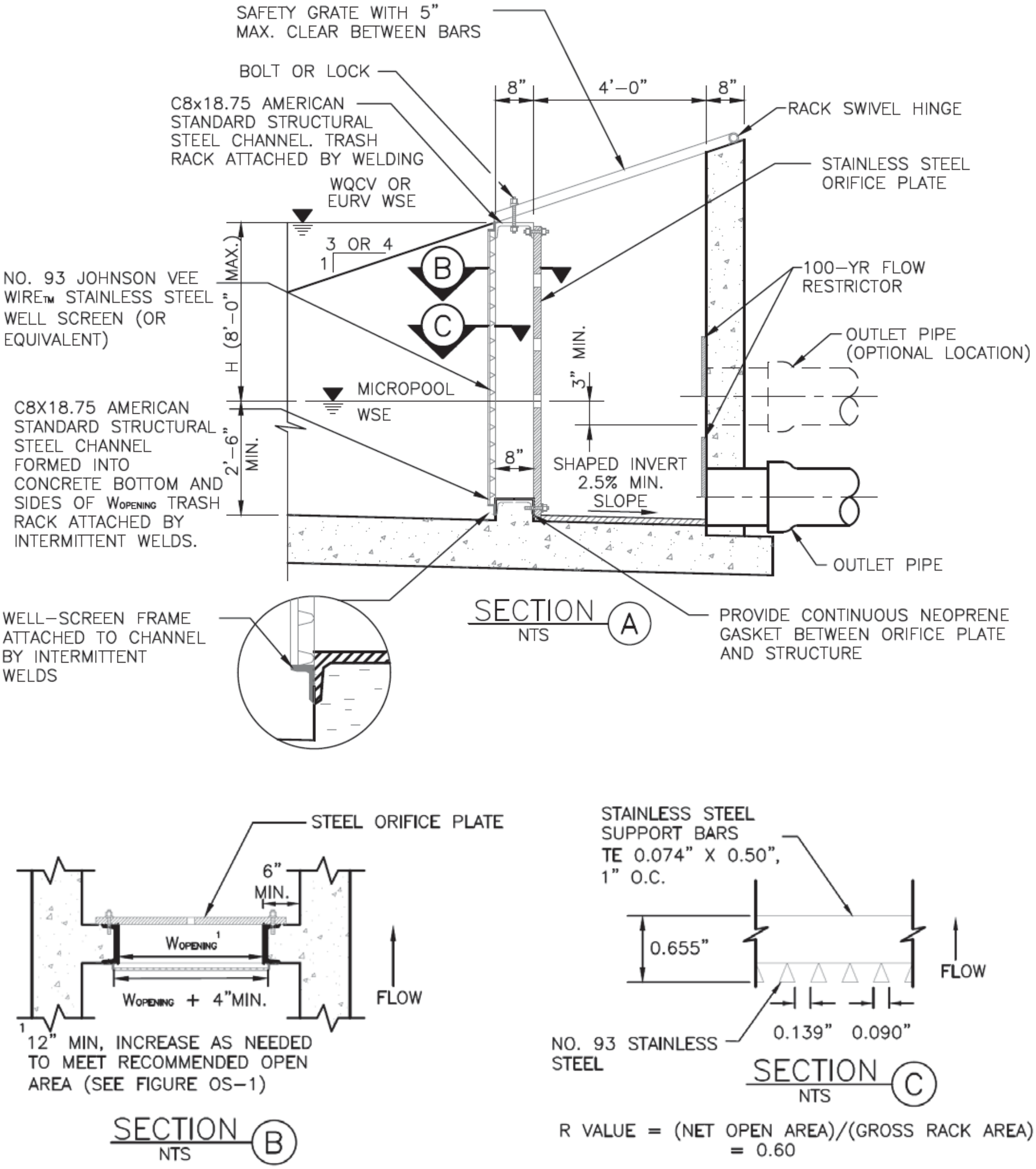
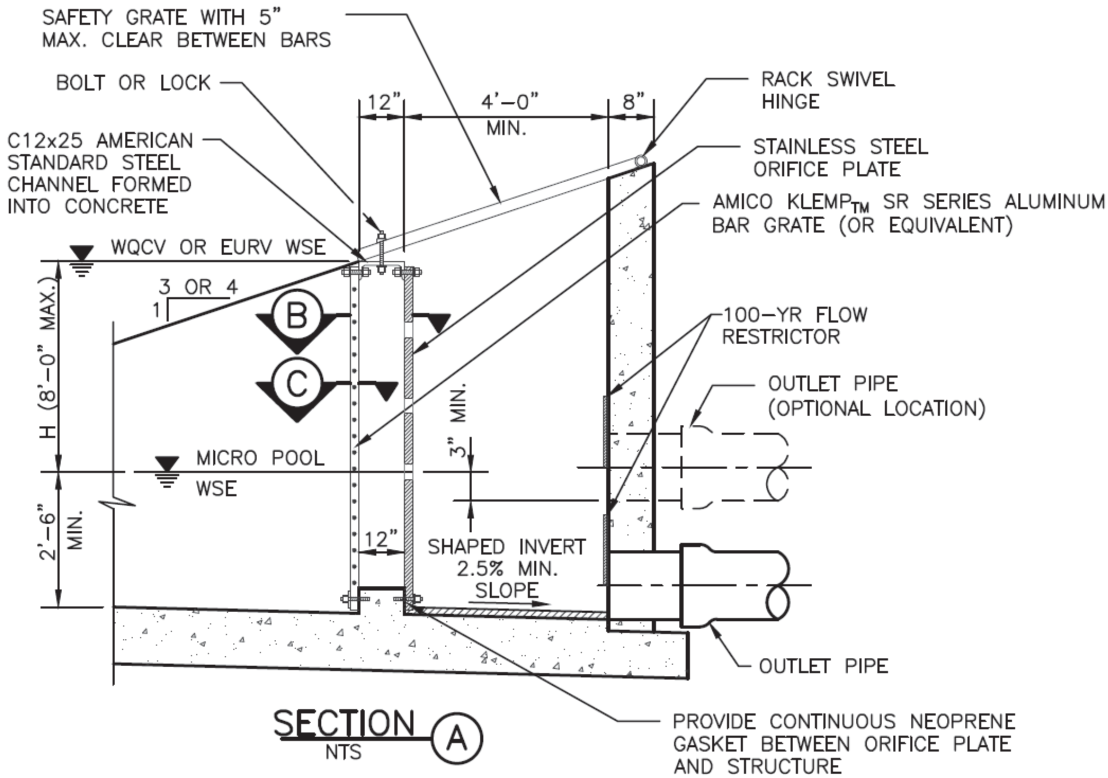
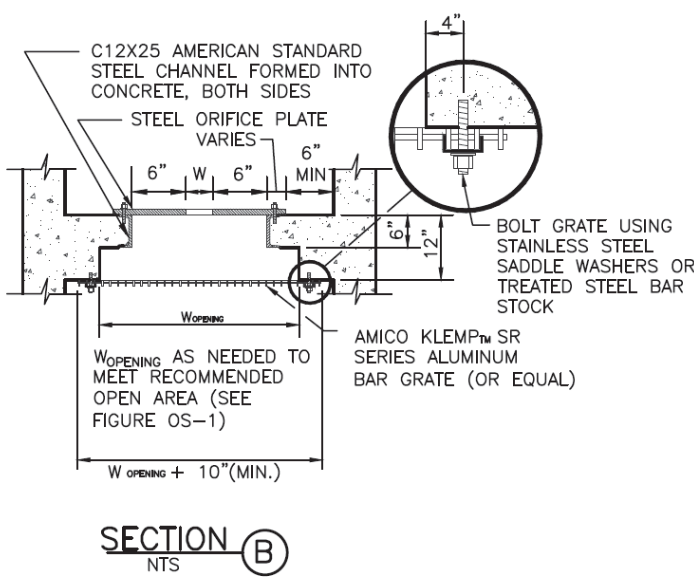
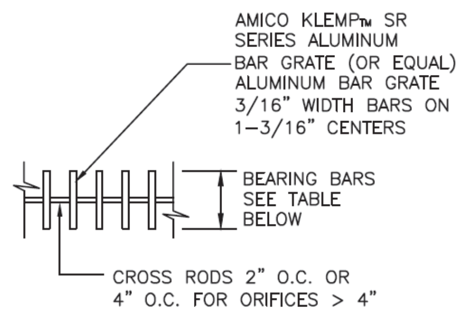


Figure OS-5. Typical outlet structure with well screen trash rack







WATER DEPTH ABOVE LOWEST OPENING, H	MINIMUM BEARING BAR SIZE, BARS ALIGNED VERTICALLY
2.0 FT.	1" x 3/16"
3.0 FT.	1–1/4" x 3/16"
4.0 FT.	1–3/4" x 3/16"
5.0 FT.	2" x 3/16"
6.0 FT.	2–1/4" x 3/16"

R VALUE=(NET OPEN AREA)/GROSS RACK AREA)
=0.71 FOR CROSS RODS ON 2" CENTERS
=0.77 FOR CROSS RODS ON 4" CENTERS

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Figure OS-6. Typical outlet structure with bar grate trash rack

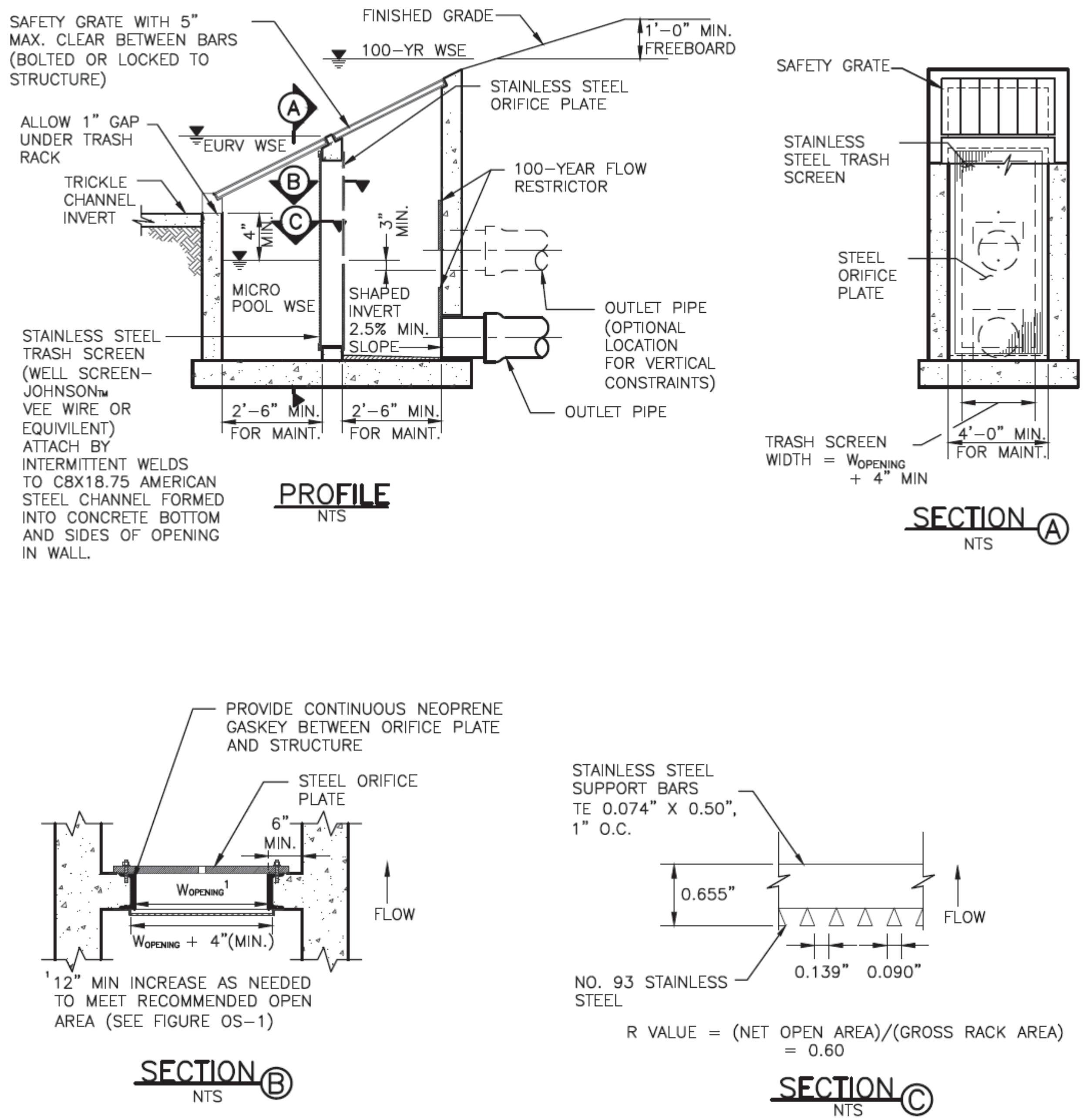

Figure OS-7. Full spectrum detention outlet structure for 5-acre impervious area or less

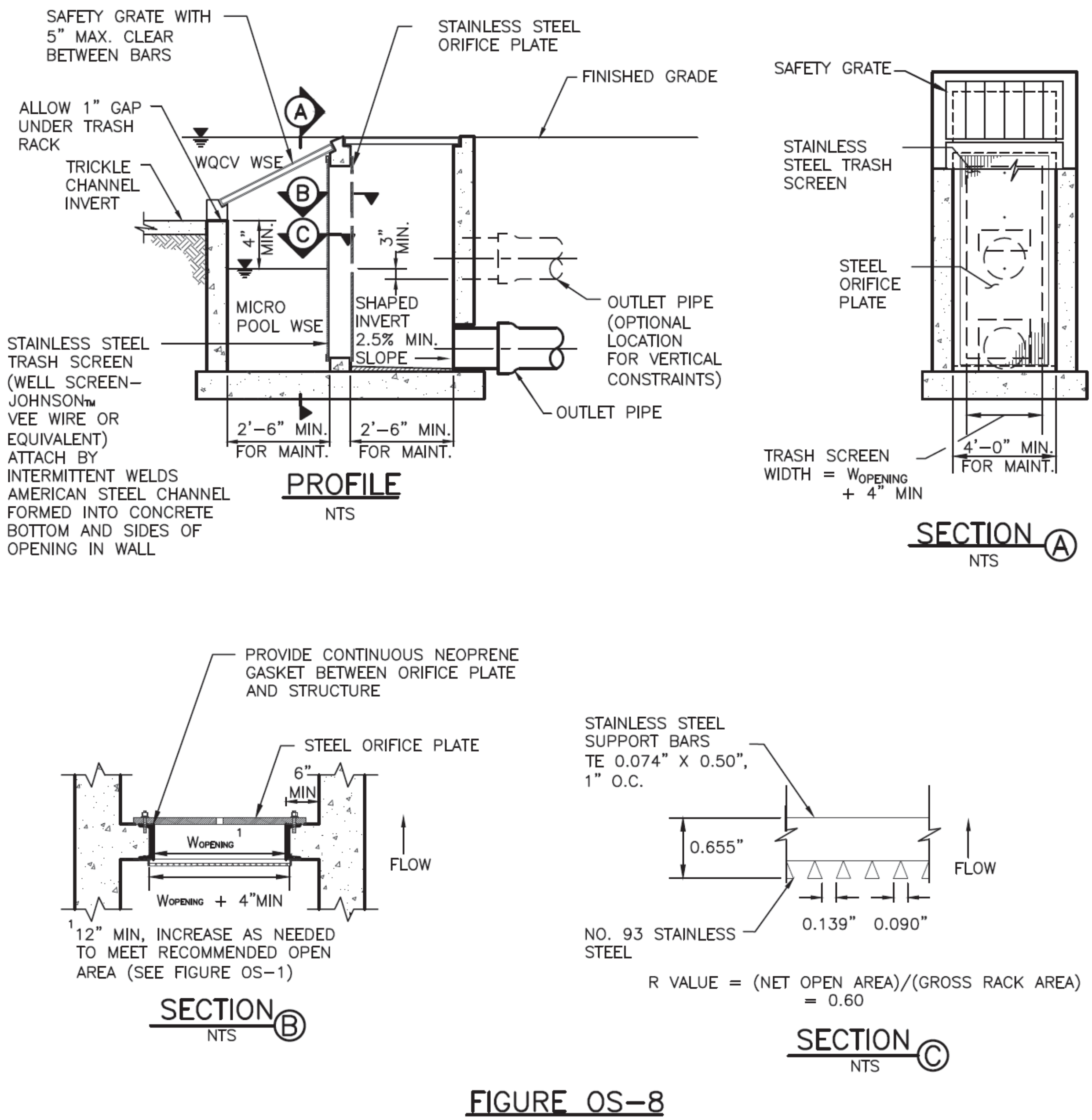

Figure OS-8. WQCV outlet structure for 5-acre impervious area or less