Drainage Criteria Manual Volume 2

The City of Colorado Springs Drainage Criteria Manual Volume 2 (DCMV2) was adopted as El Paso County's stormwater quality design criteria, with the intent to use Appendix I of the El Paso County's Engineering Criteria Manual (ECM) to provide additions and revisions applicable to the County in order to expand its scope to cover rural areas and other situations specific to the County. The goal has been to maintain consistency between criteria used in the County and in the City of Colorado Springs. Please refer to section 1.3 of Appendix I of the ECM for additional clarification.

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List of Abbreviations

>	greater than
≤	less than or equal to
ASTM	American Society for Testing and Materials
BMPs	best management practices
BOD	biochemical oxygen demand
CDPHE	Colorado Department of Public Health and Environment
CDPS	Colorado Discharge Permit System
cfs	cubic feet per second
COD	chemical oxygen demand
CRS	Colorado Revised Statutes
CWA	Clean Water Act
DBPS	drainage basin planning study
DCIA	directly connected impervious areas
DO	dissolved oxygen
EMCs	event mean concentrations
EPA	United States Environmental Protection Agency
fps	feet per second
ft	feet
FHWA	Federal Highway Administration
H:V	horizontal to vertical ratio of a slope
I	impervious ratio of a catchment
I_a	percent imperviousness of catchment
I_{wq}	percent imperviousness of catchment
mg/L	milligrams per liter
µg/L	micrograms per liter
MDCIA	minimizing directly connected impervious area
MS4	municipal separate storm sewer system
MSDS	material safety data sheets
MWCOG	Metropolitan Washington Council of Governments
N/A	not available
NPDES	National Pollution Discharge Elimination System
pH	negative $\log_{10}$ of the concentration of hydrogen ions, a measure of acidity
ppm	parts per million
S_o	slope
TAC	Technical Advisory Committee
TOC	total organic carbon
TSS	total suspended solids
UDFCD	Urban Drainage and Flood Control District
USDCM	*Urban Storm Drainage Criteria Manual*
USGS	United States Geological Survey
WQCV	water quality capture volume

Abbreviations of Structural BMPs in the *Manual*

GB	grass buffer
GS	grass swale – sedimentation facility
MBP	modular block porous pavement
PPD	porous pavement detention
PLD	porous landscape detention – sedimentation facility
EDB	extended detention basin – sedimentation facility
SFB	sand filter extended detention basin
CWB	constructed wetlands basin – sedimentation facility
RP	retention pond – sedimentation facility
CWC	constructed wetland channel – sedimentation facility

Standard Symbols

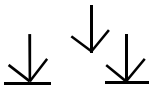
List of Symbols


Silt fence


Straw bale barrier


Temporary swale


Modular block porous pavement


Grass buffer (hatch)


Water level


Perforated collector pipes

Definitions

Best Management Practices (BMPs) - schedules of activities, prohibitions of practice, maintenance procedures, and other management practices to prevent or reduce the pollution of water of the State. BMPs also include treatment requirements, operating procedures, and practices to control site runoff, spillage or leaks, waste disposal, or drainage from material storage.

City Engineer - The City Engineer or his designated representative.

Dedicated Asphalt Plants and Concrete Plants - portable asphalt plants and concrete plants that are located on or adjacent to a construction site and that provide materials only to that specific construction site.

Earth Disturbance/Earth Disturbing Activity - a man-made alteration or disturbance of the ambient land surface, natural cover or topography of land, including all grading, cut and fill, stockpiling of imported fill, building, paving, landscaping and other activities which may result in, or contribute to, soil erosion or sedimentation of the Waters of the State.

Erodibility - The susceptibility of a particular soil type to erosion by water or wind.

Erosion - The wearing away of the land surface by water, wind, ice or other geological agents, including the detachment and movement of soil or rock fragments by water, wind, ice, gravity, or any combination thereof.

Erosion Control Measures - Practices that slow or stop erosion.

Final Stabilization - when all earth disturbing activities at the site have been completed, and uniform vegetative cover has been established with (for purposes of an Erosion and Stormwater Quality Control Permit) a density of at least 70 percent of pre-disturbance levels and such cover is capable of adequately controlling soil erosion, as determined by the City Engineer, or equivalent permanent, physical erosion reduction methods have been employed. Also includes installation of permanent roads and structural stormwater quality BMPs and removal of all temporary sediment controls.

Manual - City of Colorado Springs, Drainage Criteria Manual – Volume 2: Stormwater Quality Policies, Procedures and Best Management Practices.

Mapping Unit - Soil name and symbol given in the Soil Conservation Service Soil Survey for each soil type. Most areas of the Colorado Springs metropolitan area are included in a soil survey.

Municipal Separate Storm Sewer - a conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains), designed or used for collecting or conveying stormwater.

Permanent - will remain in place for a long period of time (referring to a land-surface cover or erosion and sediment control measure).

Runoff Coefficient - the fraction of total rainfall that will appear as runoff.

Sedimentation - The process of solid materials, both inorganic (mineral) and organic, coming to rest on the earth's surface either above or below sea level.

Sediment - Particulate solid material, either inorganic or organic, that will settle or be deposited in a liquid under the force of gravity.

Sediment Barrier - Straw bale barrier (dike) or a silt fence.

Sediment Basin - A depression, either excavated or formed by a dam, that holds water and debris and facilitates sedimentation of soil particles. Normally used for drainage areas equal to and greater than 1.0 acre.

Temporary - planned to be removed or inactivated after a period of time (referring to installation of erosion or sediment control measures, either structural or nonstructural).

Waters of the State - any and all surface and subsurface waters which are contained in or flow through this State, but does not include waters in sewage systems, waters in treatment works of disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed.

1.0 Overview/Purpose

The *Drainage Criteria Manual – Volume 2, Stormwater Quality Policies, Procedures and Best Management Practices* ("*Manual*") is meant to provide owners, developers, engineers, and contractors with information they will need to comply with City stormwater quality requirements for drainage planning/design relating to new development/significant redevelopment and construction activities. The material in the *Manual* is meant to assist users in determining what requirements apply and what best management practices ("BMPs") are necessary for a given site. As with any manual, it is impossible to be all-inclusive: addressing every situation. It is the owner's responsibility to ensure that the work at the site is in compliance with all applicable statutes and ordinances. This manual should be used in addition to other references and personal experience.

The *Manual* covers the following areas:

1. Basics of stormwater quality and regulatory requirements.
2. Requirements for the development and implementation of an Erosion and Stormwater Quality Control Plan.
3. Information on the use, design and maintenance of construction BMPs that can be used to comply with the Erosion and Stormwater Quality requirements.
4. Information on construction inspection and enforcement.
5. Requirements and procedures for inclusion of permanent stormwater quality elements in new developments/significant redevelopments.
6. Information on the use, design and maintenance of New Development BMPs that can be used for compliance with the New Development requirements.
7. Procedures for assessing existing structural controls for retrofitting with water quality features.

The stormwater quality criteria and requirements of this *Manual* are meant to be in addition to the drainage requirements and criteria listed in the *City of Colorado Springs and El Paso County Drainage Criteria Manual*. If there are any conflicts or discrepancies between the criteria and requirements of this *Manual* and those in the *Drainage Criteria Manual, Subdivision Policy Manual* or the City Engineering Standard Specifications, the criteria and requirements in this *Manual* take precedence.

The BMPs included in the *Manual* are not meant to be comprehensive. It is anticipated that as time goes on new technologies will be introduced as well as additional refinement of the current technologies. It is expected that the list of BMPs will be expanded as time goes on. Should the owner/engineer desire use of other BMPs, it will be necessary to submit information to City Engineering that supports their use and ability to adequately control stormwater quality. City Engineering will review these requests on a case-by-case basis.

2.0 Stormwater Quality Management

Most of the public's concerns with stormwater are usually related to flooding, not water quality. People complain when their basements flood or roads become impassable and the public suffers when severe catastrophic floods cause widespread damage to property and loss of life. Very few people are aware of the water quality impacts that stormwater has on our rivers, streams, or lakes. Stormwater runoff quality can have significant impacts on the receiving waters that affect not only the aquatic ecosystem, but also the quality of our communities.

2.1 Environmental Impacts of Runoff

Stormwater impacts streams by affecting the stream hydrology, stream morphology, water quality and aquatic ecology. The extent of impact is related to the climate, land use, and the measures implemented to address the impacts.

Briefly, the impacts on streams are:

- Stream Hydrology: Urban development affects the environment through changes in the size and frequency of storm runoff events, changes in base flows of the stream and changes in stream flow velocities during storms results in decrease in travel time for runoff. Peak discharges in a stream can increase from urbanization due to decrease in infiltration of rainfall into the ground, loss of buffering vegetation and resultant reduced evapotranspiration. This results in more surface runoff and larger loads of various constituents found in stormwater.
- Stream Morphology: When the hydrology of the stream changes, it results in changes to the physical characteristics of the stream. Such changes include streambed degradation, stream widening, and streambank erosion. As the stream profile degrades and the stream tries to widen to accommodate higher flows, instream bank erosion increases along with increases in sediment loads. These changes in the stream bed also result in change to the habitat of aquatic life.
- Water Quality: Water quality is impacted through urbanization as a result of erosion during construction, changes in stream morphology, and washing off of accumulated deposits on the urban landscape. Water quality problems include turbid water, nutrient enrichment, bacterial contamination, organic matter loads, metals, salts, temperature increases and increased trash and debris.

2.2 Stormwater Runoff Constituents and Sources

Urban runoff contains many types and forms of constituents; some occurring in higher concentrations than found in runoff before development and some that are not naturally present in surface runoff from undeveloped land. Runoff from undeveloped watersheds contains sediment particles, oxygen-demanding compounds, nutrients, metals, and other

constituents. Once developed, constituent loads increase because surface runoff volumes increase and the sources of many of these pollutants also increase. Also, additional sources of constituents may exist in a catchment and find their way into runoff. They may include the following:

- Metals, lubricating compounds, solvents, and other constituents originating from vehicles, machinery, and industrial and commercial activities.
- Pesticides, herbicides, and fertilizers.
- Household solvents, paints, roofing materials, and other such materials.
- Pet litter, garbage, and other debris.
- Suspended solids washed off impermeable surfaces.
- Increased soil erosion during construction activities.

Table SQ-1 lists the common constituents in stormwater runoff and their impacts.

TABLE SQ-1
Urban Runoff Pollutants

Constituents	Sources	Effects
Sediments – TSS, Turbidity, Dissolved Solids	Construction sites urban/agricultural runoff landfills, septic fields	Habitat changes, stream turbidity, recreation and aesthetic loss, contaminant transport, bank erosion
Nutrients – Nitrate, Nitrite, Ammonia, Organic Nitrogen, Phosphate, Total Phosphorus	Lawn/agricultural runoff, landfills, septic fields, atmospheric deposition, erosion	Algae blooms, ammonia toxicity, nitrate toxicity
Pathogens – Total and Fecal Coliforms, Fecal Streptococci Viruses, E.Coli, Enteroccus	Urban/agricultural runoff, septic systems, illicit sanitary connections, domestic/wild animals	Ear/intestinal infections, shellfish bed closure, recreation/aesthetic loss
Organic Enrichment – BOD, COD, TOC and DO	Urban/agricultural runoff, landfills, septic systems	Dissolved oxygen depletion, odors, fish kills
Toxic Pollutants – Metals, Organics	Urban/agricultural runoff, pesticides/herbicides, underground storage tanks, hazardous waste sites, landfills, illegal disposals, industrial discharges	Toxicity to humans and aquatic life, bioaccumulation in the food chain
Salts – Sodium Chloride	Urban runoff snowmelt	Contamination of drinking water, harmful to salt intolerant plants

Source: Handbook: Urban Runoff Pollution Prevention and Control Planning, 1993.

2.3 NPDES Permit Regulations

In 1972, Congress passed what is currently referred to as the Clean Water Act (CWA). The Act established the National Pollutant Discharge Elimination System (NPDES) program. Until recently, efforts under the NPDES program have focused on non-stormwater discharges from industries and municipal wastewater treatment plants. In the last several

years, the U.S. Environmental Protection Agency (EPA) has expanded the NPDES program to cover stormwater discharges.

Phase I Stormwater Regulations

As effective controls have been implemented on non-stormwater discharges, it has become more evident that diffuse sources can create impacts on water quality. In 1987, the CWA was revised to address stormwater discharges. The CWA defined municipal and industrial stormwater runoff discharges as "point sources" and called for a two-phase permitting strategy. Phase I affected:

- Any discharge of stormwater that was permitted under the NPDES program prior to February 4, 1987.
- Discharges associated with industrial activity including construction sites.
- Any discharge from a large or medium municipal separate storm sewer system (MS4). A large system serves a population greater than 250,000. A medium system serves a population between 100,000 and 250,000.
- Those discharges that the permitting authority determines contributes to a violation of a water quality standard or is a significant contributor of pollutants to waters of the U.S.

Regulations which addressed permit application requirements for these affected facilities were published on November 16, 1990. These regulations have resulted in thousands of industries and a large number of municipalities covered by stormwater permits. In Colorado, the Colorado Department of Public Health and Environment (CDPHE) administers the NPDES program for the EPA and issues Colorado Discharge Permit System (CDPS) Permits. The City of Colorado Springs was issued a CDPS permit by the CDPHE on September 12, 1997, which became effective on October 12, 1997.

MS4 permits are developed on a case-by-case basis. The City of Colorado Springs' CDPS permit requires that they develop and implement certain programs. These programs are:

1. Drainage and Street Maintenance and Pesticides/Herbicides/Fertilizers Program. This program includes the following areas:
    a. Maintenance of structural controls.
    b. Public street maintenance procedures and practices relating to snow and ice handling, street sweeping, street maintenance/improvements and street drainage facilities.
    c. Program to address water quality concerns associated with the application of pesticides, herbicides and fertilizers by the City.
2. Planning, Design, Flood Management Projects, Structural Controls and Construction Activities Program. This program generally includes the following areas:
    a. A New Development/Site Planning Program that requires permanent water quality elements.

b. Review of new flood control structures for inclusion of water quality elements and evaluation of existing facilities for retrofitting opportunities.

c. Requirement for Construction BMPs to ensure that adequate measures are taken to control runoff from construction sites that pose water quality concerns.

d. Construction site inspection and enforcement of erosion and stormwater quality control measures and BMPs.

3. Identification and Monitoring of Industries and Landfills/Illicit Discharges Program.

   a. A program for the prevention of illicit discharges and illegal disposal. The program must include detection and removal of illicit discharges.

   b. Implementation of an ongoing field screening program. This involves sampling of dry weather flows from the MS4 outfalls.

   c. Investigation of municipal storm sewer illicit discharges.

   d. A program for preventing, responding to and containing spills into the MS4.

   e. A program that controls sanitary sewer seepage into the MS4.

   f. A program to identify, monitor, and control pollutants in stormwater discharges to the MS4 from municipal landfills, hazardous waste treatment, disposal and recovery facilities, and industrial facilities.

4. Public Education and Information Program

   a. Educational activities to promote public reporting of illicit discharges and improper disposal as well as promote proper management and disposal of toxic materials.

   b. A program to inform and educate the public on the proper management and disposal of used oil and toxic materials.

   c. A program to encourage the education and training of construction site operators on erosion and sedimentation control BMPs.

5. Municipal Facility Runoff Control Program. This program requires the development and implementation of runoff control plans for specific municipal facilities.

6. Wet Weather Monitoring Program. This program involves the long-term monitoring and assessment of trends in water quality due to stormwater runoff.

Phase II Stormwater Regulations

On October 29, 1999, EPA Administrator Browner signed the Final Storm Water Phase II Rule which was published in the Federal Register on December 8, 1999. The Storm Water Phase II regulations center on three major items. These are:

1. Reduction in the size of construction sites required to obtain an NPDES stormwater permit from 5 acres to 1 acre.

2. An expansion of the exemption from permitting for industrial facilities which have all sources covered.

3. Expansion of the MS4 permits to communities with populations under 100,000.

The Phase II regulations extend the municipal stormwater program to small municipalities that are:

1. Within urbanized areas (except tribally owned systems serving less than 1,000 or others where requirements are waived by the State or EPA).
2. Designated via criteria not yet developed by the State or EPA.
3. Contributing significant loadings to a regulated MS4.

For Colorado, this means that approximately 50 additional communities could potentially fall under this program. Of interest to the City of Colorado Springs is the inclusion of El Paso County, Fountain, Manitou Springs and possibly others that could be designated later. The regulation proposes covering these Phase II communities under a general permit rather than individual permits. The required programs, referred to as the "Six Minimum Controls" include:

1. Public Education and Outreach on Stormwater Impacts.
2. Public Involvement/Participation.
3. Illicit Discharge Detection and Elimination.
4. Construction Site Program.
5. Post-Construction Stormwater Management in New Development and Redevelopment.
6. Pollution Prevention/Good Housekeeping for Municipal Operations.

The permit application deadline for Phase II municipalities is March 10, 2003.

Non-Stormwater Discharges

It is sometimes difficult to determine which discharges fall under the stormwater program and which require a traditional CDPS permit. It is clear that discharges from municipal wastewater treatment plants or industrial processes require a CDPS permit, but others are less obvious. A stormwater discharge is one which is a direct result of stormwater (rainfall or snow melt) and stops shortly after the event ends. Everything other than stormwater discharges require a permit if it enters State Waters. The Colorado Water Quality Control Act defines "State Waters" as any and all surface and subsurface waters which are contained in or flow through this state, but does not include waters in sewers systems, waters in treatment works or disposal systems, waters in potable water distribution systems, and all water withdrawn for use until use and treatment have been completed. However, State regulations do not allow a discharge into a ditch or man-made conveyance for the purpose of evading the requirement to obtain a permit, per CRS 25-8-501(1). Litigation has shown that the definition of State Waters is interpreted very broadly.

Table SQ-2 lists common discharges that are not covered by industrial or MS4 stormwater permits. The table includes a description of the activity and suggested measures to best manage the discharge.

TABLE SQ-2
Non-Stormwater Discharges

Discharge	Description	Suggested Measures
Vehicle Washing (Non-residential)	Spraying a vehicle to rinse off grime/dirt and allowing to flow into the MS4 or State Waters. This is whether or not soaps or solvents are used. Does not affect residents washing their vehicles.	Do washing at stationary third party facilities which are connected to the sanitary sewer. Ensure that waters are captured and not allowed offsite. With appropriate approval collect wastewater and send to a sanitary sewer.
Rinsing of trucks carrying materials such as concrete trucks	Involves the washing of concrete or other materials from the mixing or tank portions of a vehicle.	With appropriate approval, dispose into the sanitary sewer (not concrete trucks). Ensure that all waters are captured and not allowed offsite.
Swimming Pool/Spa Draining (Non-residential)	Involves the emptying of the contents of a swimming pool or hot tub. Private residential discharges are not affected.	Dechlorinate water. Use water for irrigation purposes. With appropriate approval, dispose into the sanitary sewer. Obtain a CDPS Permit (required by State).
Hydrostatic Testing	Involves the addition of water to a tank or pipeline to ensure water tightness and strength of joints.	Ensure that waters are captured and not allowed offsite. With appropriate approval, dispose into a sanitary sewer. Obtain a CDPS Permit (required by State).

The NPDES stormwater regulations allow for certain non-stormwater discharges to be released under a municipal permit. Table SQ-3 lists these discharges.

TABLE SQ-3
Allowable Non-Stormwater Discharges

The following non-stormwater discharges or flows are not considered illicit or illegal unless they are identified by the municipality or the State as sources of pollutants.

- Landscape irrigation.
- Diverted stream flows.
- Rising ground waters.
- Uncontaminated ground water infiltration to separate storm sewers.
- Discharges from potable water sources.
- Foundation drains.
- Air conditioning condensation.
- Irrigation water.
- Natural springs.
- Water from crawl space pumps.
- Footing drains.
- Lawn watering.
- Individual residential car washing.
- Flows from riparian habitats and wetlands.
- Emergency fire fighting activities.
- Uncontaminated water from irrigation system meter pits.
- Uncontaminated pumped groundwater.

TABLE SQ-3
Allowable Non-Stormwater Discharges (continued)

Non-stormwater discharges allowed under the municipal stormwater permits.

- Individual residential swimming pool and hot tub discharges.
- Individual residential street washing.
- Water-line flushing.
- Water line flushing (excludes flushing of disinfection water for new pipes).
- Street wash water for construction activities (with City approved BMPs).

Other sources of allowable dry weather flow include:

- Discharges of process wastewater as long as authorized under separate CDPS permits.

In order to address many small discharges, the Colorado Water Quality Control Division developed the minimal discharge general permit. This permit covers the following types of discharges:

- Facilities discharging wastewater from washing the exteriors of trucks, cars, airplanes, boats, driveways, parking lots, and roads.
- Facilities discharging wastewater from the washing of bleachers, elevated seating and grandstands, such as those found at outdoor sporting or entertainment events.
- Commercial facilities discharging wastewater from draining, cleaning, and filter backwash of swimming pools, spas, hot tubs, and similar structures including water slides and water theme amusement parks.
- Commercial facilities discharging wastewater from the washing of temporary stables, traveling petting zoos, or any other facility that discharges wash water associated with animal wastes.
- Facilities discharging wastewater from commercial mobile cleaning vehicles such as steam cleaning, carpet cleaning and pressure washing (including building washing).
- Facilities discharging groundwater from foundation, basement, or underground structure dewatering.
- Facilities discharging non-contact cooling or heating water.
- Facilities discharging hydrostatic test water from the testing of new or used pipes, tanks or other similar vessels.
- Facilities discharging water such as facilities that employ super chlorination (50 to 500 mg/L) of water for the disinfection of these facilities and wish to discharge effluent.
- Facilities discharging wastewater from washing of root crops such as potatoes, sugar beets, onions, and other fruit/vegetable agricultural produce.

The general permit allows for quick coverage of these types of discharges. Compliance is required with state water quality standards and effluent guidelines. Monitoring and reporting of the quality of the discharge is also required.

2.4 Summary

This *Manual* has been structured to provide owners, developers, engineers and contractors with information which can be used to control water quality impacts from stormwater and comply with applicable regulatory requirements.

3.0 Construction Stormwater Management

3.1 Introduction

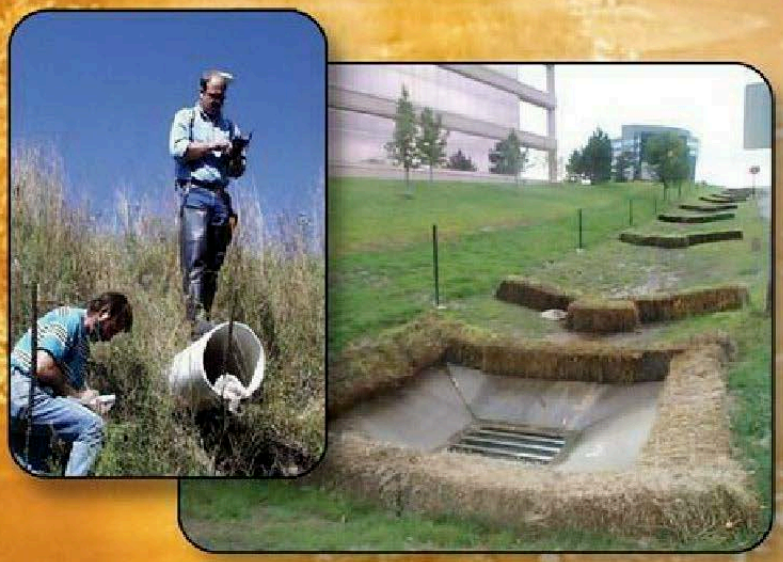
This section of the Stormwater Quality BMP *Manual* provides a set of criteria and technical guidance for erosion, sediment, and stormwater quality control at construction sites. These criteria were developed to help mitigate (1) the increased soil erosion and subsequent deposition of sediment off-site and (2) other potential stormwater quality impacts during the period of construction from start of earth disturbance until final landscaping and other potential permanent stormwater quality measures are effectively in place.

An Erosion and Stormwater Quality Control Plan must be developed and submitted to the City Engineer to obtain an Erosion and Stormwater Quality Control permit. Criteria for when an Erosion and Stormwater Quality Control Plan is required are listed in Section 3.2: *General Principles – Applicability*. Site planning and drainage planning should, whenever possible, occur concurrently with site grading and erosion and stormwater quality control planning. When site grading precedes final development, a Grading Plan and an Erosion and Stormwater Quality Control Plan must be submitted. This plan may have to be modified at the time a final site development plan is prepared. This modified plan must be submitted for review concurrent with the development plan, or prior to final plat approval (if no development plan required), or prior to approval of a building permit (existing platted lots).

Implementation and maintenance of erosion, sediment, and stormwater quality control measures are ultimately the responsibility of the property owner. Because site conditions will affect the suitability and effectiveness of erosion, sediment, and stormwater quality control measures, a plan specific to each site is required. In addition, should the approved plan not function as intended, and it is determined by the City that additional or revised measures are needed, the owner will have to implement such changes as needed to reduce soil erosion and sediment discharged from the construction site and to minimize other stormwater quality impacts.

DRAINAGE CRITERIA

Drainage Criteria Manual Vol 2



Stormwater Quality Policies, Procedures and Best Management Practices (BMPs)

City of Colorado Springs
Engineering Division

DRAINAGE CRITERIA MANUAL
VOLUME 2

STORMWATER QUALITY POLICIES, PROCEDURES AND BEST MANAGEMENT PRACTICES (BMPs)

November 1, 2002

PREPARED JOINTLY BY

CITY OF COLORADO SPRINGS
CITY ENGINEERING DIVISION

CH2MHILL

RESOLUTION NO. 135-02

A RESOLUTION ADOPTING THE CITY OF COLORADO SPRINGS DRAINAGE CRITERIA MANUAL VOLUME 2 – STORMWATER QUALITY POLICIES, PROCEDURES AND BEST MANAGEMENT PRACTICES (BMPs) AND INCORPORATING INTO THE CITY OF COLORADO SPRINGS SUBDIVISION POLICY MANUAL AND PUBLIC WORKS DESIGN MANUAL

WHEREAS, the City of Colorado Springs was required under its 1997 federally-mandated Municipal Stormwater Discharge Permit to review, revise and develop stormwater quality codes, policies, procedures and Best Management Practices (BMPs) relating to construction and new development/redevelopment activities; and

WHEREAS, the City of Colorado Springs City Engineering Division has developed a Drainage Criteria Manual Volume 2 – Stormwater Quality Policies, Procedures and Best Management Practices (BMPs); and

WHEREAS, the Drainage Criteria Manual Volume 2 enhances and adds to existing policies, procedures, criteria and BMPs relating to grading and erosion control activities and adds new stormwater quality policies, procedures, criteria and BMPs relating to new development/redevelopment activities; and

WHEREAS, the City of Colorado Springs will benefit from an improved stormwater quality program relating to construction and new development/redevelopment activities;

NOW, THEREFORE, BE IT RESOLVED BY THE CITY COUNCIL OF THE CITY OF COLORADO SPRINGS:

Section 1. That the City of Colorado Springs Drainage Criteria Manual Volume 2 – Stormwater Quality Policies, Procedures and Best Management Practices (BMPs) is hereby incorporated into the City of Colorado Springs Subdivision Policy Manual and Public Works Design Manual.

Section 2. That the City of Colorado Springs Drainage Criteria Manual Volume 2 – Stormwater Quality Policies, Procedures and Best Management Practices (BMPs) is adopted and shall become effective for use in all construction and new development/redevelopment activities, as designated in the Manual and beginning with any applicable reports, studies and plans submitted to City Engineering for review or approval on or after November 1, 2002.

Dated at Colorado Springs, Colorado, this 13th day of August, 2002.

Mayor

ATTEST:

City Clerk

Acknowledgements

The development of this Stormwater Quality BMP *Manual* was made possible by the participation and contributions of the following people:

City of Colorado Springs

Bruce Thorson	City Engineering, Project Manager

CH2M HILL

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James Wulliman	Technical Advisor and Co-author – Construction BMPs
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David Hornbacker Colorado Springs Utilities, Development Services

Urban Drainage and Flood Control District

Ben Urbonas Provided significant contributions by allowing the City to use information from the Urban Drainage and Flood Control District's "*Urban Storm Drainage Criteria Manual*-Volume 3, Best Management Practices," including the *New Development Planning* and *BMP Factsheet* Sections, *Typical Structural Details*, *Design Forms*, and other portions of the manual. Some revisions have been made to these various sections to better tailor this Manual to the City of Colorado Springs.

3.2 Erosion and Stormwater Quality Control Plan

General Principles

Purpose

The required Erosion and Stormwater Quality Control Plan is a plan for controlling erosion, sedimentation and stormwater quality during construction in compliance with the City laws, ordinances, regulations, resolutions, standards and specifications, including this Drainage Criteria *Manual* – Volume 2: Stormwater Quality Policies, Procedures and Best Management Practices. The plan shall be a part of the total site development plan and shall prescribe all the steps necessary including scheduling to assure erosion, sediment and stormwater quality control during all phases of construction including final stabilization.

The objectives for erosion and stormwater quality control during construction include the following:

1. Conduct all land disturbing activities in a manner that effectively reduces accelerated soil erosion and reduces sediment movement and deposition off-site.
2. Schedule construction activities to minimize the total amount of soil exposed at any given time to reduce the period of accelerated soil erosion.
3. Establish temporary or permanent cover on areas that have been disturbed as soon as possible after overlot or final grading is completed.
4. Design and construct all temporary or permanent facilities for the conveyance of water around, through, or from the disturbed area to limit the flow of water to non-erosive velocities.
5. Remove sediment caused by accelerated soil erosion from surface runoff water before it leaves the site.
6. Stabilize the areas of land disturbance with permanent vegetative cover or stormwater quality control measures.
7. Implement other BMPs such as spill containment and control measures and proper materials storage practices to minimize impacts to stormwater quality.

Applicability

At a minimum, an Erosion and Stormwater Quality Control Plan is required whenever a Grading Plan is required or when one (1) acre or more of land will be disturbed. All requirements for any land disturbance in Hillside Overlay areas are incorporated into Section 504 of Part 5 of Article 3 of Chapter 7 of the City Code. The Erosion and Stormwater Quality Control Plan shall require the design, implementation and maintenance of BMPs as set forth in this *Manual* and shall include the plan elements as set forth in this *Manual*.

Typical activities for which an Erosion and Stormwater Quality Control Plan is generally not required are designated as minor land disturbing activities and include:

1. Any project involving earth disturbing activity of less than 1 acre, and which disturbs less than 500 cubic yards of material (cut and/or fill).
2. Individual home landscaping, gardening, maintenance and repair work.
3. Agriculture and related activities.
4. Other land disturbing activities which will result in minimum soil erosion or the movement of sediment into waters or onto property off the project site and that include land disturbance of less than 1 acre and less than 500 cubic yards of material (cut and/or fill).

An Erosion and Stormwater Quality Control Plan may be required for specific minor land disturbing activities if deemed necessary by the City Engineer.

Planning and Relationship to Other Plans

Planning for Erosion and Stormwater Quality Control shall begin with the Preliminary Drainage Report preparation, and shall include first hand knowledge of the site by the engineer. Plan approval for the Erosion and Stormwater Quality Control Plan shall be concurrent with review of the Preliminary/Final Drainage Report and approval of the Grading Plan. The plan may be combined with the Grading Plan if all information can be clearly presented.

Basic Grading, Erosion and Stormwater Quality Requirements and General Prohibitions

Any land disturbance by any owner, developer, builder, contractor, or other person shall comply with the Basic Grading, Erosion and Stormwater Quality Requirements and General Prohibitions as noted below. In many cases, this will require the design, implementation and maintenance of Best Management Practices (BMPs) as specified in the *Manual*, even if an Erosion and Stormwater Quality Control Plan is not required. A typical example for this requirement would be a home building contractor constructing one or more homes in an area on individual lots where the construction activity on each lot meets the definition of minor earth disturbing activity.

1. Stormwater discharges from construction sites shall not cause or threaten to cause pollution, contamination, or degradation of State Waters.
2. Concrete wash water shall not be discharged to or allowed to runoff to State Waters, including any surface or subsurface storm drainage system or facilities.
3. Building, construction, excavation, or other waste materials shall not be temporarily placed or stored in the street, alley, or other public way, unless in accordance with an approved Traffic Control Plan. BMPs may be required by City Engineering if deemed necessary, based on specific conditions and circumstances (e.g., estimated time of exposure, season of the year, etc.).
4. Vehicle tracking of soils off-site shall be minimized.

5. All wastes composed of building materials must be removed from the construction site for disposal in accordance with local and State regulatory requirements. No building material wastes or unused building materials shall be buried, dumped, or discharged at the site.

6. No chemicals are to be used by the contractor, which have the potential to be released in stormwater unless permission for the use of a specific chemical is granted in writing by the City Engineer. In granting the use of such chemicals, special conditions and monitoring may be required.

7. Bulk storage structures for petroleum products and other chemicals shall have adequate protection so as to contain all spills and prevent any spilled material from entering State Waters, including any surface or subsurface storm drainage system or facilities.

8. All persons engaged in earth disturbance shall implement and maintain acceptable soil erosion and sediment control measures including BMPs in conformance with the erosion control technical standards of the *Manual* and in accordance with the Erosion and Stormwater Quality Control Plan approved by the City of Colorado Springs, if required.

9. All temporary erosion control facilities including BMPs and all permanent facilities intended to control erosion of any earth disturbance operations, shall be installed as defined in the approved plans and the *Manual* and maintained throughout the duration of the earth disturbance operation. The installation of the first level of temporary erosion control facilities and BMPs shall be installed and inspected prior to any earth disturbance operations taking place.

10. Any earth disturbance shall be conducted in such a manner so as to effectively reduce accelerated soil erosion and resulting sedimentation.

11. All earth disturbances shall be designed, constructed, and completed in such a manner so that the exposed area of any disturbed land shall be limited to the shortest practical period of time.

12. All work and earth disturbance shall be done in a manner that minimizes pollution of any on-site or off-site waters, including wetlands.

13. Suspended sediment caused by accelerated soil erosion shall be minimized in runoff water before it leaves the site of the earth disturbance.

14. Any temporary or permanent facility designed and constructed for the conveyance of stormwater around, through, or from the earth disturbance area shall be designed to limit the discharge to a non-erosive velocity.

15. Temporary soil erosion control facilities shall be removed and earth disturbance areas graded and stabilized with permanent soil erosion control measures pursuant to the standards and specifications prescribed in the *Manual*, and in accordance with the permanent erosion control features shown on the Erosion and Stormwater Quality Control Plans approved by the City of Colorado Springs, if required.

16. Soil erosion control measures for all slopes, channels, ditches, or any disturbed land area shall be completed within twenty-one (21) calendar days after final grading, or final

earth disturbance, has been completed. Disturbed areas and stockpiles which are not at final grade but will remain dormant for longer than 30 days shall also be mulched within 21 days after interim grading. An area that is going to remain in an interim state for more than 60 days shall also be seeded. All temporary soil erosion control measures and BMPs shall be maintained until permanent soil erosion control measures are implemented.

17. No person shall cause, permit, or contribute to the discharge into the municipal separate storm sewer pollutants that could cause the City of Colorado Springs to be in violation of its Colorado Discharge Permit System Municipal Stormwater Discharge Permit.

18. The owner, site developer, contractor, and/or their authorized agents shall be responsible for the removal of all construction debris, dirt, trash, rock, sediment, and sand that may accumulate in the storm sewer or other drainage conveyance system and stormwater appurtenances as a result of site development.

19. No person shall cause the impediment of stormwater flow in the flow line of the curb and gutter, including the temporary or permanent ramping with materials for vehicle access.

20. Individuals shall comply with the "Colorado Water Quality Control Act" (Title 25, Article 8, CRS), and the "Clean Water Act" (33 USC 1344), regulations promulgated, certifications or permits issued, in addition to the requirements included in the *Manual*. In the event of conflicts between these requirements and water quality control laws, rules, or regulations of other Federal or State agencies, the more restrictive laws, rules, or regulations shall apply.

21. The quantity of materials stored on the project site shall be limited, as much as practical, to that quantity required to perform the work in an orderly sequence. All materials stored on-site shall be stored in a neat, orderly manner, in their original containers, with original manufacturer's labels. Materials shall not be stored in a location where they may be carried by stormwater runoff into a State Water at any time.

22. Spill prevention and containment measures shall be used at storage, and equipment fueling and servicing areas to prevent the pollution of any State Waters, including wetlands. All spills shall be cleaned up immediately after discovery, or contained until appropriate cleanup methods can be employed. Manufacturer's recommended methods for spill cleanup shall be followed, along with proper disposal methods.

Minimum Best Management Practices Elements

The following best management practices must be included in the Erosion and Stormwater Quality Control Plan. See section 3.3 – *Construction BMP Factsheets and Guidelines for Implementing Construction BMPs* for additional details.

1. Erosion and Sediment Control

   - Sediment Trapping Devices (perimeter controls, vehicle tracking, inlet protection)
   - Sediment Control Devices (Basins and Check Dams)
   - Stabilization Requirements (ground stabilization and slope controls)

2. Spill Prevention and Response
3. Material Management
4. Inspection and Maintenance

Plan Elements

An Erosion and Stormwater Quality Control Plan shall be developed that consists of a narrative description of the construction project and appropriate plans/maps. The Erosion and Stormwater Quality Control Plan shall consist of the most appropriate or best selection of erosion control practices and sediment trapping facilities in conjunction with an appropriate schedule in order to accomplish adequate control. Adequate erosion control measures shall be constructed prior to land disturbing activities such that no adverse affect of site alternatives will impact the surrounding properties. Particular attention shall be given to concentrated flows of water either to prevent their occurrence or to provide appropriate conveyance devices to prevent erosion. Sediment trapping devices shall be required at all points where sediment laden water might leave the site. The Erosion and Stormwater Quality Control Plan shall include permanent structures for conveying storm runoff, how the site will be graded, final site stabilization, temporary sediment control features including sediment basins and finally, stabilization of the site where temporary features have been removed. Plans showing improvements or construction outside the property line of the site will not be approved unless the plan is accompanied by an appropriate legal easement or written acceptance by the adjacent property owner for the area in which such work is required.

The plan shall be annotated with appropriate standard symbols as shown on the List of Standard Symbols. The symbols should be bold and tend to "stand out" on the plans.

The required plan elements are listed as follows:

Applicant Information

The name, address, telephone number, email address and fax number of the applicant and/ or owner and the engineer must be listed on the plan. In addition, it is recommended that the same information be provided for the contractor, if known).

Site Map

The information listed below shall be included on one or multiple site maps. The map shall use one of the following scales; 1″=20′, 1″=30′, 1″=40′, 1″=50′ or 1″=100′. The scale selected must be suitable for practical use and readability. The contour interval for these plans shall be 2 feet or closer.

1. Construction site boundaries.
2. Areas of soil disturbance.
3. Areas of cut and fill.
4. Areas used for the storage of building materials, soils, equipment, fuel, lubricants, chemicals, or waste storage.
5. Location of any dedicated asphalt or concrete batch plants.

6. Critical erosion areas and location of major erosion and sediment control facilities or structures.
7. Existing and proposed water courses including springs, streams, wetlands and other surface waters.
8. Boundaries of the 100-year flood plains, if determined.
9. Vicinity map showing relationship of the site to existing and planned roadways, jurisdictional boundaries, and major creeks/streams.
10. Soil types.
11. Existing and proposed contours.
12. Adjacent existing and proposed development affected by the construction.
13. Other proposed features and structures on the site.
14. Vegetation.
15. Property lines for the parcel/lot on which the land disturbance will occur.
16. Existing and proposed utility locations. The following note shall be added: "The Plan shall not substantially change the depth of cover, or access to utility facilities. Additionally, the Plan shall not increase or divert water towards utility facilities. Any changes to utility facilities to accommodate the plan, must be discussed and agreed to by the affected utility prior to implementing the plan. The resulting cost to relocate or protect utilities, or provide interim access is at the expense of the Plan applicant."

Description of Construction Activities

This includes the nature and purpose of the land disturbing activity.

Timing

The proposed sequence for major construction activities. This includes the anticipated starting and completion time periods of the site grading and/or construction sequence, including installation and removal time periods of erosion and sediment control measures, and the time of exposure of each area prior to completion of temporary erosion and sediment control measures.

Areas

Estimates of the total area of the site and the area of the site that will be cleared, excavated or graded.

Soils Information

A brief description of the soils on the site including information on soil type and names, mapping unit, erodibility, permeability, hydrologic soil group, depth, texture and soil structure. In addition, an estimate of the runoff coefficient of the site before and after construction activities should be included. This information may be obtained from the soil report for the site, or, if available, from soils reports from adjacent sites.

Existing Site Conditions

A description of the existing topography, vegetation, and drainage including a description of any wetlands. This includes a description of the existing vegetation at the site and an estimate of the percent vegetative ground cover. In addition, a description should be included of any anticipated non-stormwater components of offsite discharges such as springs, and landscape irrigation return flows.

Other Pollutant Sources

The location and description of any potential pollutant sources including, but not limited to, vehicle fueling areas, storage of fertilizers or chemicals, etc.

Receiving Waters

The name of the receiving water(s) and the site, type and location of any concentrated flow points from the site. If the discharge is into an existing storm sewer system, this should be stated, along with the name of the ultimate receiving water.

Best Management Practices

The plan shall include a narrative description of appropriate controls and measures that will be implemented before and during construction activities at the facility. It shall clearly describe the relationship between the phases of construction and the implementation and maintenance of control measures. For example, what BMPs will be implemented during each of the following stages of construction:

1. Clearing and grubbing necessary for perimeter controls.
2. Initiation of perimeter controls.
3. Remaining clearing and grubbing.
4. Road grading.
5. Drainage facility installation.
6. Utilities installation.
7. Final grading.
8. Stabilization.
9. Removal of temporary control measures.

The description of controls shall address the following areas:

1. Erosion and Sediment Control. This includes:
    - Structural Practices – A description of structural site management practices that will minimize erosion and sediment transport.
    - Non-Structural Practices – A description of interim and permanent stabilization practices, including site-specific scheduling of the implementation of the practices.
2. Materials Handling. The plan shall identify any procedures of significant materials handled at the site that could contribute pollutants to runoff.
3. Spill Prevention and Response. Areas where potential spills can occur shall have spill prevention and response procedures identified.

4. Other Controls. A description of other measures to control pollutants in stormwater discharges including plans for waste disposal.

Detail Drawings

Design drawings of sediment controls, temporary diversions and any practices used that are not referenced in the BMPs or design criteria.

Plans for all Drainage Features

Plans will be submitted for all drainage features including paved areas, retaining walls, cribbing, planting, temporary or permanent soil erosion control measures, or other features to be constructed in connection with, or as a part of, the proposed work.

Final Stabilization and Long-Term Stormwater Management

A description of the measures used to achieve final stabilization and permanent measures to control pollutants in stormwater discharges that will occur after construction operations have been completed.

Final stabilization is reached when all soil disturbing activities at the site have been completed, and uniform vegetative cover has been established with a density of at least 70 percent of pre-disturbance levels and such cover is adequate to control soil erosion, as determined by the City Engineer, or equivalent permanent, physical erosion reduction methods have been employed. The seeded areas shall be kept in good condition at all times until the project is completed. The plan shall include procedures for promptly repairing any damaged areas.

For purposes of this plan, establishment of a vegetative cover capable of providing erosion control equivalent to a density of at least 70 percent of pre-existing conditions at the site and capable of adequately controlling future erosion can be considered final stabilization. The developer will be responsible for providing to the City the documentation to make this comparison. The City may, after consultation with the developer and upon good cause, amend the final stabilization criteria for specific operations. Where possible, coordination of erosion control elements and building schedule will occur so that previously seeded areas are not redisturbed.

Construction Staging and Sequencing

A schedule of anticipated starting and completion dates for each sequence and stage of land-disturbing activities and BMP installation including the expected date on which the final stabilization will be completed. Where possible, the clearing and grubbing operations shall be scheduled and performed so that grading operations and final stabilization can follow immediately.

Owner Inspections

A description of procedures to inspect the vegetation, erosion and sediment control measures, and other protective measures identified in the plan.

For sites where construction has not been completed, the owner/developer or their representative shall make a thorough inspection of their stormwater management system at

least every 14 days and after any precipitation or snowmelt event that causes surface erosion. The inspections shall be made during the progress of the work, during work suspension and until final acceptance of the work. The person making these inspections must be certified in a City-approved inspection training program.

1. The construction site perimeter, disturbed areas and areas used for material storage that are exposed to precipitation shall be inspected for evidence of, or the potential for, pollutants entering the drainage system. Erosion and sediment control measures identified in the plan shall be observed to ensure that they are operating correctly.
2. Based on the results of the inspection, the description of potential pollutant sources, and the pollution prevention and control measures that are identified in the plan shall be revised and modified as appropriate as soon as practicable after such inspection. Modification to control measures shall be implemented in a timely manner, but in no case more than seven (7) calendar days after the inspection.
3. The operator shall keep a record of inspections. Uncontrolled releases of mud or muddy water or measurable quantities of sediment found off the site shall be recorded with a brief explanation as to the measures taken to prevent future releases as well as any measures taken to clean up the sediment that has left the site. Inspection records shall be made available to the City upon request.

The owner/developer shall make a thorough inspection of their stormwater management system at least once every month for sites where all construction activities are completed but final stabilization has not been achieved because planted vegetative cover has not become established. When site conditions make this schedule impractical, the owner/developer may petition the City to grant an alternative inspection schedule. These inspections must be conducted in accordance with the above paragraphs.

Maintenance

A detailed description of the maintenance program for sediment control facilities, including inspection programs, vegetative establishment on exposed soils, method and frequency of removal and disposal of waste materials from control facilities, and disposition of temporary structural measures shall be included. The description shall include a program for continuous maintenance of erosion and sediment control features so that they function properly during construction and work suspensions until the project is accepted by the City.

Soil Borings/Tests and Groundwater

Soil borings and tests, including groundwater analysis and plan for safe discharge must be included if appropriate.

Cost Estimate

A cost estimate shall be provided for all temporary and permanent BMPs, including reasonable costs for replacement and maintenance of BMPs depending on the anticipated length of construction until final stabilization.

Plan Expiration/Resubmittal Requirements

Grading Plans and/or Erosion and Stormwater Quality Control Plans (Plans) expire if construction has not commenced within 12 months of the City Engineer's acceptance of the plan. The plans must be resubmitted for acceptance. Previously accepted Plans must also be resubmitted to the City Engineer for acceptance when any of the following occur: (1) a change in ownership of the property to be disturbed, (2) proposed development changes to the site, or (3) proposed grading revisions.

Signatory Requirements

The Erosion and Stormwater Quality Control Plan is to be signed and sealed by a Colorado Registered Engineer and to be signed by the Owner with a statement that "The Owner will comply with the requirements of the Erosion and Stormwater Quality Control Plan." This statement may be modified if a combined Grading, Erosion and Stormwater Quality Control Plan is submitted. The following Owner statement shall also be included on all Grading and/or Erosion and Stormwater Quality Control Plans: "I acknowledge the responsibility to determine whether the construction activities on these plans require Colorado Discharge Permit System (CDPS) permitting for Stormwater Discharges associated with Construction Activity."

Best Management Practices (BMPs)

The objective of erosion control is to limit the amount and rate of erosion occurring on disturbed areas until the site is stabilized. The objective of sediment control is to capture the soil that has been eroded before it leaves the construction site. Despite the use of both erosion control and sediment control measures, it is recognized that some amount of sediment will remain in runoff leaving the construction site. This should be minimal.

The best management practices for a site are usually comprised of four major elements:

- Erosion Control Measures. Used to limit erosion of soil from disturbed areas at a construction site.
- Sediment Control Measures. Used to limit transport of sediment to off-site properties and downstream receiving waters.
- Drainageway Protection Measures. Used to protect streams and other drainageways located on or adjacent to the construction site from erosion and sediment damages.
- Other Stormwater Quality Control Measures. Used to control other potential pollutants from impacting stormwater runoff.

Erosion controls (or BMPs) are surface treatments that stabilize soil exposed by excavation or grading. Erosion control measures are referred to as source controls, vegetative controls, or non-structural controls.

Sediment controls (or BMPs) capture soil that has been eroded. Soil particles suspended in runoff can be filtered through a porous media or deposited by slowing the flow and allowing the natural process of sedimentation to occur. Sediment controls (or BMPs) are facilities built to perform this function, and are referred to as structural controls.

Drainageway control measures (or BMPs) protect channels or storm sewers during site construction. This can be accomplished by limiting equipment travel across a stream, constructing a temporary channel crossing, or diverting a stream into a temporary channel while work is done on the permanent channel. Where storm sewers are used, sediment can be filtered prior to entry of runoff into the storm drainage system.

Non-sediment impacts to water quality can be managed by other controls (or BMPs) on equipment, material storage, or use of chemicals at construction sites.

Planning Process

Planning for the inclusion of appropriate BMPs should occur early in the site development process. The planning process can be divided into five separate steps:

1. Gather information on topography, soils, drainage, vegetation, and other predominant site features.
2. Analyze the information in order to anticipate erosion, sedimentation and stormwater quality problems.
3. Devise a plan that schedules construction activities and minimizes the amount of erosion created by development.
4. Develop an Erosion and Stormwater Quality Control Plan which specifies effective erosion, sediment, and stormwater quality control measures.
5. Follow the Erosion and Stormwater Quality Control Plan and revise it when necessary.

Site Assessment

Topography is the primary factor to be considered in determining the best management practices to be used at the site. Soils, vegetation, and hydrologic features must also be considered.

Final grading will determine the slope gradient and slope length of the disturbed area. Small areas, or subbasins, will be created that have relatively uniform characteristics of slope and slope length. After grading is completed, areas that remain exposed to precipitation and runoff will require the inclusion of BMPs. The overall size of subbasin areas will determine what BMPs are appropriate for each area.

Soil conditions should be assessed as to their potential for erosion and suitability for revegetation. A detailed analysis of soil-erosion potential is not necessary because all soils will be subject to erosion and can be generalized as equivalent for the design of BMPs.

In many land disturbing activities (excluding Hillside Overlay areas), significant vegetation will be removed from a construction site during clearing and grading operations. An assessment of existing vegetation on the site is of limited use when post-development landscaping and irrigation are planned, but can be useful in selecting grasses when non-irrigated revegetation is planned. Analysis of soil is useful to determine fertilizer requirements for vegetation establishment.

Analysis of streams and other hydrologic features of a site is important in the design of BMPs. The drainage basins upslope and within the site should be assessed. The

configuration of hillslope areas and drainageways, in the context of planned roads and buildings, will determine what erosion and sediment controls will be needed. The location of permanent drainage channels and other elements of the drainage system should be defined as a part of the plan.

Selection of Controls

The following guidelines are recommended in determining the appropriate BMPs for the site:

1. Determine the limits of clearing and grading. If the entire site will not undergo excavation and grading, the boundaries of cut-and-fill operations should be defined. Buffer strips of natural vegetation may be utilized as a control measure.

2. Define the layout of buildings and roads. This will have been decided previously as a part of the general development plan. If building layout is not final, the road areas stabilized with pavement and the drainage features related to roads should be defined as they relate to the plan.

3. Determine permanent drainage features. The location of permanent channels, storm sewers, detention ponds, roadside swales, and stormwater quality controls such as detention ponds, wetlands, grassed-lined swales, buffer strips, and areas of porous pavement, if known, should be defined.

4. Determine extent of temporary channel diversions. If permanent channel improvements are a part of the plan, the route, sizing, and lining needed for temporary channel diversions should be determined. Location and type of temporary channel crossings can be assessed.

5. Determine the boundaries of watersheds. The size of drainage basins will determine the types of sediment controls to be used. Areas located off the site that contribute overland flow runoff must be assessed. Measures to limit the size of upland overland flow areas, such as diversion dikes, may be initially considered at this stage.

6. Select sediment controls. Areas greater than one (1) acre will require that sediment basins be installed. Division of large drainage basins into subareas each served by a sediment basin can also be considered.

7. Areas smaller than one acre can utilize other sediment controls. Limitations on the size of areas served by individual controls are defined in these criteria.

8. Determine preliminary staging of construction. The schedule of construction will determine areas to be disturbed at various stages throughout development of the site. The opportunity for staging cut-and-fill operations to minimize the period of exposure of soils can be assessed. The sequence for installing sediment controls and erosion controls can also be determined at this time. This staging plan and schedule is subject to modification by the contractor in coordination with the City.

9. Identify locations of topsoil stockpiles. Areas for storing topsoil should be determined and noted as to a general location.

10. Identify location of temporary construction roads, vehicle tracking controls, and material storage areas. These three elements can be determined in the context of previously defined aspects of the plan.

11. Select Erosion Controls. All areas of exposed soil will require a control measure be defined dependent on the duration of exposure. These can be selected based on the schedule of construction.

Summary of Criteria

All runoff leaving a disturbed area shall pass through at least one BMP before it exits the site. The list below is a summary of recommended BMPs. Additional information on these BMPs can be found in section 3.3.

- Silt Fence. Silt fences shall be used at the perimeter of the site to prevent overland flows from transporting sediment off-site.
- Sediment Basin. Sediment basins are to be installed when the contributing area to be disturbed is greater than one (1) acre.
- Temporary Swales/Berms. Temporary swales are to be used to convey stormwater runoff to a sediment-trapping device or to divert runoff away from a slope face. Temporary swales can also be used at the perimeter of the site to prevent overland flows from transporting sediment off-site.
- Vehicle Tracking Controls. Whenever construction vehicles enter onto paved roads, provisions must be made to prevent the transport of sediment (mud and dirt) by vehicles tracking onto the paved surface. Sediment transported onto a public road, regardless of the size of the site, shall be cleaned at the end of each day.
- Check Dam. Check dams are to be used in open channels that receive flow from drainage areas between 1 and 10 acres, also in steeply sloped swales.
- Slope Drain. Slope drains shall be used to convey stormwater down steep slopes.
- Erosion Control Blankets. Erosion control blankets shall be installed in temporary swales with slopes greater than 2 percent, but less than 5 percent and with velocities less than 8 feet per second and on recently seeded slopes, as necessary. See Temporary Swale Figure TSW-3 for swales where slope is greater than 5% or velocity is greater than 8 feet per second.
- Inlet Protection. All storm sewer inlets made operable during construction must have sediment entrapment facilities installed to prevent sediment-laden runoff from entering the inlet.
- Surface Roughening. Surface roughening should be performed after final grading to create depressions two to four inches deep and four to six inches apart, parallel to contours.
- Temporary Mulching/Seeding. All disturbed areas must be properly mulched, or seeded and mulched, within 21 days after final grade is reached on any portion of the site not otherwise permanently stabilized.

- Chemicals, Oils and Material Storage. Areas used for storage of chemicals, petroleum-based products and waste materials, including solid and liquid waste, shall be designed to prevent discharge of these materials in the runoff from a construction site.
- Maintenance. All temporary and permanent erosion and sediment control practices shall be maintained and repaired by the owner during the construction phase as needed to assure continued performance of their intended function. All facilities must be inspected and then cleaned, repaired or replaced if necessary, following each precipitation or snowmelt event that results in runoff.

Additional Information Requirements/Modifications to Plan

City Requested

Additional information may be required for projects where the City Engineer deems that soil erosion, sedimentation, or stormwater quality control problems will not be adequately handled by the submitted plan. Such data may include, but not be limited to, other engineering studies, computations, schedules, and supportive data such as product design information and specifications as deemed necessary by the City Engineer.

It shall be understood that additional or revised BMPs may be required should construction site observation indicate the BMPs are not adequately controlling erosion, sedimentation or stormwater runoff from equipment fueling/maintenance and materials storage areas.

Owner/Contractor/Engineer Proposed

Minor field modifications may be approved by the City Engineering Inspector. Such modifications would include minor adjustments to BMP field locations or a change to a similar BMP to better correspond to actual site conditions or to improve BMP performance. No plan changes or formal written approval will be required, except that documentation of acceptance should be provided by the City Engineering Inspector to the contractor/owner. All other requested modifications shall be in writing and submitted to City Engineering. Such proposed modifications, including revised plans, shall be submitted at least ten (10) working days prior to desired date of implementation. City Engineering will re-approve the Plan/Permit if the proposed modifications are acceptable.

Plan Implementation

Acceptance

No clearing, grading, excavation, filling, or other land-disturbing activities shall be permitted until signoff and acceptance of the Grading Plan and Erosion and Stormwater Quality Control Plan is received from City Engineering.

Installation of BMPs

Once signoff and acceptance is received, the approved erosion and sediment control measures must be installed before land-disturbing activities are initiated so that no adverse effect of site alteration will impact surrounding property. These measures shall apply to all features of the construction site including, but not limited to, street and utility installations,

as well as to the protection of individual lots. During all phases of construction, it shall be the responsibility of those initiating such land disturbing activities to maintain all erosion control features in a functional manner.

City Inspections

Right to Inspect

The City shall have the right to enter the construction site at any time to determine if the site is in compliance with the plan.

Correction of Deficiencies

If the approved or implemented erosion, sediment and stormwater quality control BMPs are observed to be inadequate, as determined by the City Engineer, modifications to correct deficiencies shall be made immediately.

Record Keeping

1. The owner or developer shall retain all copies of the approved plan, all reports and inspections required by the permit and records of all data used to complete the plan.
2. The owner or developer shall retain a copy of the plan and all required reports and inspections at the construction site from the date of project initiation to the date of final stabilization, unless the City approves another location, specified by the owner or developer.

Guarantee

A financial assurance of all temporary and permanent BMPs included on the Erosion and Stormwater Quality Control Plan shall be provided, subject to current policies.

Relation to CDPS Stormwater Requirements

The Erosion and Stormwater Quality Control Plan has been structured to meet the requirements of the CDPS Stormwater Construction Permit, in addition to City requirements. It is anticipated that a single plan could meet both State and City requirements. However, City requirements for the Erosion and Stormwater Quality Control Plan are more inclusive than State requirements for a Stormwater Construction Permit. In addition, the developer should note that compliance with one program does not fill the need to comply with the other. Currently, a CDPS permit is required whenever the site disturbance exceeds 1 acre.

Consistency and Compliance with Other Plans and Regulations

Drainage, Grading, Utility, and Site Development Plans

The Erosion and Stormwater Quality Control Plan should be consistent with the final drainage report for a development and other plans including Grading Plans, site development plans, and utility facility plans. All hydrologic features of the drainage report should be incorporated into the site at the time of development. Permanent drainage features will be built during the construction phase. Temporary sediment controls can be

located and designed to take advantage of the final drainage design features. All temporary controls should be staged and removed at the appropriate time relative to the construction of permanent drainage features.

Stormwater Quality Plans

New developments may incorporate elements of permanent stormwater quality controls (BMPs) in the design of construction BMPs. The Erosion and Stormwater Quality Control Plan must be prepared consistent with these structural and nonstructural controls. If practical, temporary controls should be modified into permanent controls. Where possible, permanent stormwater quality controls should be constructed at the initial stages of construction, or modified at the end of construction.

Other Regulations

Compliance with all other local, State and Federal regulations is the responsibility of the owner, developer , contractor and engineer as it relates to the development and implementation of the Erosion and Stormwater Quality Control Plan.

3.3 Construction BMP Factsheets

This section provides a description, criteria for use, construction details/installation requirements, and maintenance requirements for the following Construction BMPs:

1. Check Dam.
2. Erosion Control Blankets.
3. Inlet Protection.
4. Mulching.
5. Sediment Basin.
6. Silt Fence.
7. Slope Drain.
8. Straw Bale Barriers.
9. Street Wash Water Associated with Construction Activities.
10. Surface Roughening.
11. Temporary Seeding.
12. Temporary Swale.
13. Vehicle Tracking.

Guidelines for Implementing Construction Best Management Practices

For Any Construction Site:

1. **Provide Perimeter Controls** on downgradient site boundaries.

   Use one of the following BMPs:

   See **Silt Fence** Fact Sheet
   See **Straw Bale Barrier** Fact Sheet
   See **Temporary Swale** Fact Sheet

2. **Provide Sediment Basin or Check Dam** at locations where concentrated flow exits site.

   Provide **Sediment Basin** for upstream drainage areas greater than 1 acre.

   See **Sediment Basin** Fact Sheet

   Provide **Check Dam** for upstream drainage areas between 1 and 10 acres.

   See **Check Dam** Fact Sheet

3. **Provide Vehicle Tracking Controls** for stabilized access to site.

   See **Vehicle Tracking Control** Fact Sheet

4. **Stabilize Disturbed Ground** within specified time limits**.**

   Use one of the following BMPs:

   See **Erosion Control Blankets** Fact Sheet
   See **Mulching** Fact Sheet
   See **Temporary Seeding** Fact Sheet

For Slopes:

1. **Provide Surface Roughening.**

   See **Surface Roughening** Fact Sheet

2. **Provide Drainage Controls.**

   Use one of the Following BMPs:

   See **Slope Drain** Fact Sheet
   See **Silt Fence** Fact Sheet
   See **Straw Bale Barrier** Fact Sheet
   See **Temporary Swale** Fact Sheet

For Storm Drain Inlets:

1. Provide Inlet Protection.

   See **Inlet Protection** Fact Sheet

Check Dam

What it is

Check dams are small, temporary or permanent dams constructed across a drainage ditch, swale or channel to reduce the velocity of concentrated flows and to trap sediment eroded from upstream. Check dams can be constructed out of rocks, gravel-filled sandbags or straw bales.

When and Where to use it

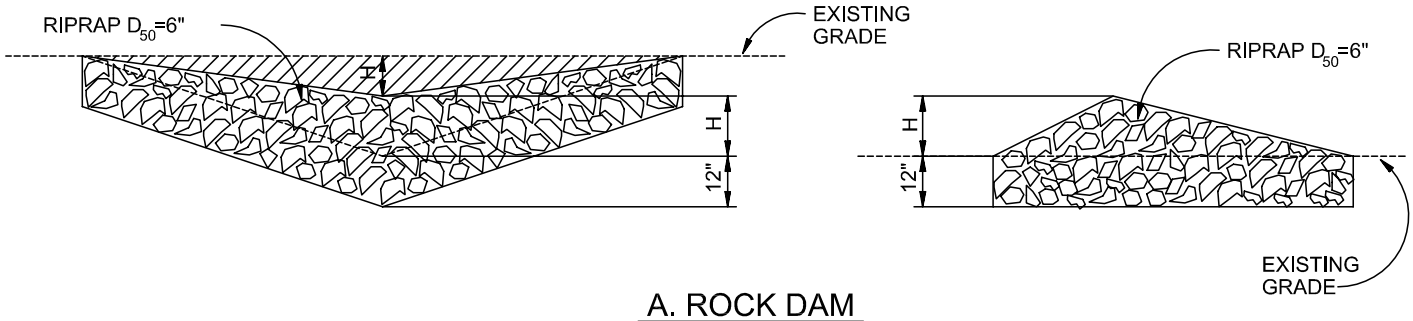
- In open channels that receive flow from drainage between 1 and 10 acres.
- In steeply sloped swales.
- In swales that need protection during the establishment of grasses or prior to installation of a non-erodible lining.

When and Where NOT to use it

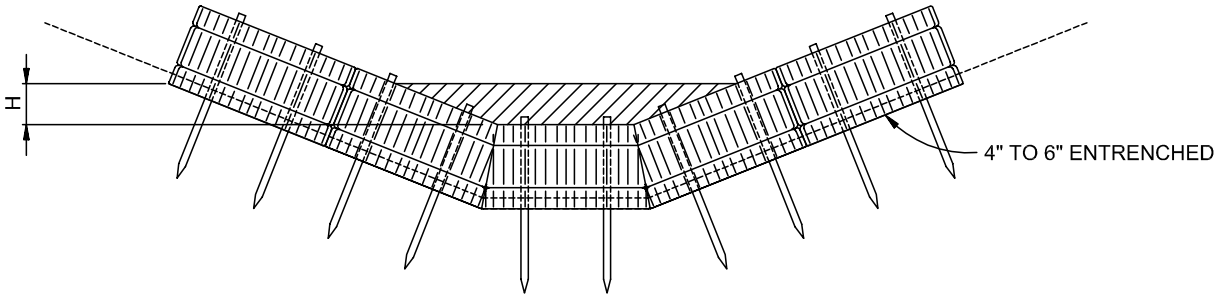
- In live streams.
- In channels that receive flow from drainage areas greater than 10 acres.
- In channels that will be overtopped by flow once the dams are constructed.

Construction Detail and Maintenance Requirements

Figure CD-1 provides a construction detail and maintenance requirements for a check dam.

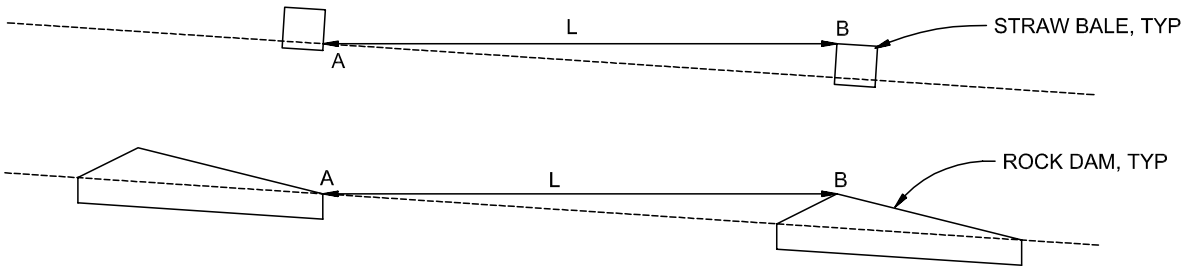


A. ROCK DAM



B. STRAW BALE CHECK DAM

(SEE STRAW BALE BARRIER INSTALATION)



L= THE DISTANCE SUCH THAT POINTS A AND B ARE AT THE SAME ELEVATION.

C. SPACING CHECK DAMS

CHECK DAM

NTS

CHECK DAM NOTES

INSTALLATION REQUIREMENTS

1. STRAW BALES USED AS CHECK DAMS ARE TO MEET THE REQUIREMENTS STATED IN FIGURE SBB-2.

2. THE "H" DIMENSION SHALL BE SELECTED TO PROVIDE WEIR FLOW CONVEYANCE FOR 2-YEAR FLOW OR GREATER.

MAINTENANCE REQUIREMENTS

1. REGULAR INSPECTIONS ARE TO BE MADE OF ALL CHECK DAMS, ESPECIALLY AFTER STORM EVENTS.

2. REPLACE STONE AS NECESSARY TO MAINTAIN THE CORRECT HEIGHT OF THE DAM.

3. ACCUMULATED SEDIMENT AND DEBRIS IS TO BE REMOVED FROM BEHIND THE DAMS AFTER EACH STORM OR WHEN 1/2 OF THE ORIGINAL HEIGHT OF THE DAM IS REACHED.

3. CHECK DAMS ARE TO REMAIN IN PLACE AND OPERATIONAL UNTIL THE DRAINAGE AREA AND CHANNEL ARE PERMANENTLY STABILIZED.

4. WHEN CHECK DAMS ARE REMOVED THE CHANNEL LINING OR VEGETATION IS TO BE RESTORED.

City of Colorado Springs Stormwater Quality	Figure CD-1 Check Dam Construction Detail and Maintenance Requirements

Erosion Control Blankets

What it is

Erosion control blankets are geotextiles or filter fabrics that are used to stabilize soils, steep slopes and drainage channels.

TYPES OF EROSION CONTROL BLANKETS

- WOVEN OR BONDED SYNETHETIC MATERIALS SUCH AS POLYPROPELENE, POLYESTER, POLYETHEYLENE, NYLON, POLYVINYL CHLORIDE, GLASS AND VARIOUS MIXTURES OF THESE.
- MULCH MATTING MADE FROM JUTE OR OTHER WOOD FIBER THAT HAS BEEN FORMED INTO SHEETS.
- NETTING MADE FROM JUTE OR OTHER WOOD FIBER, PLASTIC, PAPER, OR COTTON USED TO HOLD MULCH AND MATTING TO THE GROUND.
- BLANKETS OF WOVEN STRAW MULCH WITH A SYNTHETIC LAYER OR NET.

When and Where to use it

- In temporary and permanent swales.
- To protect recently seeded slopes.
- In drainageway channels.

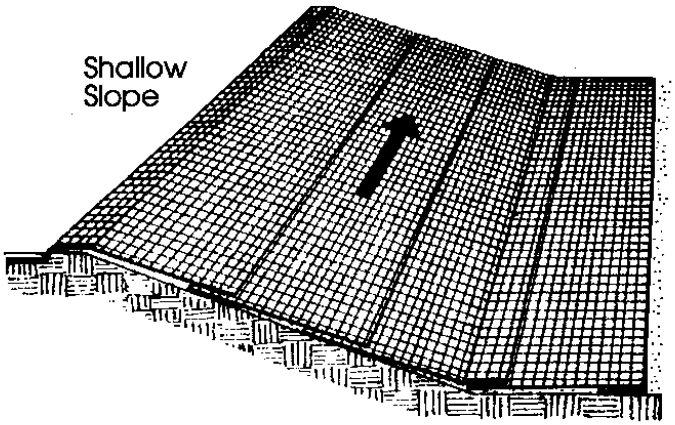
When and Where NOT to use it

- In swales with slopes greater than 5 percent or with stormwater velocities > 8 feet per second.

Installation and Maintenance Requirements

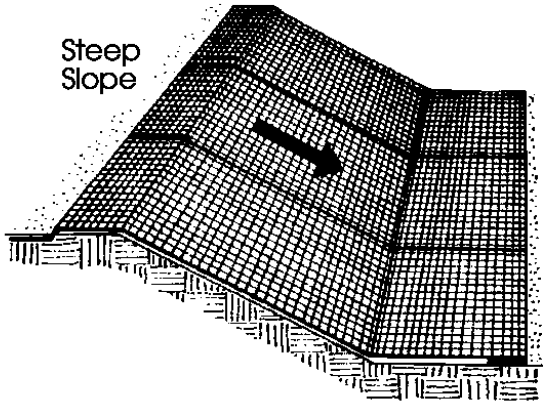
Installation requirements are provided in Figures ECB-1 and ECB-2.

Maintenance requirements include regular inspections to determine if fabric is damaged or has come loose, and appropriate repairs or replacement of damaged materials.



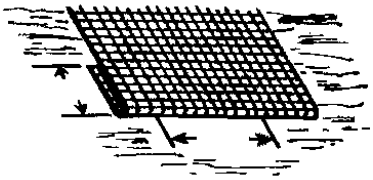
On shallow slopes, strips of netting may be applied across the slope.

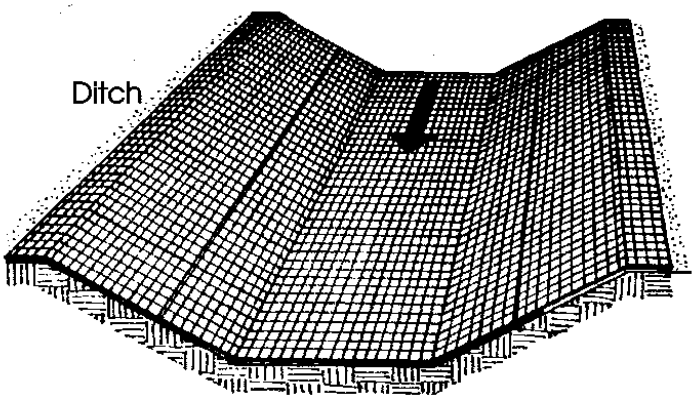
Where there is a berm at the top of the slope, bring the netting over the berm and anchor it behind the berm.



On steep slopes, apply strips of netting parallel to the direction of flow and anchor securely.

Bring netting down to a level area before terminating the installation. Turn the end under 6" and staple at 12" intervals.



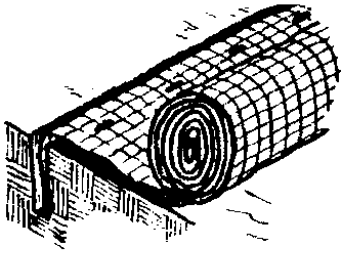


In ditches, apply netting parallel to the direction of flow. Use check slots every 15 feet. Do not join strips in the center of the ditch.

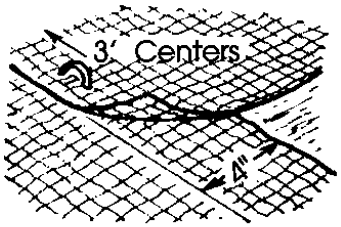
From: Virginia Soil and Water Conservation Commission, 1985

City of Colorado Springs Storm Water Quality	Figure ECB-1 Erosion Control Blanket Application Examples

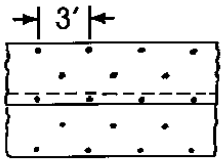
DEN/M/153722.CS.CB/FigECB-1/9-99

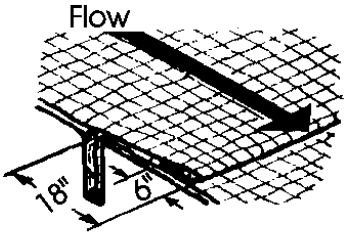


Anchor Slot: Bury the up-channel end of the net in a 6" deep trench. Tamp the soil firmly. Staple at 12" intervals across the net.

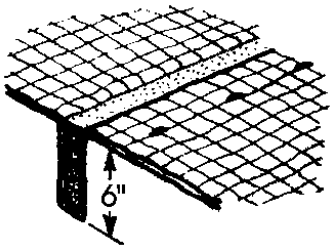


Overlap: Overlap edges of the strips at least 4". Staple every 3 feet down the center of the strip.

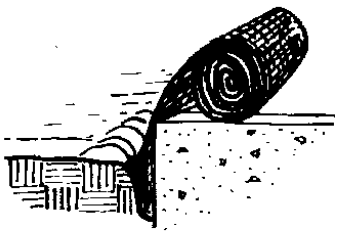




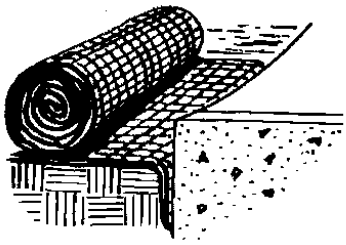
Joining Strips: Insert the new roll of net in a trench, as with the Anchor Slot. Overlap the up-channel end of the previous roll 18" and turn the end under 6". Staple the end of the previous roll just below the anchor slot and at the end at 12" intervals.



Check Slots: On erodible soils or steep slopes, check slots should be made every 15 feet. Insert a fold of the net into a 6" trench and tamp firmly. Staple at 12" intervals across the net. Lay the net smoothly on the surface of the soil - do not stretch the net, and do not allow wrinkles.



Anchoring Ends At Structures: Place the end of the net in a 6" slot on the up-channel side of the structure. Fill the trench and tamp firmly. Roll the net up the channel. Place staples at 12" intervals along the anchor end of the net.



From: Virginia Soil and Water Conservation Commission, 1985

City of Colorado Springs Storm Water Quality	Figure ECB-2 Erosion Control Blanket Installation Requirements

DEN/M/153722.CS.CB/FigECB-2/9-99

Inlet Protection

What it is

Inlet protection is a sediment control barrier formed around a storm drain inlet. A number of alternative inlet protection designs are available, including:

- Silt Fence Inlet Protection.
- Straw Bale Barrier Inlet Protection.
- Block and Gravel Bag Inlet Protection.
- Curb Socks Inlet Protection.

When and Where to use it

Application of inlet protection differs by design.

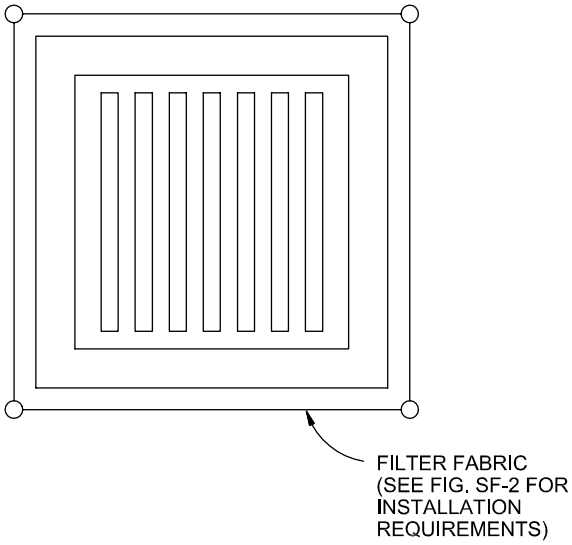
- Filter fabric and straw bale inlet protection are used for area inlets (not located within streets).
- Block and gravel bag curb inlet protection is used for street inlets in sumps.
- Curb sock protection is used for street inlets in sumps or on continuous grade.

When and Where NOT to use it

- Filter fabric and straw bale inlet protection cannot be used for drain inlets that are paved because these designs require excavation and/or staking of materials.
- Block and gravel bag inlet protection is not recommended for continuous grade inlets due to concerns about damage from bypassed flow.

Construction Detail and Maintenance Requirements

Figures IP-1 through IP-4 provide a construction detail and maintenance requirements for each inlet protection design alternative.



FILTER FABRIC INLET PROTECTION

NTS

FILTER FABRIC INLET PROTECTION NOTES

INSTALLATION REQUIREMENTS

1. INLET PROTECTION SHALL BE INSTALLED IMMEDIATELY AFTER CONSTRUCTION OF INLET.

2. SEE SILT FENCE FIGURE SF-2 FOR INSTALLATION REQUIREMENTS.

3. POSTS ARE TO BE PLACED AT EACH CORNER OF THE INLET AND AROUND THE EDGES AT A MAXIMUM SPACING OF 3 FEET.

MAINTENANCE REQUIREMENTS

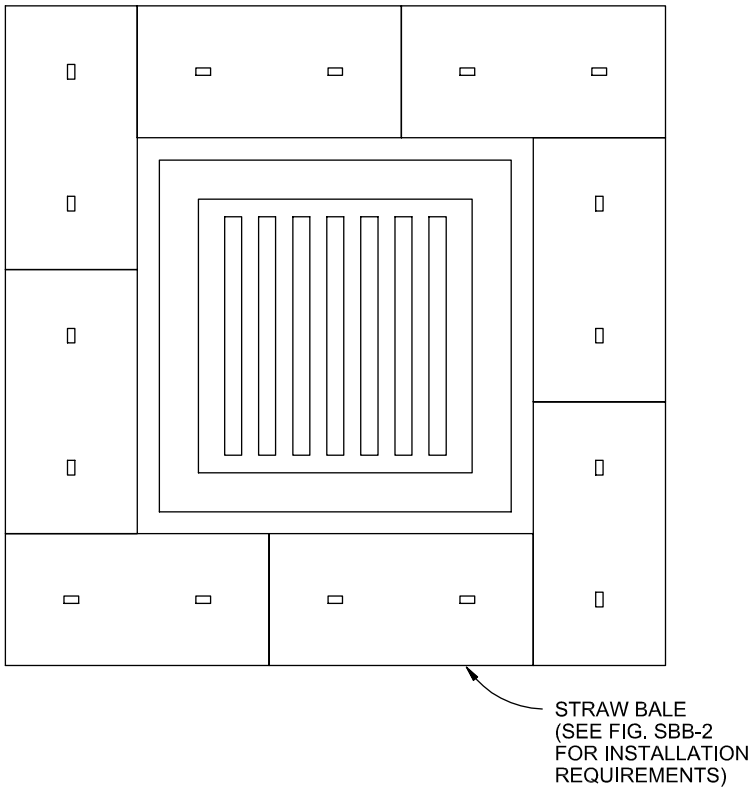
1. CONTRACTOR SHALL INSPECT INLET PROTECTION IMMEDIATELY AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL, AND WEEKLY DURING PERIODS NO RAINFALL.

2. DAMAGED, COLLAPSED, UNENTRENCHED OR INEFFECTIVE INLET PROTECTION SHALL BE PROMPTLY REPAIRED OR REPLACED.

3. SEDIMENT SHALL BE REMOVED FROM BEHIND FILTER FABRIC WHEN IT ACCUMULATES TO HALF THE EXPOSED GEOTEXTILE HEIGHT.

4. FILTER FABRIC PROTECTION SHALL BE REMOVED WHEN ADEQUATE VEGETATIVE COVER IS ATTAINED IN THE DRAINAGE AREA AS APPROVED BY THE CITY.

City of Colorado Springs Stormwater Quality	Figure IP-1 Filter Fabric Inlet Protection Construction Detail and Maintenance Requirements



STRAW BALE INLET PROTECTION

NTS

STRAW BALE INLET PROTECTION NOTES

INSTALLATION REQUIREMENTS

1. INLET PROTECTION SHALL BE INSTALLED IMMEDIATELY AFTER CONSTRUCTION OF INLET.

2. BALES ARE TO BE PLACED IN A SINGLE ROW AROUND THE INLET WITH THE END OF THE BALES TIGHTLY ABUTTING ONE ANOTHER.

3. SEE STRAW BALE BARRIER FIGURE SBB-2 FOR INSTALLATION REQUIREMENTS.

MAINTENANCE REQUIREMENTS

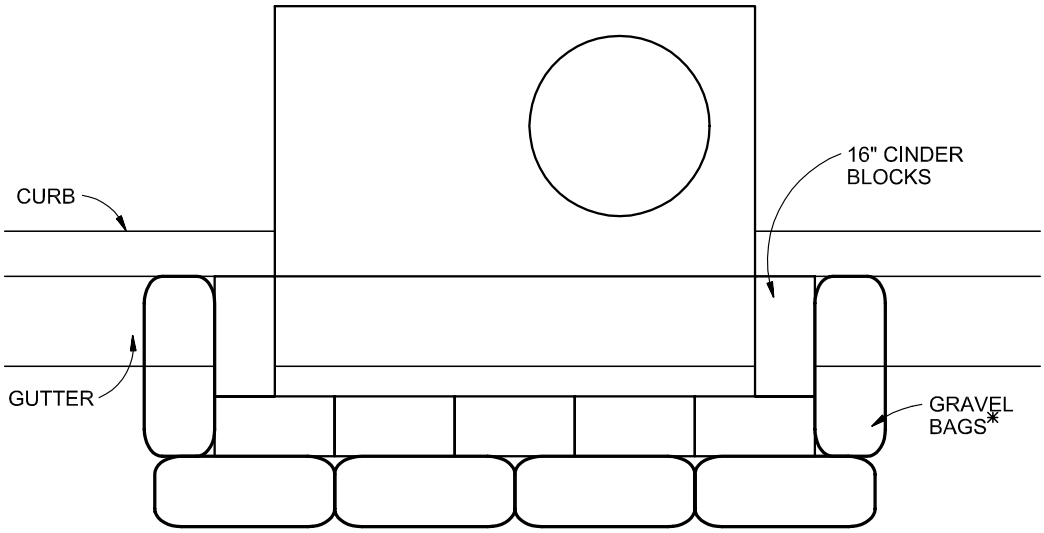
1. CONTRACTOR SHALL INSPECT STRAW BALE INLET PROTECTION IMMEDIATELY AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL, AND WEEKLY DURING PERIODS NO RAINFALL.
.

2. DAMAGED OR INEFFECTIVE INLET PROTECTION SHALL PROMPTLY BE REPAIRED, REPLACING BALES IF NECESSARY, AND UNENTRENCHED BALES NEED TO BE REPAIRED WITH COMPACTED BACKFILL MATERIAL.

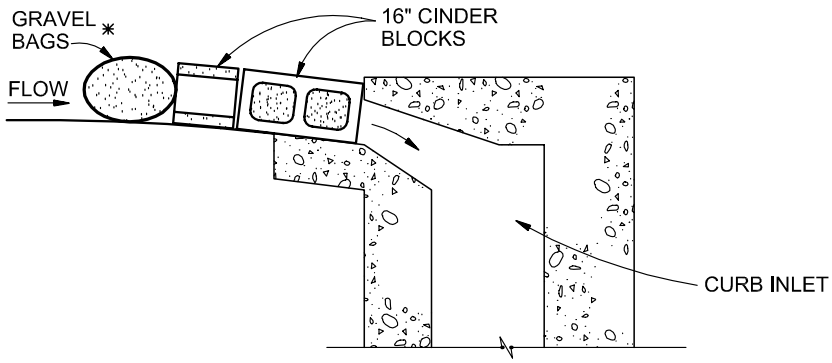
3. SEDIMENT SHALL BE REMOVED FROM BEHIND STRAW BALES WHEN IT ACCUMULATES TO APPROXIMATELY 1/3 THE HEIGHT OF THE BARRIER.

4. INLET PROTECTION SHALL BE REMOVED WHEN ADEQUATE VEGETATIVE COVER IS ATTAINED WITHIN THE DRAINAGE AREA AS APPROVED BY THE CITY.

City of Colorado Springs Stormwater Quality	Figure IP-2 Straw Bale Inlet Protection Construction Detail and Maintenance Requirements



PLAN



SECTION

BLOCK AND GRAVEL BAG*CURB INLET PROTECTION

NTS

BLOCK AND GRAVEL BAG*CURB INLET PROTECTION NOTES

INSTALLATION REQUIREMENTS

1. INLET PROTECTION SHALL BE INSTALLED IMMEDIATELY AFTER CONSTRUCTION OF INLET.

2. CONCRETE BLOCKS ARE TO BE LAID AROUND THE INLET IN A SINGLE ROW ON THEIR SIDES, ABUTTING ONE ANOTHER WITH THE OPEN ENDS OF THE BLOCK FACING OUTWARD.

3. GRAVEL BAGS ARE TO BE PLACED AROUND THE CONCRETE BLOCKS CLOSELY ABUTTING ONE ANOTHER SO THERE ARE NO GAPS.

4. GRAVEL BAGS ARE TO CONTAIN WASHED SAND OR GRAVEL APPROXIMATELY 3/4 INCH IN DIAMETER.

5. BAGS ARE TO BE MADE OF 1/4" INCH WIRE MESH (USED WITH GRAVEL ONLY) OR GEOTEXTILE.

MAINTENANCE REQUIREMENTS

1. CONTRACTOR SHALL INSPECT INLET PROTECTION IMMEDIATELY AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL, AND WEEKLY DURING PERIODS NO RAINFALL.
.

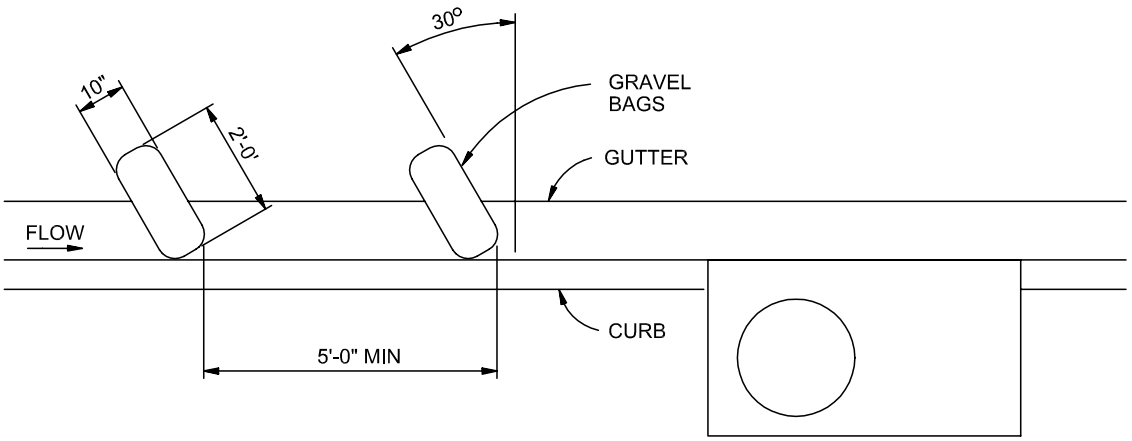
2. DAMAGED OR INEFFECTIVE INLET PROTECTION SHALL PROMPTLY BE REPAIRED OR REPLACED.

3. SEDIMENT SHALL BE REMOVED WHEN SEDIMENT HAS ACCUMULATED TO APPROXIMATELY 1/2 THE DESIGN DEPTH OF THE TRAP.

4. INLET PROTECTION SHALL BE REMOVED WHEN ADEQUATE VEGETATIVE COVER IS ATTAINED WITHIN THE DRAINAGE AREA AS APPROVED BY THE CITY.

* AN ALTERNATE 3/4" TO 1" GRAVEL FILTER OVER A WIRE SCREEN MAY BE USED IN PLACE OF GRAVEL BAGS. THE WIRE MESH SHALL EXTEND ABOVE THE TOP OF THE CONCRETE BLOCKS AND THE GRAVEL PLACED OVER THE WIRE SCREEN TO THE TOP OF THE CONCRETE BLOCKS.

City of Colorado Springs Stormwater Quality	Figure IP-3 Block & Gravel Bag Curb Inlet Protection Construction Detail and Maintenance Requirements



CURB SOCK INLET PROTECTION

NTS

CURB SOCK INLET PROTECTION NOTES

INSTALLATION REQUIREMENTS

1. INLET PROTECTION SHALL BE INSTALLED IMMEDIATELY AFTER CONSTRUCTION OF INLET.

2. SOCK IS TO BE MADE OF 1/4 INCH WIRE MESH (USED WITH GRAVEL ONLY) OR GEOTEXTILE.

3. WASHED SAND OR GRAVEL 3/4 INCH TO 4 INCHES IN DIAMETER IS PLACED INSIDE THE SOCK.

4. PLACEMENT OF THE SOCK IS TO BE 30 DEGREES FROM PERPENDICULAR IN THE OPPOSITE DIRECTION OF FLOW.

5. SOCKS ARE TO BE FLUSH WITH THE CURB AND SPACED AT A MINIMUM 5 FEET APART.

6. AT LEAST 2 CURB SOCKS IN SERIES IS REQUIRED.

MAINTENANCE REQUIREMENTS

1. CONTRACTOR SHALL INSPECT INLET PROTECTION IMMEDIATELY AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL AND WEEKLY DURING PERIODS NO RAINFALL.

2. DAMAGED OR INEFFECTIVE INLET PROTECTION SHALL PROMPTLY BE REPAIRED OR REPLACED.

3. SEDIMENT SHALL BE REMOVED FROM BEHIND THE SOCK WHEN GUTTER WIDTH IS FILLED.

4. INLET PROTECTION SHALL BE REMOVED WHEN ADEQUATE VEGETATIVE COVER IS ATTAINED WITHIN THE DRAINAGE AREA AS APPROVED BY THE CITY.

City of Colorado Springs Stormwater Quality	Figure IP-4 Curb Sock Inlet Protection Construction Detail and Maintenance Requirements

Mulching

What it is

Mulching is used to temporarily stabilize soils by securely applying materials such as grass, hay, woodchips or wood fibers to the soil's surface. Mulching protects the soil from raindrop impact and reduces the velocity of overland runoff. Mulch also aids in the growth of temporary seeding by holding seeds and topsoil in place, retaining moisture, and insulating against extreme temperatures.

When and Where to use it

- All disturbed areas and stockpiles shall be mulched within 21 days after final grade is reached.
- Disturbed areas and stockpiles which are not at final grade but will remain dormant for longer than 30 days shall also be mulched within 21 days after interim grading.
- An area that is going to remain in an interim state for more than 60 days shall also be seeded.
- Mulching is <u>always</u> to be used when applying temporary or permanent seeding.
- Mulching is often used when temporary seeding cannot be used due to the season or climate.

When and Where NOT to use it

- In areas that will involve paving, building, or utility construction within 21 days after final grade is reached.

Application Techniques and Maintenance Requirements

Figure MU-1 provides application techniques and maintenance requirements for mulching.

MULCHING NOTES

INSTALLATION REQUIREMENTS

1. ALL DISTURBED AREAS MUST BE MULCHED WITHIN 21 DAYS AFTER FINAL GRADE AND SEEDED AREAS ARE TO BE MULCHED WITHIN 24 HOURS AFTER SEEDING.

2. MATERIAL USED FOR MULCH CAN BE CERTIFIED CLEAN, WEED- AND SEED-FREE LONG STEMMED FIELD OR MARSH HAY, OR STRAW OF OATS, BARLEY, WHEAT, RYE, OR TRITICALE CERTIFIED BY THE COLORADO DEPARTMENT OF AGRICULTURE WEED FREE FORAGE CERTIFICATION PROGRAM.

3. HYDRAULIC MULCHING MATERIAL SHALL CONSIST OF VIRGIN WOOD FIBER MANUFACTURED FROM CLEAN WHOLE WOOD CHIPS. WOOD CHIPS CANNOT CONTAIN ANY GROWTH OR GERMINATION INHIBITORS OR BE PRODUCED FROM RECYCLED MATERIAL. GRAVEL CAN ALSO BE USED.

4. MULCH IS TO BE APPLIED EVENLY AT A RATE OF 2 TONS PER ACRE.

5. MULCH IS TO BE ANCHORED EITHER BY CRIMPING (TUCKING MULCH FIBERS 4 INCHES INTO THE SOIL), USING NETTING (USED ON SMALL AREAS WITH STEEP SLOPES), OR WITH A TACKIFIER.

6. HYDRAULIC MULCHING AND TACKIFIERS ARE NOT TO BE USED IN THE PRESENCE OF FREE SURFACE WATER.

MAINTENANCE REQUIREMENTS

1. REGULAR INSPECTIONS ARE TO BE MADE OF ALL MULCHED AREAS.

2. MULCH IS TO BE REPLACED IMMEDIATELY IN THOSE AREAS IT HAS BEEN REMOVED, AND IF NECESSARY THE AREA SHOULD BE RESEEDED.

Sediment Basin

What it is

A temporary sediment basin detains sediment-laden runoff long enough to allow much of the sediment to settle out. Sediment basins are constructed by excavation and/or by placing an earthen embankment across a low area or drainage swale. Basins can be designed to maintain a permanent pool or to drain completely dry through a controlled outlet structure.

When and Where to use it

- Required in disturbed areas draining more than one acre.
- Where there is sufficient space and appropriate topography.
- In areas that allow access for maintenance and sediment removal.
- Positioned so that it captures sediment from the entire upstream disturbed area.
- Where a permanent detention basin is planned for the site.

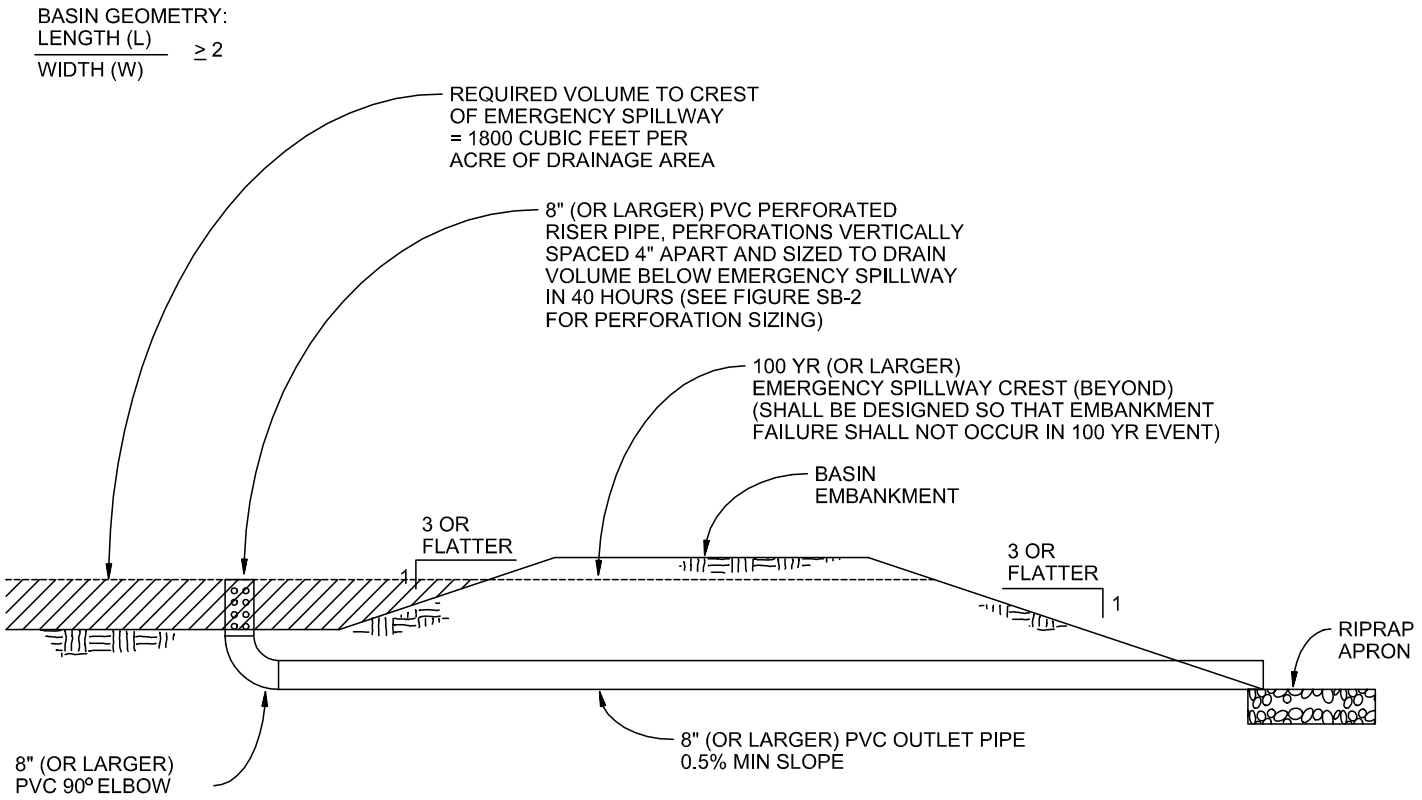
When and Where NOT to use it

- Sediment basins are not to be installed in active streams.

This low area will provide for some removal of sediment; however, it lacks a designed outlet structure.

Construction Detail and Maintenance Requirements

Figure SB-1 provides a construction detail and maintenance requirements for a sediment basin.



SEDIMENT BASIN

NTS

SEDMENT BASIN NOTES

INSTALLATION REQUIREMENTS

1. SEDIMENT BASINS SHALL BE INSTALLED BEFORE ANY CLEARING AND/OR GRADING IS UNDERTAKEN.

2. THE AREA UNDER WHICH THE EMBANKMENT IS TO BE INSTALLED SHALL BE CLEARED, GRUBBED, AND STRIPPED OF ALL VEGETATION AND ROOT MAT.

3. THE OUTLET OF THE BASIN SHALL BE DESIGNED TO DRAIN ITS VOLUME IN 40 HOURS.

4. THE OUTLET IS TO BE LOCATED AT THE FURTHEST DISTANCE FROM THE INLET OF THE BASIN. BAFFLES MAY BE NEEDED TO INCREASE THE FLOW LENGTH AND SETTLING TIME.

5. EMBANKMENT MATERIAL SHALL CONSIST OF SOIL WITH A MINIMUM OF 15% PASSING A #200 SIEVE. EXCAVATED SOIL CAN BE USED IF IT MEETS THIS REQUIREMENT.

6. EMBANKMENT IS TO BE COMPACTED TO AT LEAST 90% OF MAXIMUM DENSITY AND WITHIN 2% OF OPTIMUM MOISTURE CONTENT ACCORDING TO ASTM D 698.

7. WHEN A BASIN IS INSTALLED NEAR A RESIDENTIAL AREA, FOR SAFETY REASONS, A SIGN SHALL BE POSTED AND THE AREA SECURED WITH A FENCE.

MAINTENANCE REQUIREMENTS

1. CONTRACTOR SHALL INSPECT SEDIMENT BASINS AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL, AND WEEKLY DURING PERIODS NO RAINFALL.

2. SEDIMENT BASINS SHALL BE CLEANED OUT BEFORE SEDIMENT HAS FILLED HALF THE VOLUME OF THE BASIN.

3. SEDIMENT BASINS SHALL REMAIN OPERATIONAL AND PROPERLY MAINTAINED UNTIL THE SITE AREA IS PERMANENTLY STABILIZED WITH ADEQUATE VEGETATIVE COVER AND/OR OTHER PERMANENT STRUCTURE AS APPROVED BY THE CITY.

City of Colorado Springs Stormwater Quality	Figure SB-1 Sediment Basin Construction Detail and Maintenance Requirements

Required Area per Row (in^2)

		Depth at Outlet (ft)							
		1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5
Design Volume (acre-ft)	2	15.04	7.71	5.10	3.76	2.95	2.41	2.02	1.73
	1	7.52	3.86	2.55	1.88	1.48	1.21	1.01	0.87
	0.6	4.51	2.31	1.53	1.13	0.89	0.72	0.61	0.52
	0.4	3.01	1.54	1.02	0.75	0.59	0.48	0.40	0.35
	0.2	1.50	0.77	0.51	0.38	0.30	0.24	0.20	0.17
	0.1	0.75	0.39	0.26	0.19	0.15	0.12	0.10	0.09
	0.06	0.45	0.23	0.15	0.11	0.09	0.07	0.06	0.05
	0.04	0.30	0.15	0.10	0.08	0.06	0.05	0.04	0.03
	0.02	0.15	0.08	0.05	0.04	0.03	0.02	0.02	0.02
	0.01	0.08	0.04	0.03	0.02	0.01	0.01	0.01	0.01

TABLE SB-1

Circular Perforation Sizing

Hole Diameter (in)	Hole Diameter (in)	Area per Row (in^2)		
		n = 1	n = 2	n = 3
1/4	0.250	0.05	0.10	0.15
5/16	0.313	0.08	0.15	0.23
3/8	0.375	0.11	0.22	0.33
7/16	0.438	0.15	0.30	0.45
1/2	0.500	0.20	0.39	0.59
9/16	0.563	0.25	0.50	0.75
5/8	0.625	0.31	0.61	0.92
11/16	0.688	0.37	0.74	1.11
3/4	0.750	0.44	0.88	1.33
7/8	0.875	0.60	1.20	1.80
1	1.000	0.79	1.57	2.36
1 1/8	1.125	0.99	1.99	2.98
1 1/4	1.250	1.23	2.45	3.68
1 3/8	1.375	1.48	2.97	4.45
1 1/2	1.500	1.77	3.53	5.30
1 5/8	1.625	2.07	4.15	6.22
1 3/4	1.750	2.41	4.81	7.22
1 7/8	1.875	2.76	5.52	8.28
2	2.000	3.14	6.28	9.42
n = Number of columns of perforations				
Minimum steel plate thickness		1/4"	5/16"	3/8"

TABLE SB-2

Silt Fence

What it is

A silt fence is a temporary sediment barrier constructed of filter fabric stretched across supporting posts. The bottom edge of the fabric is entrenched and covered with backfill.

When and Where to use it

- On the down gradient perimeters of a construction site.
- On a contour to control overland sheet flow.
- At the top or toe of a steep slope.
- As a form of inlet protection (see inlet protection factsheet).

Figure SF-1 depicts five cases where the use of silt fence is appropriate.

When and Where NOT to use it

- In areas of concentrated flows such as in ditches, swales or channels that drain areas greater than 1.0 acre.
- At the top of a slope or at high points which do not receive any drainage flows.

This photo reveals a silt fence that has become unentrenched because it was not securely installed.

This photo illustrates what will happen to a silt fence if it is installed in an area of concentrated flow.

Construction Detail and Maintenance Requirements

Figure SF-2 provides a construction detail and maintenance requirements for a silt fence.

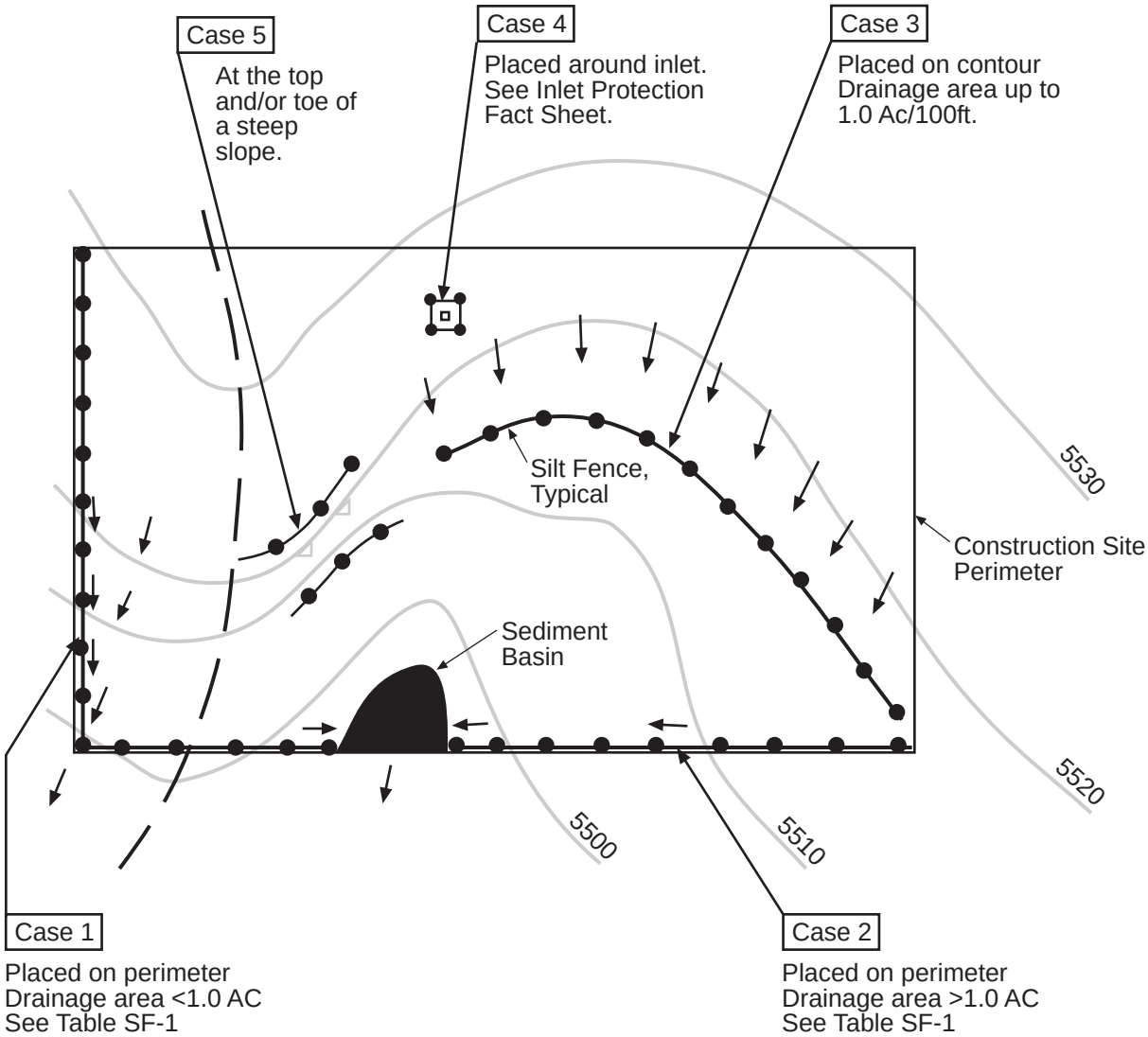


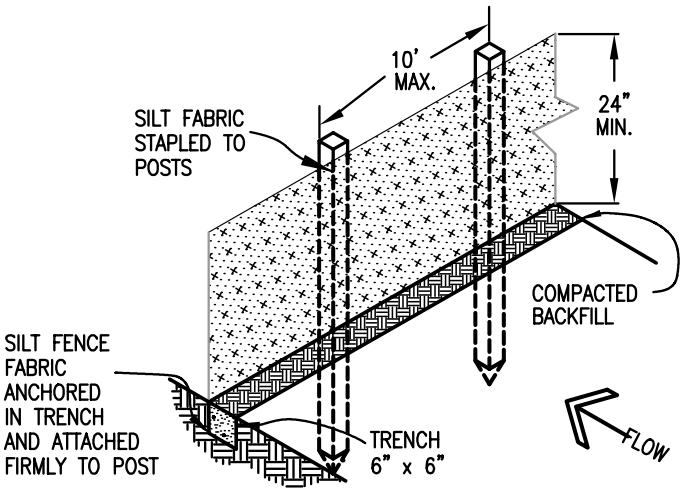
Table SF-1

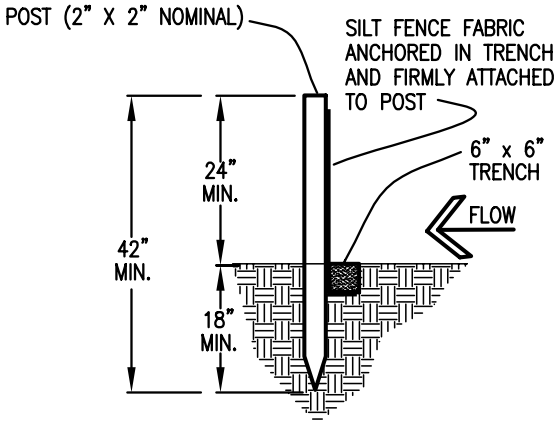
Silt Fence Used as Perimeter Control	Case 1		Case 2 DA > 1.0 AC
	DA < 0.25 AC	0.25 < DA < 1 AC	
Continuous Grade	OK (1)	OK (1)	OK (1)
Area of Concentrated Flow	OK	NO (2)	NO (3)

(1) Temporary Swale or Straw Bale Barrier may be used as alternative to a Silt Fence.
(2) Check Dam may also be used as alternative to Silt Fence at low point.
(3) Sediment Basin is required for concentrated flow from drainage areas > 1.0 AC.

City of Colorado Springs Storm Water Quality	Figure SF-1 Silt Fence Application Examples

DEN/M/153722.CS.CB/FigSF-1/9-99





SILT FENCE

SILT FENCE NOTES

INSTALLATION REQUIREMENTS

1. SILT FENCES SHALL BE INSTALLED PRIOR TO ANY LAND DISTURBING ACTIVITIES.

2. WHEN JOINTS ARE NECESSARY, SILT FENCE GEOTEXTILE SHALL BE SPLICED TOGETHER ONLY AT SUPPORT POST AND SECURELY SEALED.

3. METAL POSTS SHALL BE "STUDDED TEE" OR "U" TYPE WITH MINIMUM WEIGHT OF 1.33 POUNDS PER LINEAR FOOT. WOOD POSTS SHALL HAVE A MINIMUM DIAMETER OR CROSS SECTION DIMENSION OF 2 INCHES.

4. THE FILTER MATERIAL SHALL BE FASTENED SECURELY TO METAL OR WOOD POSTS USING WIRE TIES, OR TO WOOD POSTS WITH 3/4" LONG #9 HEAVY-DUTY STAPLES. THE SILT FENCE GEOTEXTILE SHALL NOT BE STAPLED TO EXISTING TREES.

5. WHILE NOT REQUIRED, WIRE MESH FENCE MAY BE USED TO SUPPORT THE GEOTEXTILE. WIRE FENCE SHALL BE FASTENED SECURELY TO THE UPSLOPE SIDE OF THE POSTS USING HEAVY-DUTY WIRE STAPLES AT LEAST 3/4" LONG, TIE WIRES OR HOG RINGS. THE WIRE SHALL EXTEND INTO THE TRENCH A MINIMUM OF 6" AND SHALL NOT EXTEND MORE THAN 3' ABOVE THE ORIGINAL GROUND SURFACE.

6. ALONG THE TOE OF FILLS, INSTALL THE SILT FENCE ALONG A LEVEL CONTOUR AND PROVIDE AN AREA BEHIND THE FENCE FOR RUNOFF TO POND AND SEDIMENT TO SETTLE. A MINIMUM DISTANCE OF 5 FEET FROM THE TOE OF THE FILL IS RECOMMENDED.

7. THE HEIGHT OF THE SILT FENCE FROM THE GROUND SURFACE SHALL BE MINIMUM OF 24 INCHES AND SHALL NOT EXCEED 36 INCHES; HIGHER FENCES MAY INPOUND VOLUMES OF WATER SUFFICIENT TO CAUSE FAILURE OF THE STRUCTURE.

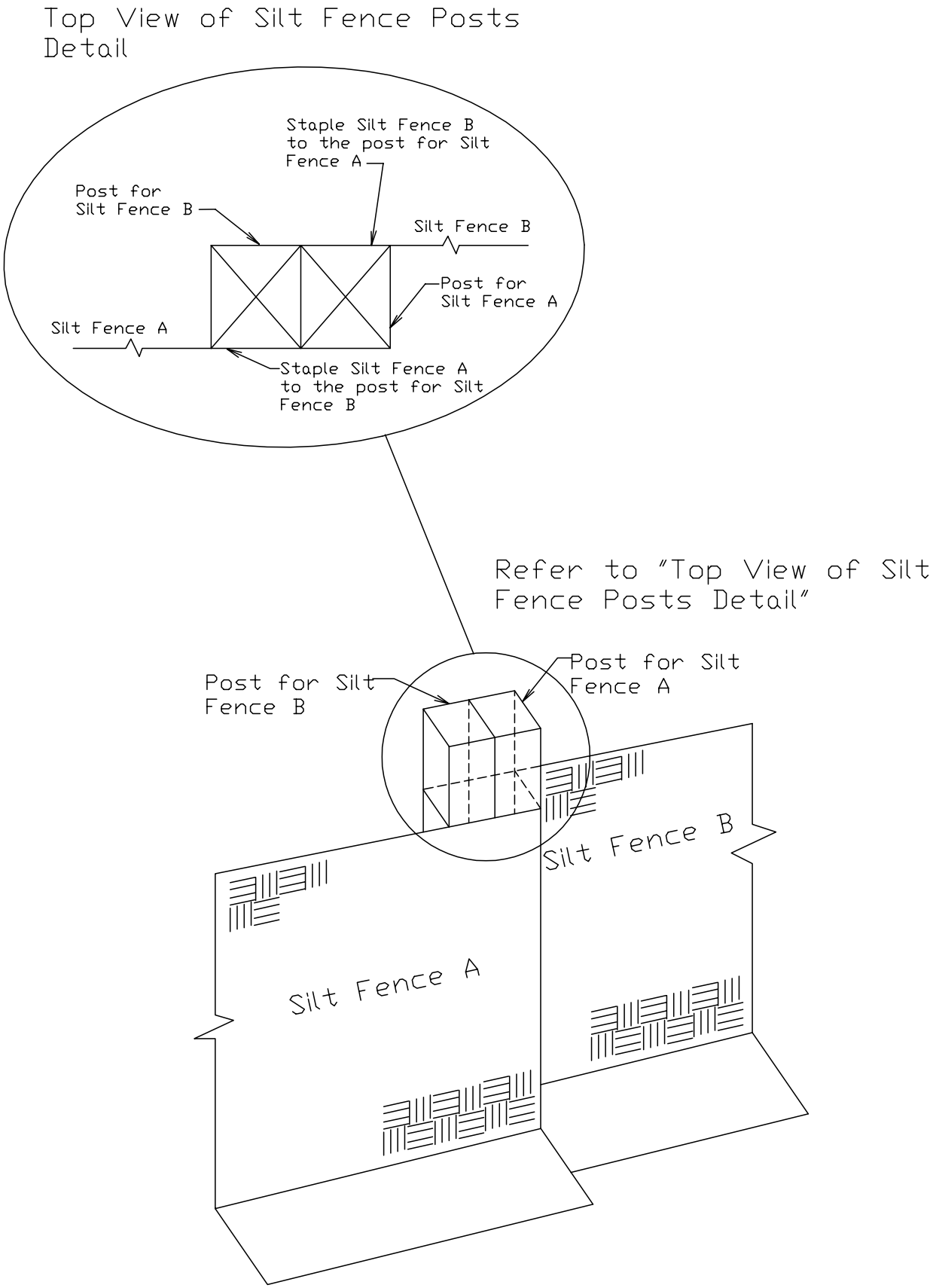
MAINTENANCE REQUIREMENTS

1. CONTRACTOR SHALL INSPECT SILT FENCES IMMEDIATELY AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL, AND WEEKLY DURING PERIODS OF NO RAINFALL. DAMAGED, COLLAPSED, UNENTRENCHED OR INEFFECTIVE SILT FENCES SHALL BE PROMPTLY REPAIRED OR REPLACED.

2. SEDIMENT SHALL BE REMOVED FROM BEHIND SILT FENCE WHEN IT ACCUMULATES TO HALF THE EXPOSED GEOTEXTILE HEIGHT.

3. SILT FENCES SHALL BE REMOVED WHEN ADEQUATE VEGETATIVE COVER IS ATTAINED AS APPROVED BY THE CITY.

City of Colorado Springs Stormwater Quality	Figure SF-2 Silt Fence Construction Detail and Maintenance Requirements



City of Colorado Springs
Stormwater Quality

Figure SF-3
Silt Fence Joint Tying
Construction Detail and Maintenance Requirements

Slope Drain

What it is

Slope drains are either flexible or rigid pipes that convey concentrated runoff from the top of a slope to a stable discharge point at the bottom of the slope. Slope drains can be either temporary or permanent depending on the method of installation and material used.

When and Where to use it

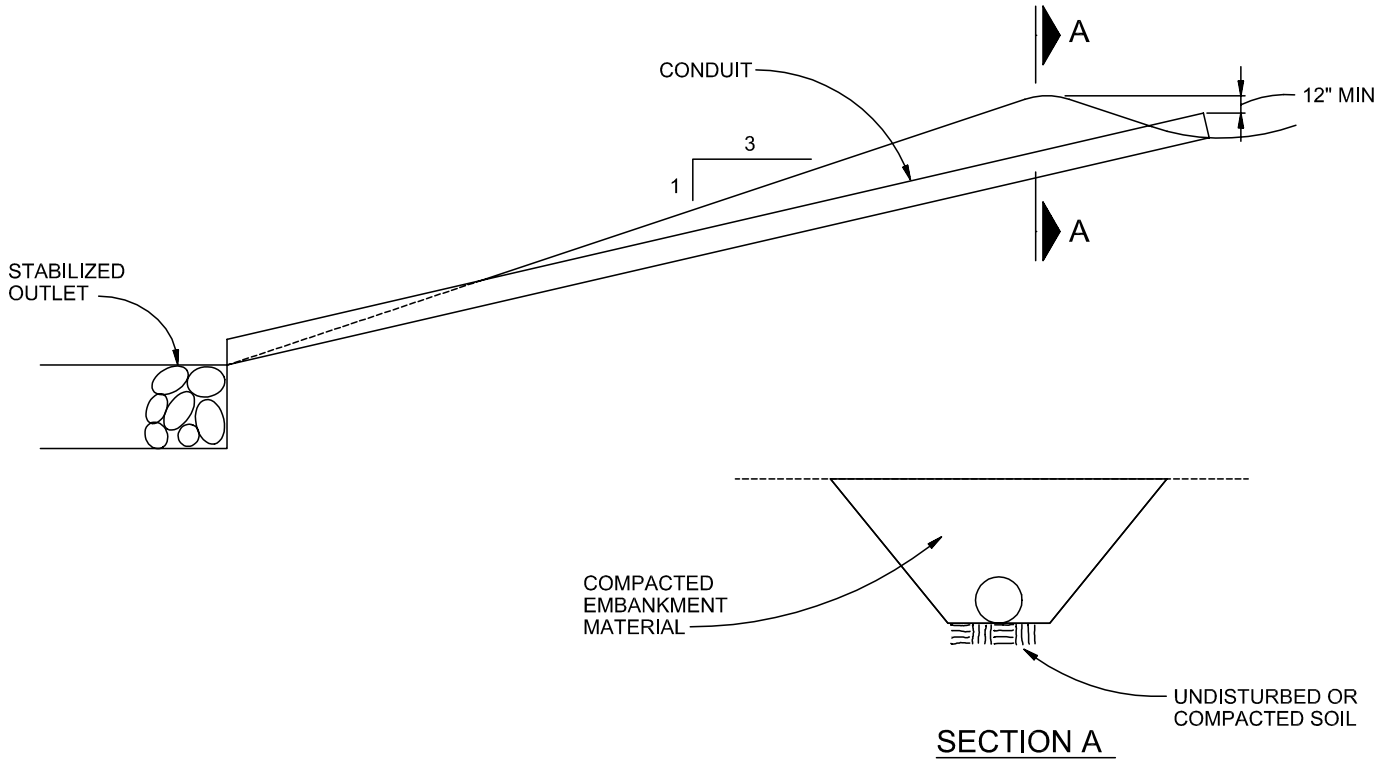
- At the top of cut-and-fill slopes to convey stormwater down the slope.
- Before a slope has been stabilized or before permanent drainage structures are ready for use.
- In combination with other BMPs that have been used to concentrate flows, including temporary swales.

When and Where NOT to use it

Slope drains should not be used for drainage areas larger than 5 acres.

Construction Detail and Maintenance Requirements

Figure SD-1 provides a construction detail and maintenance requirements for a slope drain.



SLOPE DRAIN

NTS

SLOPE DRAIN NOTES

INSTALLATION REQUIREMENTS

1. THE SLOPE DRAIN IS TO BE DESIGNED TO CONVEY THE PEAK RUNOFF FOR THE 2-YEAR STORM.

2. PIPE MATERIAL MAY INCLUDE CORRUGATED METAL, OR RIGID OR FLEXIBLE PLASTIC.

3. EMBANKMENT MATERIAL SHALL CONSIST OF SOIL WITH A MINIMUM OF 15% PASSING A #200 SIEVE. EXCAVATED SOIL CAN BE USED IF IT MEETS THIS REQUIREMENT.

4. EMBANKMENT IS TO BE COMPACTED TO AT LEAST 90% OF MAXIMUM DENSITY AND WITHIN 2% OF OPTIMUM MOISTURE CONTENT ACCORDING TO ASTM D 698.

5. SLOPE DRAIN SECTIONS ARE TO BE SECURELY FASTENED TOGETHER AND HAVE WATERTIGHT FITTINGS.

6. THE OUTLET IS TO BE STABILIZED AND, UNLESS THE DRAIN DISCHARGES DIRECTLY TO A SEDIMENT BASIN, A TEMPORARY SURFACE IS TO BE PROVIDED TO CONVEY FLOWS DOWN STREAM.

7. IMMEDIATELY STABILIZE ALL AREAS DISTURBED BY INSTALLATION OR REMOVAL OF THE PIPE SLOPE DRAIN.

MAINTENANCE REQUIREMENTS

1. INLET AND OUTLET POINTS ARE TO BE CHECKED REGULARLY, AND AFTER HEAVY STORMS FOR CLOGGING AND OVERCHARGING. ANY BREAKS IN THE PIPE ARE TO BE PROMPTLY REPAIRED, AND CLOGS REMOVED AS NEEDED.

2. WATER IS NOT TO BYPASS OR UNDERCUT THE INLET OR PIPE. IF THESE PROBLEMS DO EXIST, THE HEADWALL NEEDS TO BE REINFORCED WITH COMPACT EARTH OR SANDBAGS.

3. THE OUTLET POINT IS TO BE FREE OF EROSION, AND, IF NECESSARY, ADDITIONAL OUTLET PROTECTION SHOULD BE INSTALLED.

4. CONSTRUCTION TRAFFIC IS NOT TO CROSS THE SLOPE DRAIN AND MATERIALS ARE NOT TO BE PLACED ON IT.

5. THE SLOPE DRAIN IS TO REMAIN IN PLACE UNTIL THE SLOPE HAS BEEN COMPLETELY STABILIZED OR UP TO 30 DAYS AFTER PERMANENT SLOPE STABILIZATION.

City of Colorado Springs Stormwater Quality	Figure SD-1 Slope Drain Construction Detail and Maintenance Requirements

Straw Bale Barriers

What it is

A straw bale barrier is a temporary sediment barrier consisting of a row of entrenched and anchored straw bales used to retain sediment from runoff in small drainage areas of disturbed soil.

When and Where to use it

- At the base of a slope.
- On the down gradient perimeters of a construction site.
- On a contour to control overland sheet flow.
- As a form of check dam (see check dam factsheet).
- As a form of inlet protection (see inlet protection factsheet).

Figure SBB-1 depicts six cases where the use of Straw Bale Barriers is appropriate.

When and Where NOT to use it

- In areas of concentrated flows such as in ditches, swales, or channels that drain areas greater than 1.0 acre (unless used as a form of check dam).
- At the top of a slope or at high points which do not receive any drainage flows.

This straw bale barrier was not installed properly because runoff is able to flow around the barrier.

Construction Detail and Maintenance Requirements

Figure SBB-2 provides a construction detail and maintenance requirements for a straw bale barrier.

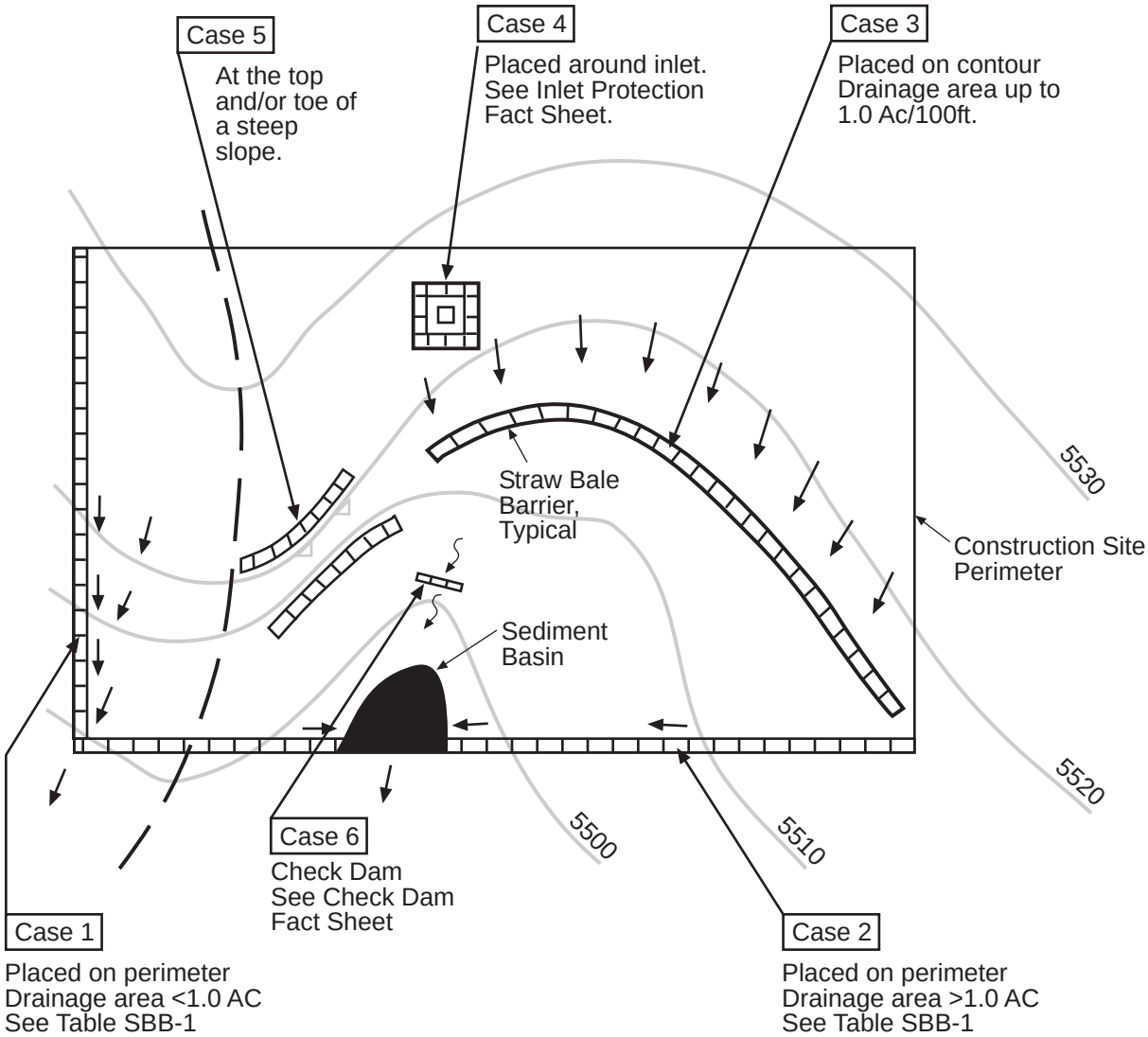
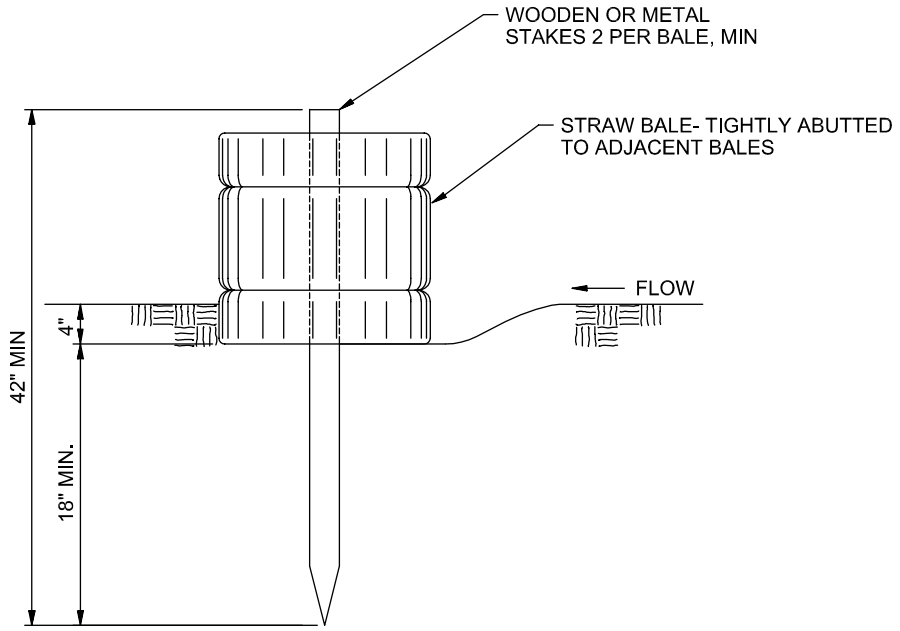


Table SBB-1

Straw Bale Barrier Used as Perimeter Control	Case 1 DA < 1.0 AC	Case 2 DA > 1.0 AC
Continuous Grade	OK (1)	OK (1)
Area of Concentrated Flow	OK (2)	NO (3)

(1) Temporary Swale or Silt Fence may be used as alternative to a Straw Bale Barrier.
(2) Straw Bale Check Dam may be used at low points.
(3) Sediment Basin is required for concentrated flow from drainage areas > 1.0 AC.

City of Colorado Springs Storm Water Quality	Figure SBB-1 Straw Bale Barrier Application Examples



STRAW BALE BARRIER

NTS

STRAW BALE BARRIER NOTES

INSTALLATION REQUIREMENTS

1. STRAW BALE BARRIERS SHALL BE INSTALLED PRIOR TO ANY LAND DISTURBING ACTIVITIES.

2. BALES SHALL CONSIST OF APPROXIMATELY 5 CUBIC FEET OF CERTIFIED WEED FREE HAY OR STRAW AND WEIGH NOT LESS THAN 35 POUNDS.

3. BALES ARE TO BE PLACED IN A SINGLE ROW WITH THE END OF THE BALES TIGHTLY ABUTTING ONE ANOTHER.

4. EACH BALE IS TO BE SECURELY ANCHORED WITH AT LEAST TWO STAKES AND THE FIRST STAKE IS TO BE DRIVEN TOWARD THE PREVIOUSLY LAID BALE TO FORCE THE BALES TOGETHER.

5. STAKES ARE TO BE A MINIMUM OF 42 INCHES LONG. METAL STAKES SHALL BE STANDARD "T" OR "U" TYPE WITH MINIMUM WEIGHT OF 1.33 POUNDS PER LINEAR FOOT. WOOD STAKES SHALL HAVE A MINIMUM DIAMETER OR CROSS SECTION DIMENSION OF 2 INCHES.

6. BALES ARE TO BE BOUND WITH EITHER WIRE OR STRING AND ORIENTED SUCH THAT THE BINDINGS ARE AROUND THE SIDES AND NOT ALONG THE TOPS AND BOTTOMS OF THE BALE.

7. GAPS BETWEEN BALES ARE TO BE CHINKED (FILLED BY WEDGING) WITH STRAW OR THE SAME MATERIAL OF THE BALE.

8. END BALES ARE TO EXTEND UPSLOPE SO THE TRAPPED RUNOFF CANNOT FLOW AROUND THE ENDS OF THE BARRIER.

MAINTENANCE REQUIREMENTS

1. CONTRACTOR SHALL INSPECT STRAW BALE BARRIERS IMMEDIATELY AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL, AND WEEKLY DURING PERIODS NO RAINFALL.

2. DAMAGED OR INEFFECTIVE BARRIERS SHALL PROMPTLY BE REPAIRED, REPLACING BALES IF NECESSARY, AND UNENTRENCHED BALES NEED TO BE REPAIRED WITH COMPACTED BACKFILL MATERIAL.

3. SEDIMENT SHALL BE REMOVED FROM BEHIND STRAW BALE BARRIERS WHEN IT ACCUMULATES TO APPROXIMATELY 1/2 THE HEIGHT OF THE BARRIER.

4. STRAW BALE BARRIERS SHALL BE REMOVED WHEN ADEQUATE VEGETATIVE COVER IS ATTAINED AS APPROVED BY THE CITY.

City of Colorado Springs Stormwater Quality	Figure SBB-2 Straw Bale Barrier Construction Detail and Maintenance Requirements

Street Wash Water Associated with Construction Activities

The CDPS Municipal Stormwater Discharge Permit for the City of Colorado Springs calls for the development and implementation of best management practices to minimize the impacts from street wash water associated with construction activities. The proposed best management practices (BMPs) are listed below. The permit allows these discharges into State Waters without obtaining a permit providing BMPs are maintained.

Activity

During construction, it is not uncommon for dirt to accumulate on roadways in the construction site and adjacent to the site. This occurs when BMPs have not been implemented on the site or from the vehicles tracking materials around the site. If the sediment is not removed from the roadways, it will be washed into the storm sewer or other drainage facilities during the next storm event. Therefore, it is necessary to clean the roadways within or adjacent to a construction site on a regular basis. There are several methods for doing this, which include sweeping the streets, scraping the streets and using water to wash down the street. The practice of washing with water, while not encouraged, may be necessary in some cases.

Areas of Concern

The concern with construction street sweeping is that the water will carry sediment into the storm sewer and then into State Waters. The sediment can have a negative impact on the aquatic life in the stream.

While the water used to clean the street may be potable in some cases, it is believed that the act of spraying the water would dissipate the chlorine.

BMPs

1. Prior to washing the street with water, efforts will first be made to scrape and sweep the dirt off the roadways. Scraped or swept material will not be deposited in the storm sewer or other drainage facility.

2. Inlet protection or other BMPs will be in place prior to the washing of the streets. Materials collected by the BMP will be removed and will not be disposed of in a manner that would result in it entering the storm sewer or other drainage system.

3. Where practical, high-pressure wash systems will be used on the hard to remove spots. Washing the entire area with a fire hose will be avoided wherever possible. Water will only be used as needed.

Surface Roughening

What it is

Surface roughening is a temporary erosion control practice where the soil surface is roughened by the creation of grooves, depressions, or steps that run parallel to the contour of the land.

When and Where to use it

- Surface roughening is appropriate for all slopes and should be performed immediately after rough grades have been established in an area.
- Surface roughening can also be used to help establish vegetative cover by reducing runoff velocity and giving seed an opportunity to take hold and grow.
- Surface roughening can be used in combination with other erosion control measures such as mulching and seeding.

When and Where NOT to use it

- Slopes that are not smooth-graded and are left sufficiently rough after final grading do not need further roughening to control erosion.
- Surface roughening alone is not sufficient to stabilize a slope for long periods of times, further stabilization measures should be implemented within two weeks of grading.
- Extremely sandy or rocky soils are not well suited for surface roughening.

Application Techniques and Maintenance Requirements

Figure SR-1 provides application techniques and maintenance requirements for surface roughening.

SURFACE ROUGHENING NOTES

APPLICATION TECHNIQUES

1. STAIR STEP GRADING – USED ON SLOPES WITH GRADIENTS BETWEEN 3:1 AND 2:1 AND FOR SOIL CONTAINING A LARGE AMOUNT OF SMALL ROCKS. STAIRS ARE TO BE WIDE ENOUGH TO WORK WITH STANDARD EARTH MOVING EQUIPMENT.
2. GROOVE CUTTING – USED ON SLOPES WITH GRADIENTS BETWEEN 3:1 AND 2:1. GROOVES ARE TO BE AT LEAST 3 INCHES DEEP AND NO MORE THAN 15 INCHES APART.
3. TRACKING – USED ON SOILS WITH HIGHER SAND CONTENT DUE TO COMPACTION BY HEAVY MACHINERY.

MAINTENANCE REQUIREMENTS

1. REGULAR INSPECTIONS ARE TO BE MADE OF ALL SURFACE ROUGHENED AREAS.
2. SURFACE ROUGHENING IS TO BE REPEATED AS OFTEN AS NECESSARY.
3. VEHICLES OR EQUIPMENT IS NOT TO BE DRIVEN OVER AREAS THAT HAVE BEEN ROUGHENED.
4. AS SURFACE ROUGHENING IS ONLY A TEMPORARY CONTROL, ADDITIONAL TREATMENTS MAY BE NECESSARY TO MAINTAIN THE SOIL SURFACE IN A ROUGHENED CONDITION.

Temporary Seeding

What it is

Temporary seeding is the use of quickly germinating vegetative cover on disturbed areas to stabilize soils and control erosion.

When and Where to use it

- On any disturbed areas that are to remain in an interim state for more than 60 days, but less than one year.

When and Where NOT to use it

- Temporary seeding shall not be used in areas that receive construction traffic; granular material shall be used to stabilize high traffic areas (see Vehicle Tracking Fact Sheet).
- Temporary seeding is not to be used on disturbed areas left in an interim state for more than 1 year. Permanent seeding is then required.

Application Techniques and Maintenance Requirements

Figure TS-1 provides application techniques and maintenance requirements for temporary seeding.

RECOMMENDED ANNUAL GRASSES

SPECIES (COMMON NAME)	GROWTH SEASON	SEEDING DATE	POUNDS OF PURE LIVE SEED (PLS) (PLS/ACRE)	PLANTING DEPTH (INCHES)
1. OATS	COOL	MARCH 16 - APRIL 30	35-50	1-2
2. SPRING WHEAT	COOL	MARCH 16 - APRIL 30	25-35	1-2
3. SPRING BARLEY	COOL	MARCH 16 - APRIL 30	25-35	1-2
4. ANNUAL RYEGRASS	COOL	MARCH 16 - JUNE 30	10-15	1/2
5. MILLET	WARM	MAY 16 - JULY 15	3-15	1/2-3/4
6. SUDANGRASS	WARM	MAY 16 - JULY 15	5-10	1/2-3/4
7. SORGHUM	WARM	MAY 16 - JULY 15	5-10	1/2-3/4
8. WINTER WHEAT	COOL	SEPTEMBER 1 - 30	20-35	1-2
9. WINTER BARLEY	COOL	SEPTEMBER 1 - 30	20-35	1-2
10. WINTER RYE	COOL	SEPTEMBER 1 - 30	20-35	1-2
11. TRITICALE	COOL	SEPTEMBER 1 - 30	25-40	1-2

THIS TABLE WAS TAKEN FROM UDFCD FOR RECOMMENDED ANNUAL GRASSES FOR THE DENVER METROPOLITAN AREA. THIS TABLE MAY BE USED UNLESS A SITE-SPECIFIC SEED MIX IS REQUESTED AND APPROVED.

TABLE TS-1

TEMPORARY SEEDING NOTES

INSTALLATION REQUIREMENTS

1. DISTURBED AREAS ARE TO BE SEEDED WITHIN 21 DAYS AFTER CONSTRUCTION ACTIVITY OR GRADING ENDS IF SEASON ALLOWS.

2. IF NECESSARY, SOIL IS TO BE CONDITIONED FOR PLANT GROWTH BY APPLYING TOPSOIL, FERTILIZER, OR LIME.

3. SOIL IS TO BE TILLED IMMEDIATELY PRIOR TO APPLYING SEEDS. COMPACT SOILS ESPECIALLY NEED TO BE LOOSENED.

4. SEEDBED DEPTH IS TO BE 4 INCHES FOR SLOPES FLATTER THAN 2:1, AND 1 INCH FOR SLOPES STEEPER THAN 2:1.

5. ANNUAL GRASSES LISTED IN TABLE TS-1 ARE TO BE USED FOR TEMPORARY SEEDING. SEED MIXES ARE NOT TO CONTAIN ANY NOXIOUS WEED SEEDS INCLUDING RUSSIAN OR CANADIAN THISTLE, KNAPWEED, PURPLE LOOSESTRIFE, EUROPEAN BINDWEED, JOHNSON GRASS, AND LEAFY SPURGE.

6. TABLE TS-1 ALSO PROVIDES REQUIREMENTS FOR SEEDING RATES, SEEDING DATES, AND PLANTING DEPTHS FOR THE APPROVED TYPES OF ANNUAL GRASSES.

7. SEEDING IS TO BE APPLIED USING MECHANICAL TYPE DRILLS EXCEPT WHERE SLOPES ARE STEEP OR ACCESS IS LIMITED THEN HYDRAULIC SEEDING MAY BE USED.

8. ALL SEEDED AREAS ARE TO BE MULCHED (SEE FACTSHEET ON MULCHING).

9. IF HYDRAULIC SEEDING IS USED THEN HYDRAULIC MULCHING SHALL BE DONE SEPARATELY TO AVOID SEEDS BECOMING ENCAPSULATED IN THE MULCH.

MAINTENANCE REQUIREMENTS

1. REGULAR INSPECTIONS ARE TO BE MADE OF ALL SEEDED AREAS TO ENSURE GROWTH.

2. AREAS WHERE GROWTH IS NOT OCCURRING QUICKLY OR THE MULCH HAS BEEN REMOVED SHALL BE RE-SEEDED AS SOON AS POSSIBLE AND RE-MULCHED IF NEEDED.

3. SEEDED AREAS ARE NOT TO BE DRIVEN OVER WITH CONSTRUCTION EQUIPMENT OR VEHICLES.

Temporary Swale

What it is

A temporary swale is an earth channel used to convey runoff. A temporary swale can be excavated or formed upslope from an earthen berm, and may be lined or unlined.

When and Where to use it

- At the top of a slope to divert upland runoff away from the slope face.
- At the bottom of a slope to convey sediment-laden runoff to a sediment-trapping device such as a sediment basin.
- Along the perimeter of the construction site to keep runoff from leaving the site.

Figure TSW-1 illustrates cases where temporary swales are most effective.

When and Where NOT to use it

- Where longitudinal slope exceeds 10 percent (lining is required where longitudinal slope exceeds 2 percent).
- In areas where concentrated flow will overtop the swale transversely.

Construction Detail and Maintenance Requirements

Figure TSW-2 provides a construction detail and maintenance requirements for a temporary swale. Figure TSW-3 provides a construction detail and maintenance requirements for swale linings.

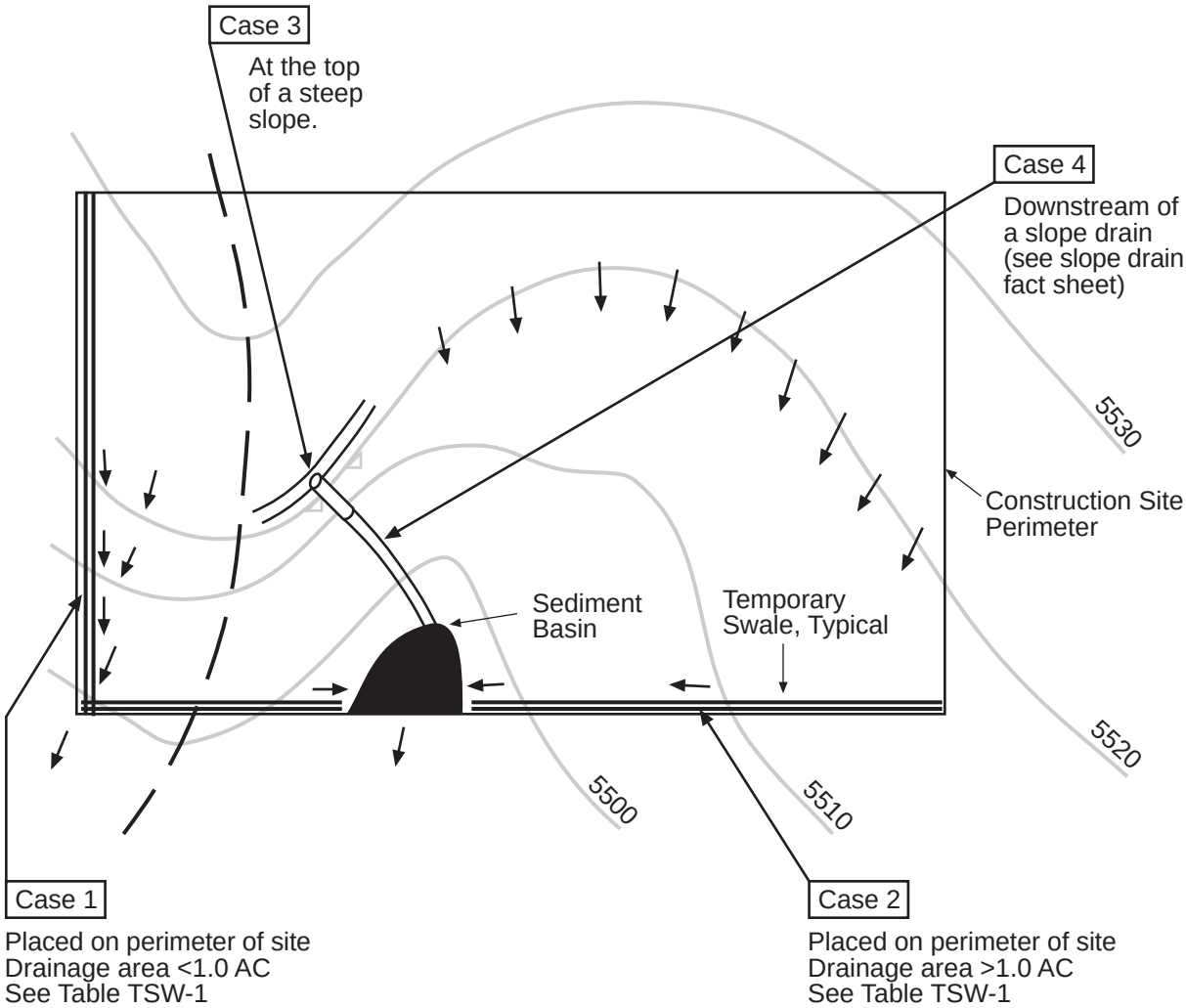
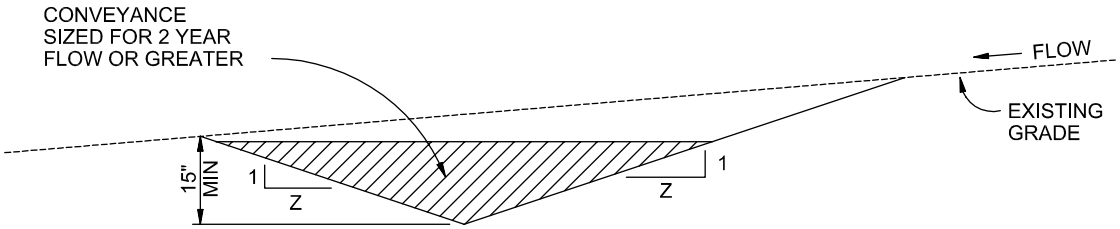


Table TSW-1

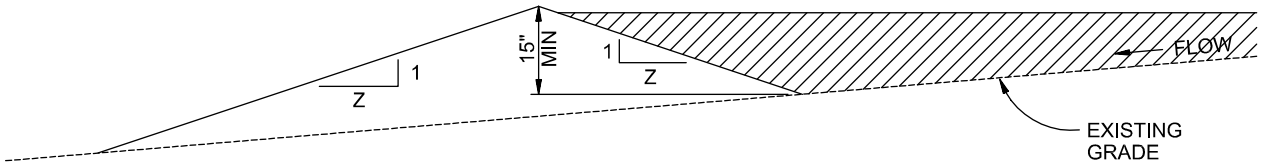
Temporary Swale Used as Perimeter Control	Case 1 DA < 1.0 AC	Case 2 DA > 1.0 AC
Continuous Grade	OK (1)	OK (1)
Area of Concentrated Flow	NO (3)	NO (2)

(1) Silt Fence or Straw Bale Barrier may be used as alternative to a Temporary Swale.
(2) With Temporary Swales Sediment Basin is required for concentrated flow from drainage areas > 1.0 AC.
(3) Check Dam is required at concentrated flow for drainage areas >1.0 acres.

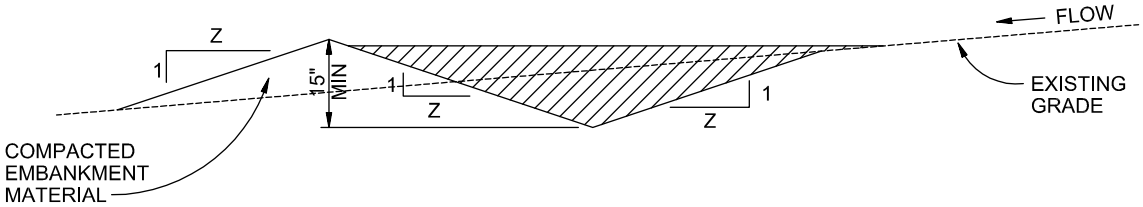
City of Colorado Springs Storm Water Quality	Figure TSW-1 Temporary Swale Application Examples



A. EXCAVATED SWALE



B. SWALE FORMED BY BERM



C. SWALE FORMED BY CUT AND FILL

TEMPORARY SWALE

NTS

TEMPORARY SWALE NOTES

INSTALLATION REQUIREMENTS

1. TEMPORARY SWALES SHALL BE INSTALLED PRIOR TO ANY LAND DISTURBING ACTIVITIES.

2. THE AREA UNDER WHICH THE EMBANKMENT IS TO BE INSTALLED SHALL BE CLEARED, GRUBBED, AND STRIPPED OF ALL VEGETATION AND ROOT MAT.

3. EMBANKMENT MATERIAL SHALL CONSIST OF SOIL WITH A MINIMUM OF 15% PASSING A #200 SIEVE. EXCAVATED SOIL CAN BE USED IF IT MEETS THIS REQUIREMENT.

4. EMBANKMENT IS TO BE COMPACTED TO AT LEAST 90% OF MAXIMUM DENSITY AND WITHIN 2% OF OPTIMUM MOISTURE CONTENT ACCORDING TO ASTM D 698.

5. SWALES WITH SLOPE > 2% SHALL BE LINED, SEE FIGURE TSW-3.

6. SWALES ARE TO DRAIN INTO A SEDIMENT BASIN OR OTHER STABILIZED OUTLET.

7. Z SHALL BE 3 OR GREATER.

MAINTENANCE REQUIREMENTS

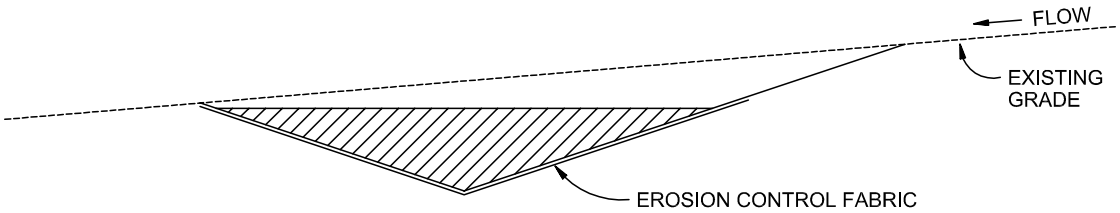
1. CONTRACTOR SHALL INSPECT SWALES AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL, AND WEEKLY DURING PERIODS OF NO RAINFALL.

2. SWALES SHALL BE ROUTINELY CLEARED OF ANY DEBRIS OR ACCUMULATION OF SEDIMENT.

3. ERODED SLOPES OR DAMAGED LININGS SHALL IMMEDIATELY BE REPAIRED.

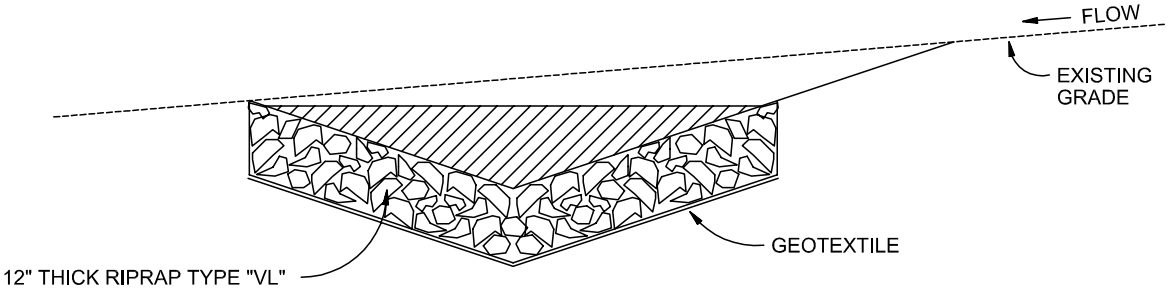
4. TEMPORARY SWALES SHALL REMAIN OPERATIONAL AND PROPERLY MAINTAINED UNTIL THE SITE AREA IS PERMANENTLY STABILIZED WITH ADEQUATE VEGETATIVE COVER AND/OR OTHER PERMANENT STRUCTURE AS APPROVED BY THE CITY.

City of Colorado Springs Stormwater Quality	Figure TSW-2 Temporary Swale Construction Detail and Maintenance Requirements



A. EROSION CONTROL FABRIC

2%≤SLOPE≤5% AND VELOCITY ≤ 8 FPS



B. RIPRAP

SLOPE>5% OR VELOCITY >8 FPS

SWALE LINING

NTS

SWALE LINING NOTES

INSTALLATION REQUIREMENTS

1. REFER TO THE EROSION CONTROL BLANKETS FACTSHEET FOR PROPER INSTALLATION OF EROSION CONTROL FABRIC LINING.

2. SWALES WITH EASILY EROSIVE SOILS AND SLOPES LESS THAN 2%, SHALL BE LINED WITH EROSION CONTROL FABRIC.

3. VELOCITIES FOR EROSION CONTROL FABRICS SHALL NOT EXCEED 8 FPS. SWALES WITH VELOCITIES GREATER THAN 8 FPS SHALL BE LINED WITH RIP RAP.

MAINTENANCE REQUIREMENTS

1. CONTRACTOR SHALL INSPECT SWALE LININGS AFTER EACH RAINFALL, AT LEAST DAILY DURING PROLONGED RAINFALL AND WEEKLY DURING PERIODS OF NO RAINFALL.

2. DAMAGED LININGS SHALL IMMEDIATELY BE REPAIRED.

3. REFER TO THE EROSION CONTROL BLANKETS FACTSHEET FOR PROPER MAINTENANCE.

4. DISPLACED RIPRAP OR COARSE AGGREGATE IS TO BE REPLACED AS SOON AS POSSIBLE.

5. SWALE LININGS ARE TO REMAIN IN PLACE AND BE PROPERLY MAINTAINED UNTIL THE TEMPORARY SWALE IS REMOVED.

City of Colorado Springs Stormwater Quality	Figure TSW-3 Swale Linings Construction Detail and Maintenance

Vehicle Tracking

What it is

Vehicle tracking refers to the stabilization of construction entrances, roads, parking areas, and staging areas to prevent the tracking of sediment from the construction site.

When and Where to use it

- All points where vehicles exit the construction site onto a public road.
- Construction entrance/exit should be located at permanent access locations if at all possible.
- Construction roads and parking areas.
- Loading and unloading areas.
- Storage and staging areas.
- Where trailers are parked.
- Any construction area that receives high vehicular traffic.

When and Where NOT to use it

- The vehicle tracking area should not be located in areas that are wet or where soils erode easily.

This picture shows an unstabilized entrance where dirt is being tracked onto a public road.

Construction Details and Maintenance Requirements

Figure VT-1 and VT-2 provide construction details and maintenance requirements for vehicle tracking.

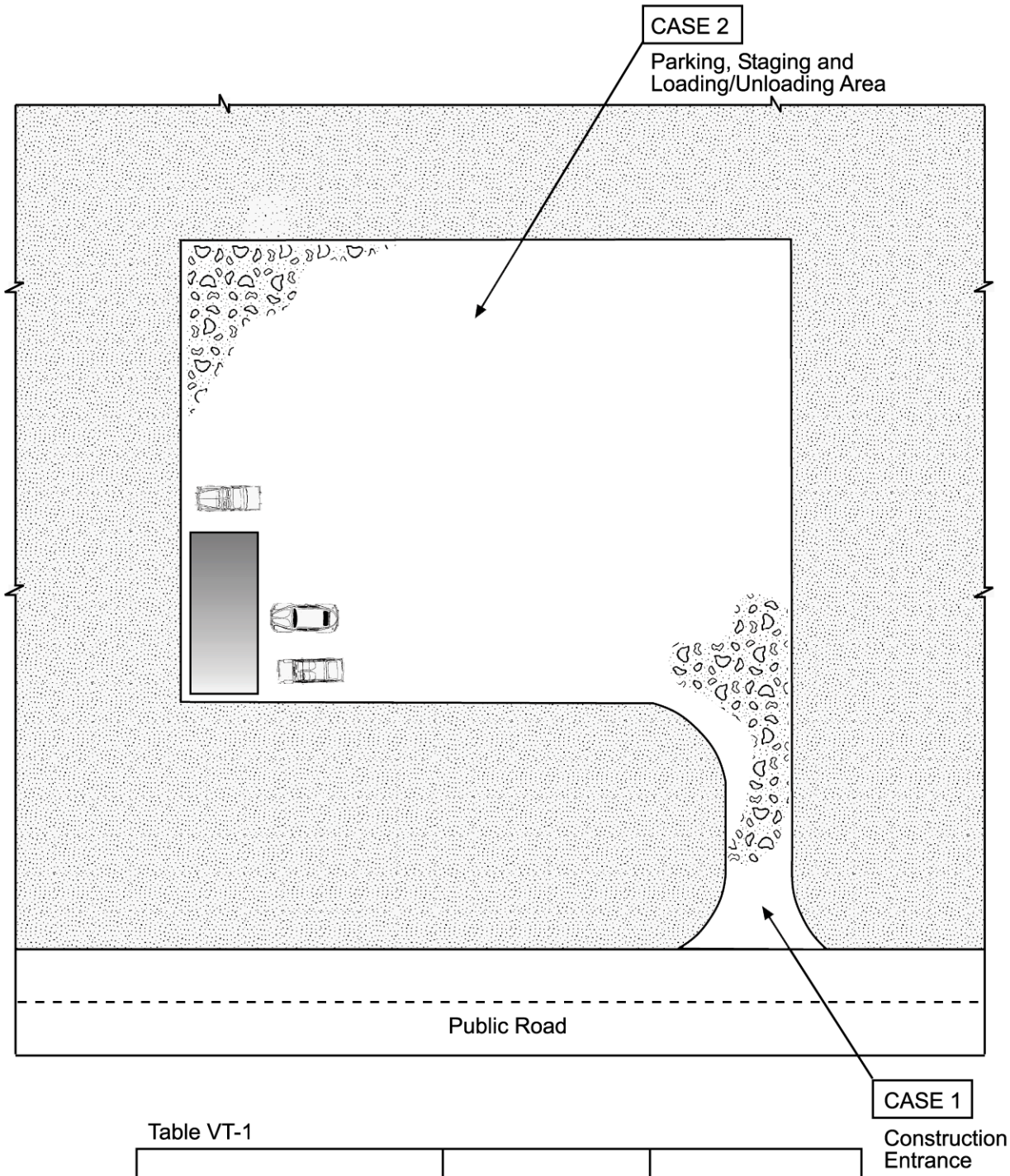
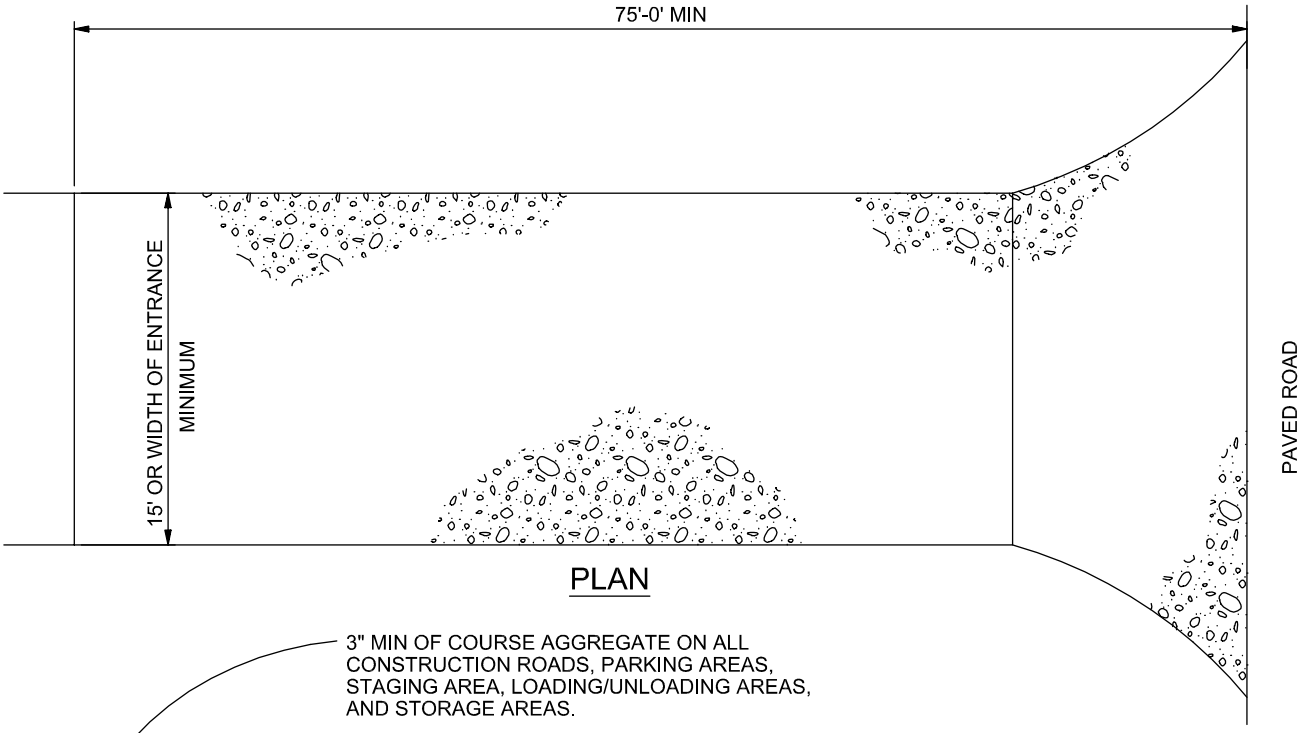


Table VT-1

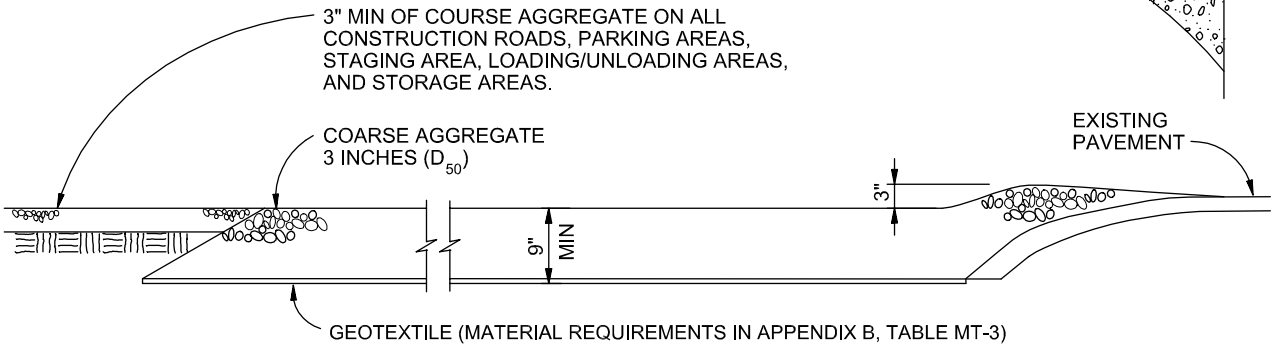
	Case 1	Case 2
Gravel Thickness	9”	3”
Filter Fabric	YES	NO

City of Colorado Springs
Storm Water Quality

Figure VT-1
Vehicle Tracking
Application Examples



PLAN



SECTION

VEHICLE TRACKING

NTS

VEHICLE TRACKING NOTES

INSTALLATION REQUIREMENTS

1. ALL ENTRANCES TO THE CONSTRUCTION SITE ARE TO BE STABILIZED PRIOR TO CONSTRUCTION BEGINNING.

2. CONSTRUCTION ENTRANCES ARE TO BE BUILT WITH AN APRON TO ALLOW FOR TURNING TRAFFIC, BUT SHOULD NOT BE BUILT OVER EXISTING PAVEMENT EXCEPT FOR A SLIGHT OVERLAP.

3. AREAS TO BE STABILIZED ARE TO BE PROPERLY GRADED AND COMPACTED PRIOR TO LAYING DOWN GEOTEXTILE AND STONE.

4. CONSTRUCTION ROADS, PARKING AREAS, LOADING/UNLOADING ZONES, STORAGE AREAS, AND STAGING AREAS ARE TO BE STABILIZED.

5. CONSTRUCTION ROADS ARE TO BE BUILT TO CONFORM TO SITE GRADES, BUT SHOULD NOT HAVE SIDE SLOPES OR ROAD GRADES THAT ARE EXCESSIVELY STEEP.

MAINTENANCE REQUIREMENTS

1. REGULAR INSPECTIONS ARE TO BE MADE OF ALL STABILIZED AREAS, ESPECIALLY AFTER STORM EVENTS.

2. STONES ARE TO BE REAPPLIED PERIODICALLY AND WHEN REPAIR IS NECESSARY.

3. SEDIMENT TRACKED ONTO PAVED ROADS IS TO BE REMOVED DAILY BY SHOVELING OR SWEEPING. SEDIMENT IS NOT TO BE WASHED DOWN STORM SEWER DRAINS.

4. STORM SEWER INLET PROTECTION IS TO BE IN PLACE, INSPECTED, AND CLEANED IF NECESSARY.

5. OTHER ASSOCIATED SEDIMENT CONTROL MEASURES ARE TO BE INSPECTED TO ENSURE GOOD WORKING CONDITION.

City of Colorado Springs Stormwater Quality	Figure VT-2 Vehicle Tracking Application Examples

3.4 Construction Site Inspections

Inspections of construction sites are conducted by City Engineering to ensure compliance with the Grading Plan and Erosion and Stormwater Quality Control Plan. Conditions for which a Grading Plan is required include:

1. Sites with excavation or fill of 500 cubic yards or more, or
2. The grading of a site with land disturbance of one or more acres, or
3. Grading on any property with a natural slope > 8 percent, or
4. Any combination of the above three, or
5. Any grading or other disturbance of land in an area zoned Hillside Area Overlay zone under Section 504 of Part 5 of Article 3 of Chapter 7 of the City Code.

At a minimum, an Erosion and Stormwater Quality Control Plan is required whenever a Grading Plan is required or when 1 acre or more of land will be disturbed. An Erosion and Stormwater Quality Control Plan may be required for other specific minor land disturbing activities (see Section 3.2 of this *Manual – General Principles, Applicability*) if deemed necessary by the City Engineer.

The focus of construction site inspections is to ensure grading is in compliance with the approved Plan and that Best Management Practices (BMPs) are installed and maintained properly to prevent site runoff, spillage and leakage, improper sludge or waste disposal, and drainage from raw material storage from leaving the site creating public safety, property or stormwater quality impacts. Inspections also serve as a means of educating owners/owner's representatives, developers, and contractors of the need to minimize the stormwater quality impacts from site operations and to assist in complying with the requirements of the City's Stormwater Construction Sites Program. City Engineering staff will work with and assist the owner/owner's representative and contractor to maintain compliance with its Grading and Erosion and Stormwater Quality Control requirements. The inspection procedures listed below provide a means of achieving this.

City Engineering's review of a Grading Plan and Erosion and Stormwater Quality Control Plan is the first step in determining the type of inspections needed and the relative priority of the site for inspections.

Types of Inspections

The following are inspections that may be performed at the construction sites within the City of Colorado Springs. Not all inspection types will be performed at all sites.

Self-Monitoring Inspections

The owner or his representative conducts self-monitoring inspections. The purpose of these inspections is to ensure that all BMPs are installed according to approved plans and that the BMPs are being properly maintained. The person performing the inspections must be a registered professional engineer in Colorado, a certified erosion control specialist, or certified in a City-approved inspection training program within 12 months of City adoption of these BMP requirements. The self-monitoring inspections are to be performed and documented on a bi-weekly basis. In addition to the bi-weekly inspections, the owner or his representative shall perform inspections of all BMPs after significant precipitation events to

insure that the BMPs have operated as designed, to determine if maintenance is needed, and to locate and clean up any areas where materials have runoff the site. The owner or his representative will record the results of all bi-weekly inspections and inspections after a significant precipitation event by completing a copy of the City of Colorado Springs Inspection Checklist (Appendix C) or similar inspection checklist. Completed Inspection Checklists will be kept on-site and available to city inspectors. Self-monitoring inspections may be required on other construction sites, even if an Erosion and Stormwater Quality Control Permit is not required. The City may require the submission of these inspection reports on a site-specific basis.

Initial Inspections

Initial inspections are to confirm that the approved plan is being implemented. The City Engineering Inspector must be contacted by the owner/owner's representative/contractor at least 48 hours prior to scheduling the Initial Inspection. It is expected that at the time of the initial inspection, the first level of BMPs will have been implemented according to those plans and that no land disturbing activity will have occurred prior to the Initial Inspection. This inspection also serves to establish contact between inspectors and the site personnel responsible for implementing the approved plans. This is especially important for those sites that have a long construction period or the potential to have a significant impact. Initial inspections are only conducted on sites that require a Grading Permit or Erosion and Stormwater Quality Control Permit. These inspections are documented on the Inspection Checklist.

Compliance Inspections

Compliance inspections are routine inspections conducted to ensure that the BMPs are implemented according to approved plans and are receiving proper maintenance. The inspector not only verifies that the BMPs are functioning according to design and only allowable discharges are occurring, but also the required documentation of activities is occurring. The inspector will examine the bi-weekly Field Inspection Checklists to make sure the owner or his representative is performing the inspections as required and to compare actual conditions to those stated on the checklist. Compliance inspections may also occur during or immediately after a precipitation event. Routine compliance inspections are only conducted for sites that require a Grading Permit or Erosion and Stormwater Quality Control Permit. The City uses the Inspection Checklist to document these inspections.

Reconnaissance Inspections

Reconnaissance inspections do not occur on a routine basis and are conducted for the general purpose of determining conditions at the site, particularly if the site has contributed sediment to drainageways or other drainage facilities, or if material has runoff the site. These inspections are generally performed from off-site on adjacent streets or property, and may occur during or immediately after a significant precipitation event. This type of inspection is normally aimed at potential problem sites or sites that typically do not require an Erosion and Stormwater Quality Control Permit. The results of a reconnaissance inspection could require a site that previously was not required to develop an Erosion and Stormwater Quality Control Plan to develop one. The inspection will be documented using the Inspection Checklist.

Complaint Response Inspections

These inspections will occur in response to either a citizen complaint or a complaint from another City agency. The inspector will inform the contractor and owner/owner's representative of the complaint, determine the validity of the complaint, and if necessary, advise on the necessary repair, maintenance or cleanup. The inspector may also require the implementation of specific measures or additional BMPs to prevent the recurrence of the problems that gave rise to the complaint. All construction sites are subject to complaint response inspections. The inspection will be documented using the Inspection Checklist.

Follow-up Inspections

Follow-up inspections are conducted to ensure that measures or requirements from a previous inspection have been performed or complied with. These requirements may involve the cleanup of a discharge, implementing additional or revised BMPs, repairing, re-installing, or maintaining damaged or non-functioning BMPs. All construction sites are subject to follow-up inspections. The inspection will be documented using the Inspection Checklist.

Final Inspections

A final inspection of the site is conducted to determine overall compliance with the Grading Plan and/or Erosion and Stormwater Quality Control Plan, to determine if measures have been taken to stabilize the site prior to final approval, and prior to release of any financial assurances. The City Engineering Inspector must be contacted by the owner/owner's representative/contractor at least 48 hours prior to scheduling the Final Inspection. The inspection will focus on whether the following have occurred and if sediment from erosion is leaving the site or entering into drainageways or other drainage facilities.

1. All grading is in compliance with the approved Plan, and all stabilization is completed, including vegetation, retaining walls or other approved measures.
2. The site has final stabilization equal to a uniform vegetative cover with a density of at least 70 percent compared to the original undisturbed site and such cover is capable of adequately controlling soil erosion, as determined by the City Engineer, or equivalent permanent, physical erosion reduction methods have been employed.
3. Removal of all temporary erosion and sediment control measures.
4. Installation of all approved permanent (post construction) stormwater quality BMPs.
5. Removal of all stockpiles of soil, construction material/debris, construction equipment, etc.
6. Streets, parking lots and other paved surfaces (on-site and off-site) are clean.
7. Removal of sediment and debris from drainage facilities (on-site and off-site) and other off-site property caused by the construction activity, including proper restoration of any damaged property.

Final inspections are only conducted for those sites that are required to have a Grading Permit or Erosion and Stormwater Quality Control Permit, unless other documentation from the owner or owner's representative is allowed by the City Engineer. The inspection will be documented using the Inspection Checklist.

Frequency and Types of Inspections of Construction Sites

The frequency and type of inspections conducted by City Engineering is dependent on the characteristics of the site, the type or phase of construction and the potential for the site to impact stormwater quality and other areas of environmental concern. The level of construction activity throughout the City and availability of staff resources will also factor into the decision. Key factors involved in the decision that relate to construction and the site are:

1. The size of the disturbed area.
2. The length of time that the site will be left disturbed.
3. The proximity of the construction site to areas of environmental concern.
4. Past experiences with the owner/contractor.
5. The phase of construction.
6. Season of land disturbing activity.

3.5 Construction Enforcement Strategy

The following strategy will be used to ensure compliance with the City's Grading Plans and/or Erosion and Stormwater Quality Control Plans.

Goal of Strategy

To encourage owners, developers, and contractors to take the necessary measures to ensure that their construction sites do not create negative impacts to public safety, property, or water resources.

Policies

The following policies apply to enforcement at construction sites in the City.

1. It will be the policy of the City of Colorado Springs to encourage compliance with grading, erosion and stormwater quality control requirements by working with engineers and developers during the design and implementation phases of a project to incorporate proper construction BMPs. The City will work with contractors to inform and educate them on the proper implementation and maintenance of construction BMPs.

2. The City will try to bring a construction site into compliance with its approved plan prior to formal enforcement. This will be accomplished by working with the owner, developer, and contractor. The intent will be to allow them reasonable opportunity to take the necessary measures before more formal action, such as a Stop Work Order or Notice and Order, is taken.

3. The City considers the owner of the land the ultimate responsible party for all construction activities. It is the responsibility of the owner to take all necessary measures to ensure that the site is in compliance with City ordinances and the Grading Plan and/or Erosion and Stormwater Quality Control Plan.

4. The City has tried to make its requirements consistent with State requirements for construction activities (CDPS General Permit – Stormwater Discharges Associated with

Construction Activities). Should requirements conflict, it will be the responsibility of the owner to bring these conflicts to the City's attention and propose how to address them.

5. Whenever a Stop Work Order is issued, it will be the City's policy to stop any or all City activities or further approvals relative to the site until the necessary measures are taken to address the concerns, as stipulated in the Stop Work Order.

Definitions

1. Stop Work Order. For this program, a Stop Work Order is an order issued by the City Engineer or his designee to the owner and contractor of a construction site. The Order is used when the owner has failed to obtain a Grading Permit from the City Engineer or to take the necessary measures to comply with the Grading Plan and/or the Erosion and Stormwater Quality Control Plan approved for the site. When the Order is issued it requires all work on the site to cease until the Owner takes the measures necessary to bring the site into compliance with the Grading Plan and the Erosion and Stormwater Quality Control Plan.

2. Notice and Order. The initiation of formal enforcement action.

3. Inspection. The term "inspection" in this document refers to an inspection performed by an employee of the City's Engineering Division, except for self-monitoring inspections which are performed by the owner or their representative, in an effort to determine the status of compliance of a construction site with its Grading Plan and/or Erosion and Stormwater Quality Control Plan. The inspection includes, but is not limited to, the following inspection types: Initial Inspections, Compliance Inspections, Reconnaissance Inspections, Complaint Inspections, Follow Up inspections, and Final Inspections.

4. Erosion and Stormwater Quality Control Plan. An Erosion and Stormwater Quality Control Plan is a plan developed in compliance with the requirements included in the *Manual*: Stormwater Quality Policies, Procedures and Best Management Practices. Its purpose is to ensure that measures are in place to ensure that the construction site does not create negative impacts on persons, property or water resources. It requires the design, implementation, and maintenance of stormwater BMPs. The plan may be combined with the Grading Plan if all required information can be clearly presented. The plan will then be a combined Grading, Erosion and Stormwater Quality Control Plan.

5. Grading Permit/Erosion Control Permit. An approved Erosion and Stormwater Quality Control Plan becomes an Erosion Control Permit once it is accepted and signed off on by the City Engineer. The permit authorizes the implementation of the approved erosion and stormwater quality control measures. Signoff and acceptance of both the Grading Plan and the Erosion and Stormwater Quality Control Plan, or a combined plan, by the City Engineer shall constitute a Grading Permit, authorizing the approved land disturbance and implementation of the approved erosion and stormwater quality control measures.

6. Letter of Noncompliance. A Letter of Noncompliance is written to the property owner and contractor to notify them that they are in violation of the Grading Permit or are in noncompliance with the requirements of the *Manual* or the City Code relating to grading, erosion, and stormwater quality requirements. The letter contains a description

of the measures required to bring the site into compliance and a date by which these measures must be implemented.

7. Municipal Summons. Issuance of a summons to appear before a judge in Municipal Court.

Enforcement Procedures

An important element of the City's enforcement program is inspections. A good program for monitoring the compliance status of sites with their plans may be sufficient encouragement to ensure compliance with their Grading and Erosion Control Permits. The City encourages compliance by requiring self-monitoring inspections by the owner. The self-monitoring inspections require the owner to identify areas of noncompliance and take corrective actions. In addition, the City's inspection priority system provides for the rewarding of complying parties with less frequent inspections.

When the City performs inspections at construction sites, it notes those areas that need to be addressed to bring the site into compliance with its Grading and Erosion Control Permit. A time frame for addressing any noncompliance is included in the inspection report as a required follow-up action. It is expected that the inspector and the site contact will come up with a schedule that is mutually agreed upon. Based on a review of the site, the inspector will list the actions that are needed. The inspector will determine if a Follow Up inspection is needed or if submission of information that verifies that the necessary actions were taken is adequate.

There are several situations where the City may determine that more aggressive action is necessary to get the site into compliance with its permit. The first situation is when there are impacts on public safety, property or water resources. This could include, but is not limited to, the deposition of sediment on a roadway that has the potential to cause accidents, the wash out of channels, spills of toxic materials, deposition of sediment that causes or has the potential to cause property damage, or the deposition of materials into water ways. The magnitude of the impacts will determine what action is appropriate. Another instance that may result in more aggressive action is when the history of the contractor/owner/ developer suggests that a more formal action is necessary. Problems that may warrant such action include:

- Where the same problem is reoccurring at the site.
- Where the site appears to be having frequent minor problems.
- The individuals involved have a history of noncompliance.

There are several options for formal action that are available to the City. Table CS-1 summarizes some of the more common options. The City may take other action as deemed appropriate.

TABLE CS-1
Enforcement Options

Enforcement Option	Description	Typical Applications
Letter of Noncompliance	This is a letter written to the owner and contractor. It contains a description of the problem, the measures required to bring the plant into compliance and a timeframe for completion of those measures.	No immediate danger to the public safety, property or water resources. Compliance has not been achieved while working with the owner/representative or contractor. When the City wants to document ongoing problems and agreed upon follow-up.
Stop Work Order	This Order requires the owner and contractor to stop all activity on the site except for the work necessary to bring the site into compliance with its Grading Permit. Depending on the compliance problem and the City's past experience with the individuals involved, the City may impose the Order on only a portion of the site.	Used when there is an immediate threat to the public safety, property or water resources. Used when the site has failed to comply with the Letter of Noncompliance.
Permit Revocation	The City may revoke the Grading Permit and/or the Erosion Control Permit if the requirements of the Grading Plan and/or Erosion and Stormwater Quality Control Plan are not implemented. Revocation of the permit has the same effect as a Stop Work Order, except that the owner will need to resubmit a Grading Plan and/or Erosion and Stormwater Quality Control Plan.	Used when the site has failed to comply with the Stop Work Order. Used when the current plan has been judged to be inadequate, and the owner or contractor have failed to take the necessary measure to improve the plan.
Notice and Order	Formal enforcement action by the City. This can result in financial penalties. This action can be taken in conjunction with any of the measures listed above.	This action will be taken whenever the City will need to collect funds for abating the violation.
Municipal Summons	Issuance of a summons to appear before a judge in Municipal Court	Used when the site has failed to comply with the Stop Work Order or Notice and Order.

It is expected that under normal conditions the progression of enforcement actions is a Letter of Noncompliance, then a Stop Work Order, then a revocation of the Grading and/or Erosion Control Permit and then a Notice and Order. Once a permit has been revoked, it will be necessary to resubmit a Grading Plan and/or an Erosion and Stormwater Quality Control Plan to the City. A Municipal Summons may be issued for noncompliance with a Stop Work Order, a Notice and Order or other situations as outlined in the City Code.

4.0 New Development Stormwater Management

4.1 New Development Planning

Overview

This chapter contains guidance and requirements for the selection and siting of structural Best Management Practices (BMPs) for new development and significant redevelopment. The guidance is provided within the context of a four-step process to be followed for new site developments and significant redevelopments.

Detailed descriptions, sizing and design criteria, and design procedures for these BMPs are provided in the *New Development BMP Factsheets*. It is recommended that discussions and collaboration regarding proposed BMPs occur early in each project between the developer's planner and engineer and City Engineering staff. These Section 4.0 requirements shall be incorporated into existing City Engineering submittals for review and acceptance including Preliminary/Final Drainage Reports and construction plans, or as otherwise specified by the City Engineer.

Definition of New Development and Significant Redevelopment/BMP Requirements

For the purpose of defining when permanent water quality Best Management Practices are required, "New Development and Significant Redevelopment" are defined as:

- All sites zoned R-4, R-5, PUD, SU, OR, OC, PBC, C-5, C-6, PIP-1, PIP-2, M-1, M-2, PF, APD, and PCR that include total development/redevelopment areas of one (1) acre or larger. Water Quality Capture Volume (WQCV), as discussed later in this section, shall be provided for the total site or individual lots/parcels. Other permanent BMPs may also be required as appropriate.

- All sites in any zone that include total development/redevelopment areas of one (1) acre or larger for which stormwater quantity detention is required, as specified in the approved Final Drainage Report. WQCV shall be incorporated into stormwater quantity detention basins as discussed later in this section. Other permanent BMPs may also be required as appropriate.

- All sites zoned R (Estate), R-1 6000, R-1 9000, R-2 and DFOZ, that include total development/redevelopment areas of two (2) acres or larger will be reviewed on a case by case basis that will include an assessment of impacts from stormwater runoff from the new development/redevelopment to State Waters and a determination of the need for any additional permanent water quality BMPs. Sites for which City Engineering determines water quality impacts to State Waters are minimal and permanent water quality BMPs are impractical will be granted a waiver, based on the submittal of sufficient justification. Written waiver requests from requiring permanent stormwater quality BMPs will be considered by the City Engineer or his designated representative.

- All other sites that do not meet the above requirements may be required to provide permanent water quality BMPs, if significant water quality impacts are anticipated as a result of development/redevelopment of the site, as determined by City Engineering.

The intent of permanent water quality BMPs is that they be placed prior to the stormwater runoff being discharged to State Waters. However, downstream BMPs (such as detention ponds or improved channels) may also be acceptable if there are minimal impacts to State Waters between the downstream BMP and the area of new development/redevelopment. With increased impacts, other permanent BMPs may also be required on or adjacent to the site or in combination with new/retrofitted downstream BMPs. When determining the need for permanent water quality BMPs, consideration will be given to, but not limited to the following: overall assessment of water quality impacts/benefits (including looking at the intervening reach between any downstream BMP and the development site), other BMPs incorporated into the overall site, costs, and long-term maintenance viability.

Whenever practical, the City of Colorado Springs promotes permanent water quality BMPs on all sites.

The Zoning District designations noted above are defined as follows:

- R: Estate residential.
- R-1 6000: Single family residential.
- R-1 9000: Single family residential.
- DFOZ: Design Flexibility Overlay (base zone must be R-Estate, R-1 6000 or R-1 9000).
- R-2: Two family residential.
- R-4: Eight family residential.
- R-5: Multi-family residential.
- PUD: Planned Unit Development.
- SU: Special Use.
- OR: Office residential.
- OC: Office complex.
- PBC: Planned Business Center.
- C-5: Intermediate Business.
- C-6: General Business.
- PIP-1: Planned Industrial Park.
- PIP-2: Planned Industrial Park.
- M-1: Light Industrial.
- M-2: Heavy Industrial.
- PF: Public Facilities.
- APD: Airport Planned Development.
- PCR: Planned Cultural Resort.

Four-Step Process

The following four-step process is recommended for selecting structural BMPs in newly developing and redeveloping urban areas:

Step 1: Employ Runoff Reduction Practices

To reduce runoff peaks and volumes from urbanizing areas, employ a practice generally termed "minimizing directly connected impervious areas" (MDCIA). The principal behind MDCIA is twofold -- to reduce impervious areas and to route runoff from impervious surfaces over grassy areas to slow down runoff and promote infiltration. The benefits are less runoff, less stormwater pollution, and less cost for drainage infrastructure. There are several approaches to reduce the effective imperviousness of a development site:

- Reduced Pavement Area. Sometimes, creative site layout can reduce the extent of paved areas including parking, thereby saving on initial capital cost of pavement and then saving on pavement maintenance, repair, and replacement over time.
- Porous Pavement. The use of modular block porous pavement or reinforced turf in low-traffic zones such as parking areas and low use service drives such as fire lanes can significantly reduce site imperviousness. This practice may reduce the extent and size of the downstream storm sewers and detention.
- Grass Buffers. Draining impervious areas over grass buffers slows down runoff and encourages infiltration, in effect reducing the impact of the impervious area.
- Grass Swales. The use of grass swales instead of storm sewers, like grass buffers, slows down runoff and promotes infiltration, also reducing effective imperviousness. It also may reduce the size and cost of downstream storm sewers and detention.

Implementing these approaches on a new development site is discussed further in the section titled *Employing Runoff Reduction Techniques*. This section provides a procedure for estimating a reduced imperviousness based on the use of grass buffers and swales. The latter three of the approaches for reducing imperviousness are structural BMPs and are described in detail in section 4.2 (*New Development BMP Factsheets*):

- Grass Buffer.
- Grass Swale.
- Modular Block Porous Pavement (or Stabilized-Grass Porous Pavement).

Step 2: Stabilize Drainageways

Drainageway, natural and manmade, erosion can be a major source of sediment and associated constituents, such as phosphorus. Natural drainageways are often subject to bed and bank erosion when urbanizing areas increase the frequency, rate, and volume of runoff. Therefore, drainageways are required to be stabilized. One of three basic methods of stabilization may be selected.

- **Constructed Grass, Riprap, or Concrete-Lined Channel.** These methods of channel stabilization have been in practice for some time. The water quality benefit associated with these channels is the reduction of severe bed and bank erosion that can occur in the absence of a stabilized channel. On the other hand, the hard-lined low flow channels that are often used do not offer much in the way of water quality enhancement or wetland habitat. The use of riprap or concrete lined flood conveyance channels is not recommended, unless hydraulic or physical conditions require such an alternative. Rock lined low-flow channels in many cases may be a better alternative.

- **Stabilized Natural Channel.** In practice, many natural drainageways in and adjacent to new developments are frequently left in an undisturbed condition. While this may be positive in terms of retaining desirable riparian vegetation and habitat, urban development may cause the channel to become destabilized. When degradation occurs in these drainageways, significant erosion, loss of riparian and aquatic habitat, and elevated levels of sediment and associated pollutants can result. Therefore, it is recommended that some level of stream stabilization always be considered. Small grade control structures sized for a 5-year or larger runoff event are often an effective means of establishing a mild slope for the baseflow channel and arresting stream degradation. Severe bends or cut banks may also need to be stabilized. Such efforts to stabilize a natural waterway also preserves and promotes natural riparian vegetation which can provide paybacks in terms of enhanced aesthetics, habitat, and water quality.

One additional method of drainageway stabilization gives special attention to stormwater quality and is described in section 4.2 (*New Development BMP Factsheets*):

- Constructed Wetland Channel.

Step 3: Provide Water Quality Capture Volume (WQCV)

All multi-family residential, commercial, and industrial sites and all sites requiring stormwater quantity detention, as listed above in the section titled *Definition of New Development and Significant Redevelopment/BMP Requirements*, must address stormwater quality by providing the WQCV. One or more of six types of water quality basins, each draining slowly to provide for long-term settling of sediment particles, may be selected. Information on selecting and configuring one or more of these WQCV facilities at a site is provided in the section *Providing Water Quality Capture Volume (WQCV)*. These six BMPs are also described in detail in the *New Development BMP Factsheets*:

- Porous Pavement Detention.
- Porous Landscape Detention.
- Extended Detention Basin.
- Sand Filter Extended Detention Basin.
- Constructed Wetland Basin.
- Retention Pond.

Step 4: Consider Need for Industrial and Commercial BMPs

If a new development or significant redevelopment activity is planned for an industrial or commercial site, the need for specialized BMPs must be considered. Two approaches are described in the *New Development BMP Factsheets*:

- Covering of Storage/Handling Areas.
- Spill Containment and Control.

Other BMPs

The Technical Advisory Committee (TAC) selected the above structural BMPs after a comprehensive screening of known structural BMPs. The members of TAC included representatives from many city and county agencies and individuals from the development community. Final selection by TAC was based on the review of documentation on potential effectiveness in a semiarid climate, local applicability, maintenance considerations, and cost.

Several BMPs were considered but were not included at this time. These include manufactured devices such as water quality vaults and inlets, infiltration trenches, oil/grease separators, and fabric inserts for inlets. Some of these BMPs show promise but need further independent research to determine their pollutant removal effectiveness in a semiarid climate and to develop cost-effective design criteria to insure that they are properly designed, constructed, and maintained. As additional BMPs are field tested, and as supporting information becomes available, they may be added to the list of approved structural BMPs.

Employing Runoff Reduction Techniques

Benefits of Reducing Imperviousness.

Reducing imperviousness may provide some of the following benefits:

- Increased infiltration and decreased rate and volume of site runoff.
- Decreased WQCV and, in turn decreased size of required WQCV facilities.
- Decreased 2-year and 5-year peak runoff rates and volumes for downstream conveyance and detention facilities.
- Reduced need for irrigation.
- Less curb and gutter.
- Smaller storm sewer systems.
- Decreased pavement.
- Decreased runoff rates and volumes further downstream in watershed, especially if MDCIA is used on a widespread basis.

BMPs for Minimizing Effective Imperviousness

Described next are structural BMPs that minimize effective imperviousness.

Grass Buffer (GB)

Uniformly graded and densely vegetated area of turf grass. This BMP requires sheet flow to promote filtration, infiltration, and settling to reduce runoff pollutants.

Grass Swale (GS)

Densely vegetated drainageway with low-pitched side slopes that collects and slowly conveys runoff. Design of longitudinal slope and cross-section size forces the flow to be slow and shallow, thereby facilitating sedimentation while limiting erosion.

Modular Block Porous Pavement (MBP)

Modular block porous pavement consists of open void concrete slab units underlain with gravel. The surface voids are filled with sand. This BMP is intended to be used in low traffic areas to accommodate vehicles while facilitating stormwater infiltration near its source. A variation of this BMP is termed stabilized-grass porous pavement, consisting of plastic rings affixed to filter fabric underlain with gravel. The surface voids are filled with sand and grass sod/or seed.

Applying MDCIA to a Site

Minimizing directly connected impervious area requires a basic change in land development design philosophy. This change seeks to reduce paved areas and directs 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 encourage filtering and infiltration of stormwater. Traditional land development practices do not focus on water quality enhancement. Instead, they promote runoff from rooftops, parking lots, driveways, and roads to quickly flow to a curb and gutter and to a formalized stormwater conveyance system. This practice concentrates runoff quickly, which results in a fast responding system and relatively large peak runoff rates during small storms.

Minimizing DCIAs can be made an integral part of landscape and drainage planning for any development. Roof collection systems can direct flow to landscaped areas, infiltration areas, grassed buffer strips, and to grass swales. In some proposed developments, portions of curb and gutter may be eliminated. In others, the use of slotted/intermittent curbing, along with stabilized grass shoulders and swales, may be feasible. Residential driveway runoff can be redirected from flowing directly into the street. Large parking lots can reduce DCIAs by using modular block or stabilized grass porous pavement in less used portions of the lot to encourage local infiltration or storage.

Site slopes should be capable of directing stormwater runoff by gravity in a sheet flow away from buildings, roads, and parking lots toward grass-covered or porous pavement covered areas. The runoff then needs to flow as a sheet over these porous surfaces before it reaches swales, storage, stormwater collection, and stormwater conveyance systems. As a result, in areas of high permeability soils, Hydrologic Soil Class A and B soils, the ground can provide for infiltration of large portions of surface runoff. (Hydrologic Soil Classes range from A to D, and are based on the minimum annual steady ponded infiltration rate for a bare ground surface. Class A soils have the highest infiltration rate and class D the lowest.) Where less permeable soils are present, significant runoff losses can also be achieved, while the use of sand trenches with underdrains under grass swales can be used to prevent the nuisance of standing water.

Steep sites with average terrain slopes exceeding 4 percent may not lend themselves well to implementing some aspects of this BMP. Some of the difficulties can be dealt with by using terracing and retaining walls. Nevertheless, most sites with general terrain slopes flatter than 4 percent should be suitable for this BMP; the flatter the better.

Minimizing DCIAs can be implemented in varying degrees. Two general levels associated with minimizing DCIAs have been identified and are described below:

- Level 1. The primary intent is to direct the runoff generated by impervious surfaces to flow over grass-covered areas, and to provide sufficient travel time so as to encourage the removal of suspended solids before runoff leaves the site, enters a curb and gutter, or enters another stormwater collection system. Thus, at Level 1, *all* impervious surfaces are made to drain over grass buffer strips before reaching a stormwater conveyance system.

- Level 2**.** As an adjunct to Level 1, this level replaces street or internal curb and gutter systems with low-velocity grass-lined swales and pervious street shoulders. Conveyance systems and storm sewer inlets will still be needed to collect runoff at downstream intersections and crossings where stormwater flow rates exceed the capacity of the swales. Small culverts will be needed at street crossings and at individual driveways until inlets are provided to convey the flow to a storm sewer. The elimination of public street curb and gutter will only be considered in special developments: residential areas with low traffic volumes and developed drainage flows; such drainage flows must be adequately handled through construction of other improvements and be acceptable from a maintenance standpoint, as determined by City Engineering.

Calculating Effective Imperviousness

The first step in estimating the magnitude of runoff from a site is to first estimate the site's imperviousness. The total imperviousness of a site is the weighted average of individual areas of like imperviousness. For instance, paved streets (and parking lots), drives and walks have an imperviousness of 100 percent, roofs have an imperviousness of 90 percent, and lawn areas have an imperviousness of 0 percent. The total imperviousness of a site can be determined taking an area-weighted average of the imperviousness of the street, walk, roof, and lawn areas.

Structural BMPs for minimizing imperviousness impact this calculation in two ways. First, the use of modular block porous pavement reduces the imperviousness associated with parking areas and drives built using modular block pavement from 100 percent to 35 percent (assuming the use of underdrains). Second, the use of grass buffers and grass swales provides a reduction in imperviousness according to Figure ND-1. This figure represents the reduction in imperviousness associated with Level 1 and Level 2 MDCIA as discussed above. Grass buffers and/or grass swales are to be configured according to the design procedure documented in section 4.2, *New Development BMP Factsheets*.

Hydrologic Modeling

The current hydrologic methodology in the City/El Paso County Drainage Criteria Manual is inadequate for the MDCIA method. If such a BMP is proposed, a proven hydrologic modeling method must be utilized and agreed to by City Engineering.

Application Examples

The following figures provide a number of illustrations of how the principle of MDCIA can be applied to development sites. Figure ND-2 shows an example of MDCIA for a residential and commercial site. Figure ND-3 shows an example for a multi-family residential site. Figure ND-4 shows typical application examples of modular block porous pavement.

The Total Percent of Watershed Imperviousness for the traditional residential layout in Figure ND-2 is approximately 47 percent. Using porous pavement and a grass swale, as shown at the bottom of the figure, reduces the Total Percent of Watershed Imperviousness to 34 percent. This shows that the inclusion of BMPs can significantly reduce total imperviousness. Additional BMP benefits are achieved when the user determines the Impervious Percent to Use with WQCV in Figure ND-1 because the MDCIA layout allows the use of the Level 2 MDCIA curve. The resulting Impervious Percent to Use with WQCV values for the traditional residential layout and the residential MDCIA layout are 47 percent and 20 percent, respectively.

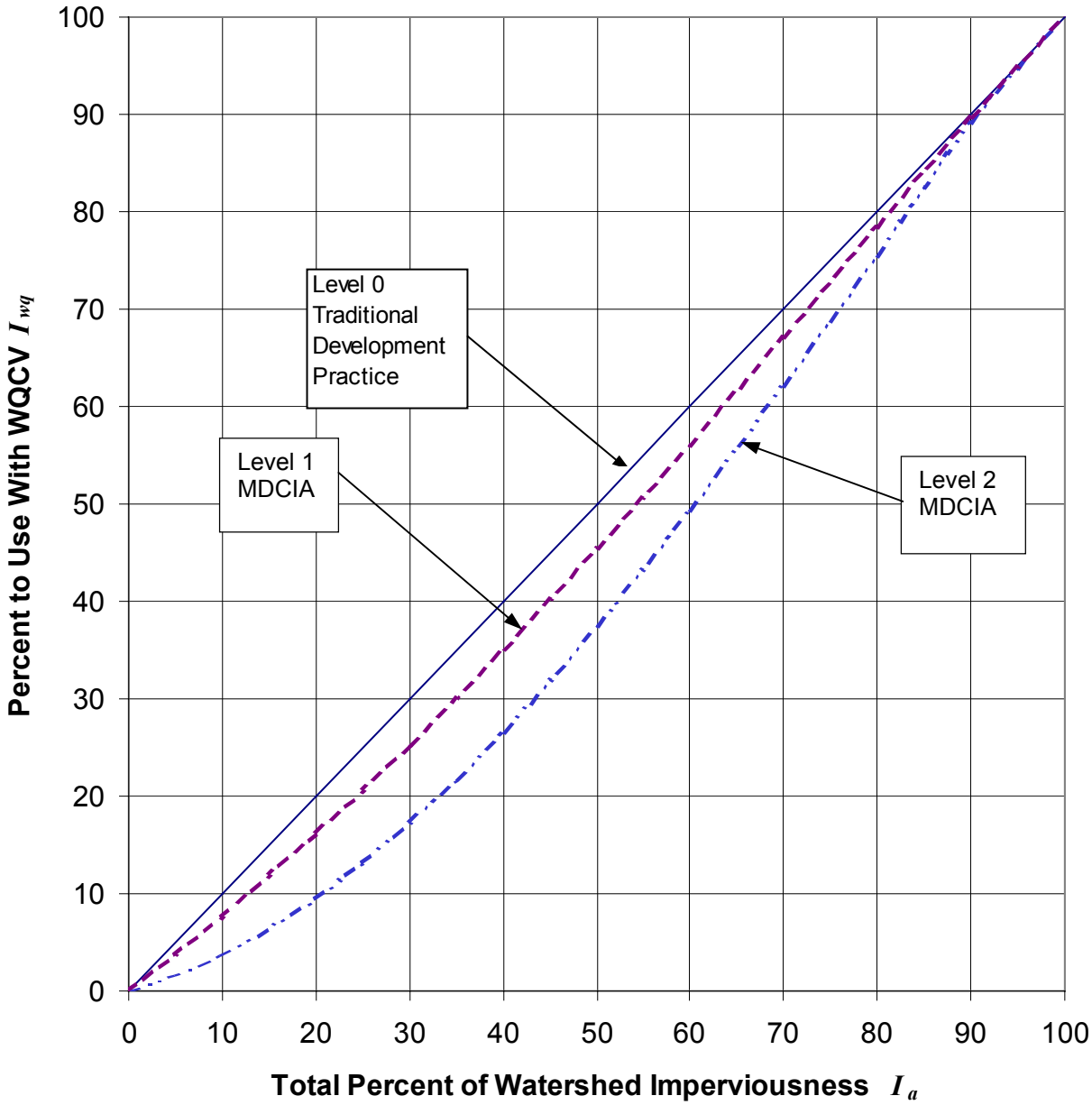
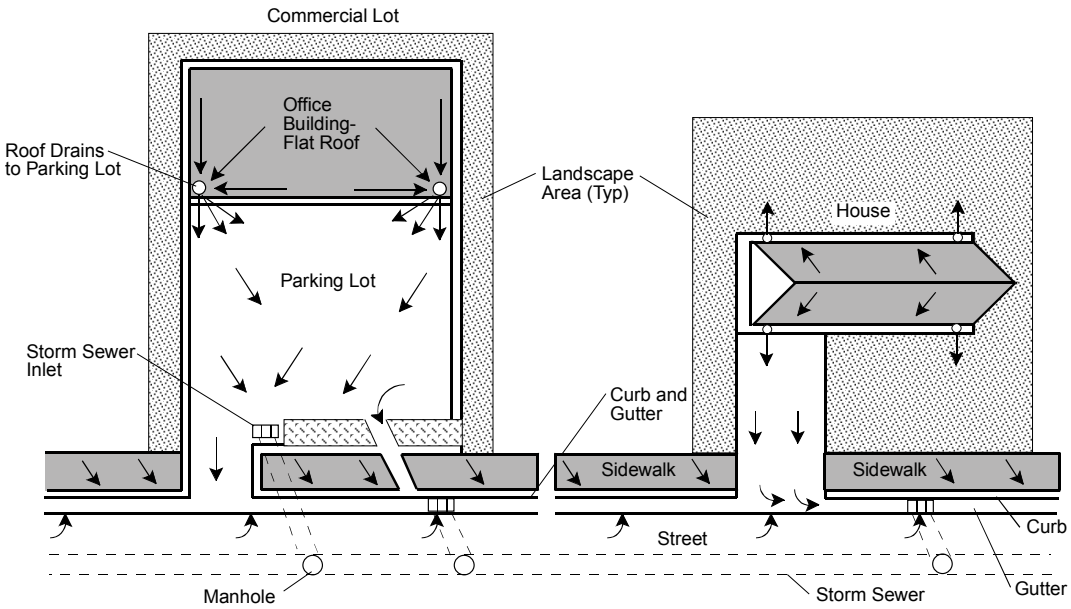
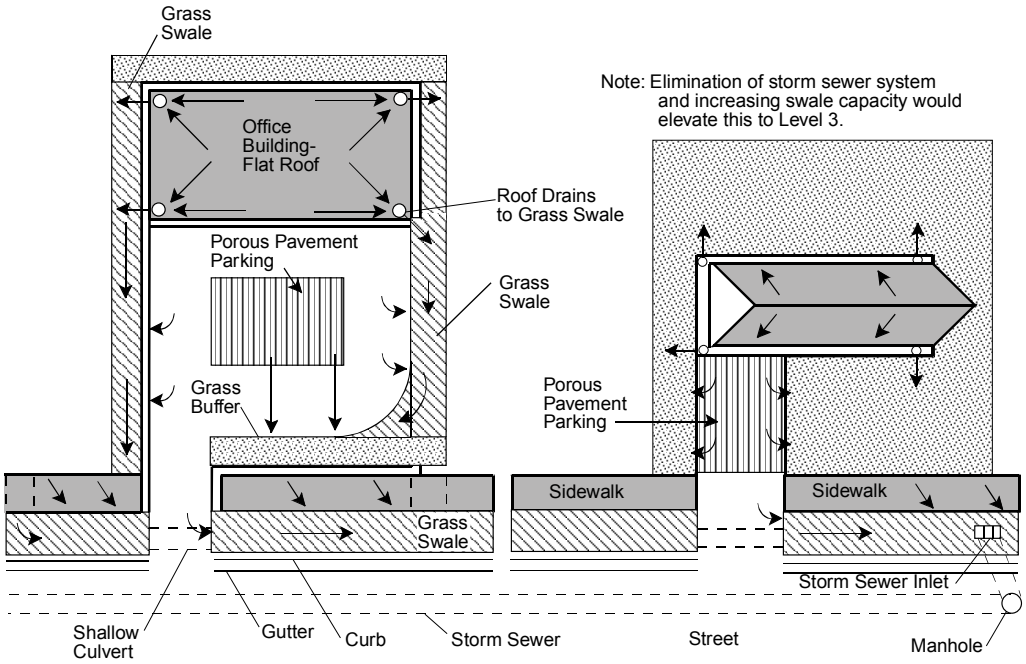


FIGURE ND-1
Imperviousness To Use With Water Quality Capture Volume (WQCV)



TRADITIONAL SITE & STREET DRAINAGE DESIGN



MINIMIZING DIRECTLY CONNECTED IMPERVIOUS AREAS (LEVEL 2 PRACTICES SHOWN)

FIGURE ND-2
Examples of Minimizing Directly Connected Impervious Areas – Residential and Commercial

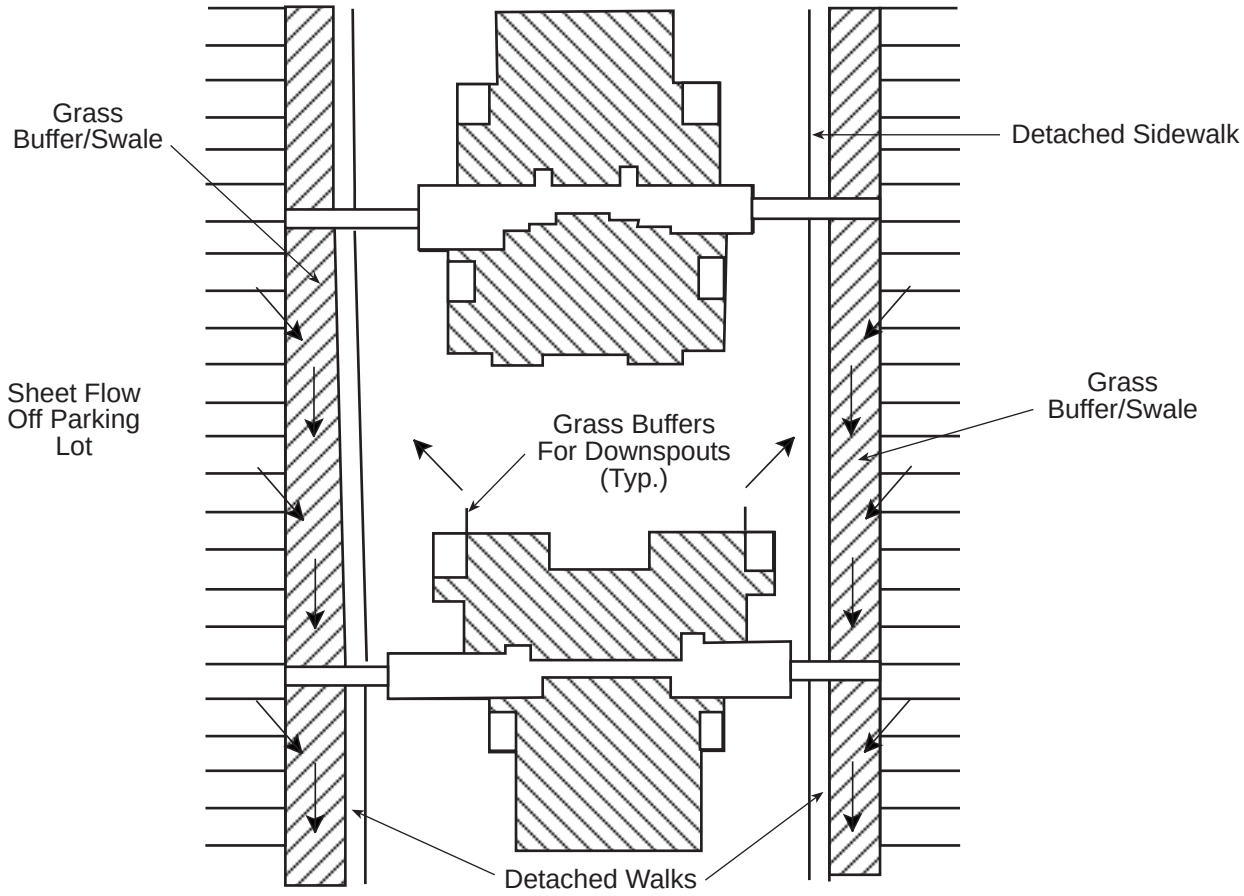


FIGURE ND-3
Examples of MDCIA for Multi-Family Residential Development

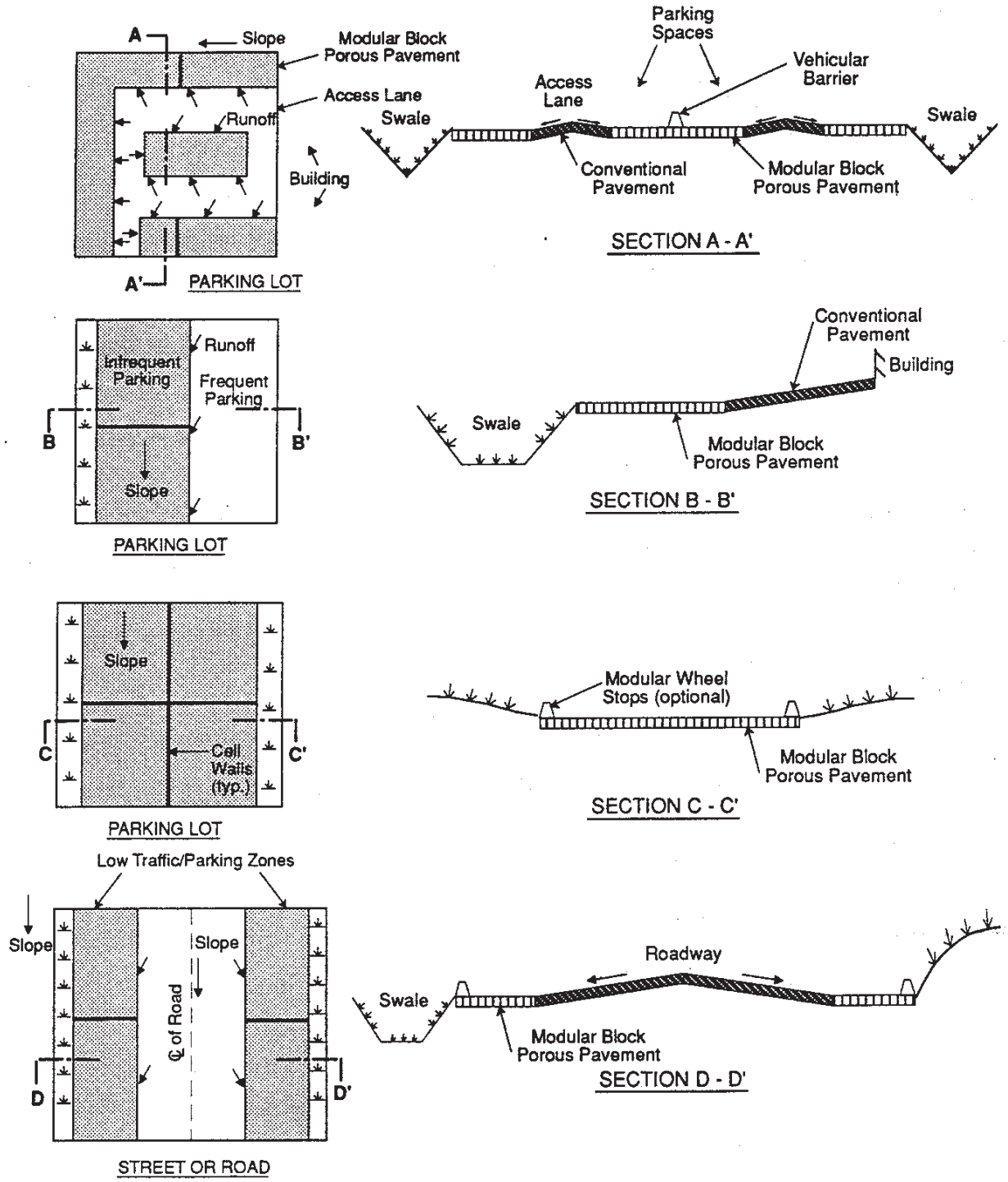


FIGURE ND-4
Typical Application of Modular Block Porous Pavement

Providing Water Quality Capture Volume (WQCV)

Benefits of WQCV Facilities

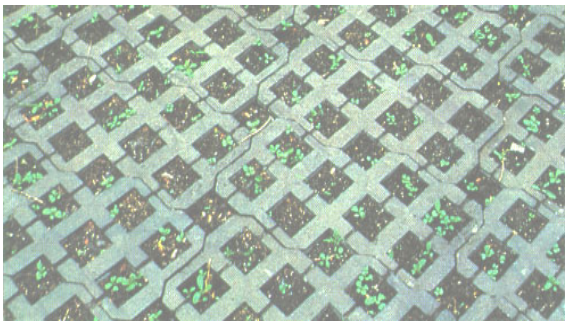
These BMPs are designed to capture and provide treatment for a specific volume of stormwater runoff (about half of the runoff from a 2-year storm). This volume is equivalent to the runoff from an 80th percentile storm, meaning that 80 percent of the most frequently occurring storms are fully captured and treated and larger events are partially treated. Detention periods range from 6 to 40 hours, depending on the type of facility. The primary pollutant removal mechanism consists of physical settling of suspended sediments and associated adsorbed pollutants. Secondary pollutant removal mechanisms include filtering, biological uptake, and adsorption.

The WQCV treatment facilities described herein have been selected because they have demonstrated proven results and are relatively cost-effective. For those sites requiring WQCV (see section 4.1: *Definition of New Development and Significant Redevelopment/BMP Requirements)* runoff from 100-percent of the impervious surfaces of a site must flow through a properly designed installation of one or more of the six WQCV BMPs that are listed herein. Alternate designs may be considered, but they must have equivalent functional requirements of these six BMPs as to WQCV and drain times.

Types of WQCV Facilities

A brief description of the six types of WQCV facilities follows.

Porous Pavement Detention (PPD)



Porous pavement detention consists of modular block porous pavement that is installed flat and is provided with a 2-inch deep detention zone above its surface to temporarily store the WQCV from the tributary drainage area including its own surface. Runoff infiltrates into the void spaces of the gravel base course through the sand filter and slowly exits through an underdrain. This application is likely to have limited use due to long-term operational and maintenance concerns.

Porous Landscape Detention (PLD)

Porous landscape detention consists of a low lying vegetated area underlain by a sand bed with an underdrain. A shallow surcharge zone exists above the porous landscape detention for temporary storage of the WQCV. This BMP allows small amounts of WQCV to be provided on parking lots or adjacent to buildings without requiring the set aside of significant developable land areas.

Extended Detention Basin (EDB)

An extended detention basin is appropriate for larger sites and is designed to totally empty out sometime after stormwater runoff ends. The extended basin uses a much smaller outlet than a flood control detention basin which extends the emptying time for the more frequently occurring runoff events to facilitate pollutant removal.

Sand Filter Extended Detention Basin (SFB)

A sand filter extended detention basin consists of a sand bed and underdrain system. Above the vegetated sand bed is an extended detention basin sized to capture the WQCV. A sand filter extended detention basin provides pollutant removal through settling and filtering and is generally suited to offline, onsite configurations where there is no base flow and the sediment load is relatively low.

Constructed Wetland Basin (CWB)

A constructed wetland basin is appropriate for large catchments and is a shallow retention pond which requires a perennial supply of water to permit the growth of rushes, willows, cattails, and reeds. It treats runoff by slowing it down to allow time for settling and biological uptake.

Retention Pond (RP)

A retention pond is appropriate for larger catchments. It has a permanent pool of water that is replaced with stormwater, in part or in total, during storm runoff events. In addition, a temporary extended detention volume is provided above this permanent pool to capture storm runoff and enhance sedimentation. It requires a perennial supply of water to maintain the pool.

Application Examples for Porous Pavement and Porous Landscape Detention

Porous pavement and porous landscape detention provide an opportunity to incorporate WQCV into a new land development site or a redevelopment site while minimizing the impact on developable area. Just as the principle of MDCIA requires a change in drainage philosophy, so does the application of porous pavement and porous landscape detention. These BMPs need to be applied on a relatively small scale and are ideally suited to small sites or individual small sub-catchment areas of large sites.

The following figures provide a number of illustrations of how porous pavement and porous landscape detention can be applied in a development site. Figure ND-5 and ND-5A show an example for a multi-family residential site, and Figure ND-6 shows an example for a commercial site parking lot.

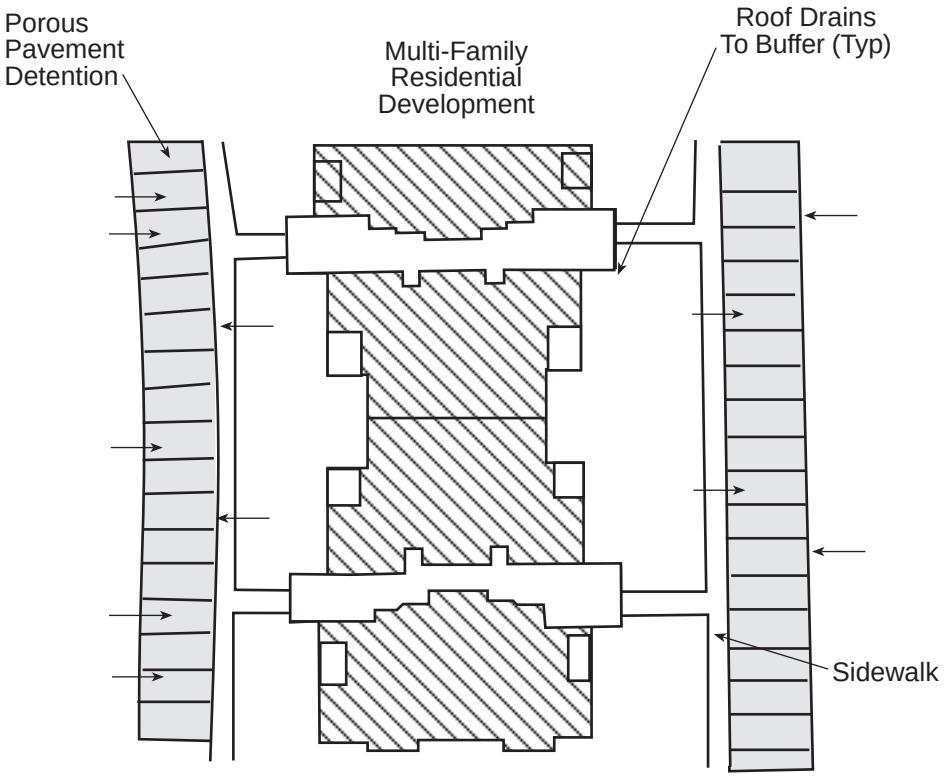


FIGURE ND-5
Example of Porous Pavement Detention for Multi-Family Residential Development

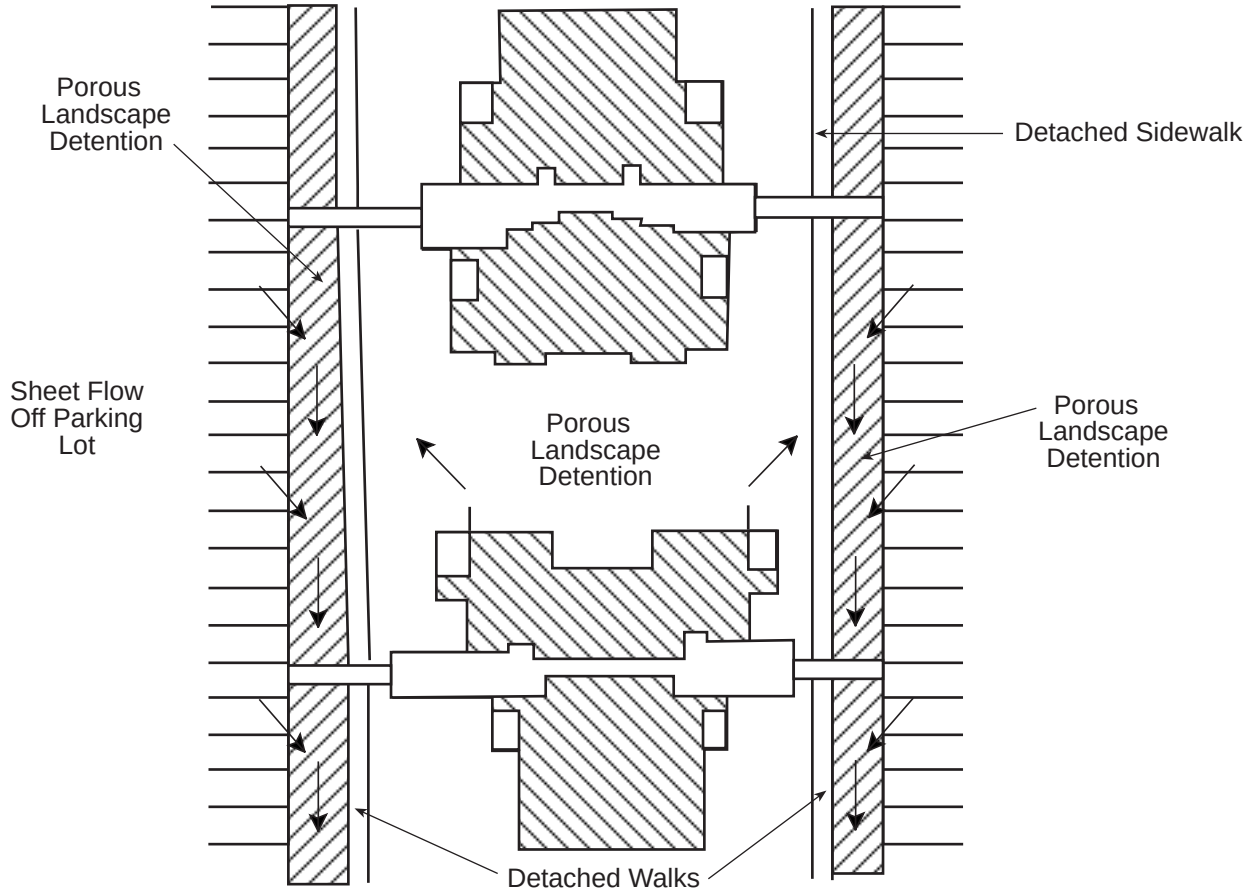


FIGURE ND-5A
Example of Porous Landscape Detention for Multi-Family Residential Development

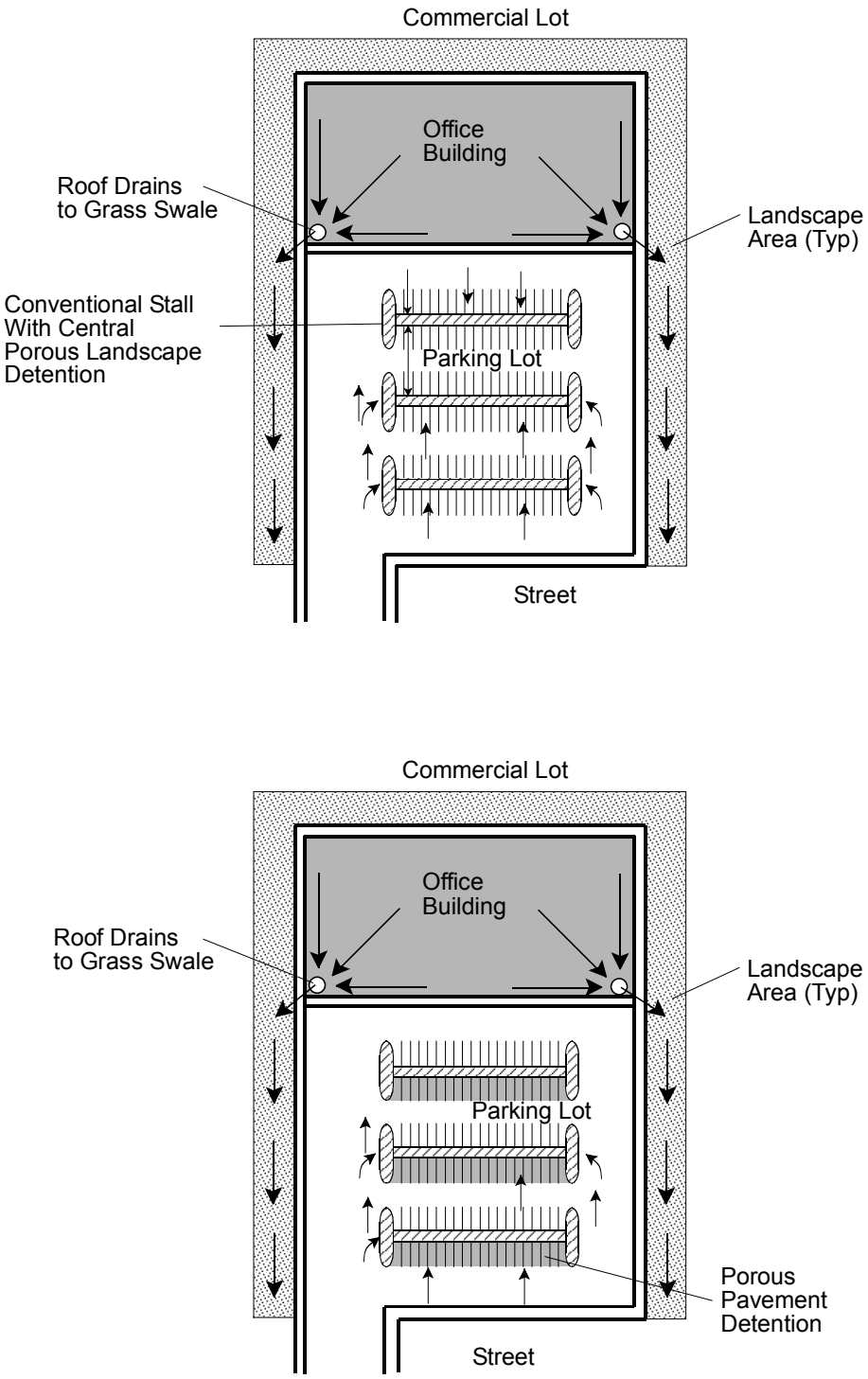


FIGURE ND-6
Examples of Porous Pavement and Porous Landscape Detention for Commercial Development (Parking Lot)

Guidance for Selecting and Locating WQCV Facilities

Figure ND-7 depicts a decision tree for selecting one of the six WQCV BMPs based on drainage catchment area and whether water is available to satisfy evapotranspiration requirements. Porous pavement and porous landscape detention is generally suited for small drainage areas (i.e. much less than 1.0 acres); however, larger subwatersheds can be subdivided into individual drainage sub-catchment areas meeting the criteria shown in Figure ND-7 for these BMPs.

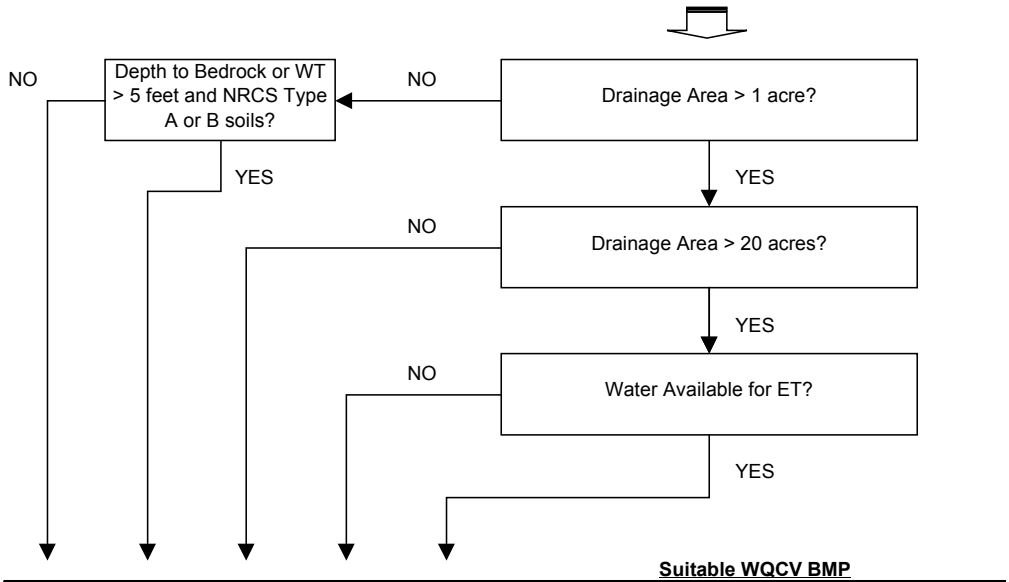
Laying out WQCV facilities within a development site and watershed requires thought and planning. This planning and decision-making should occur during a master drainage planning process (Drainage Basin Planning Study or Master Development Drainage Plan) undertaken by local jurisdictions or a developer's engineer. Such plans, studies or other reports may depict a recommended approach for implementing WQCV on a watershed basis. Such reports may call for a few large regional WQCV facilities, smaller sub-regional facilities, or alternatively an onsite approach. It is always a good idea to find out if a master planning study has been completed that addresses water quality and to attempt to follow the Plan's recommendations.

The following guidance is for areas where a master plan addressing water quality has not been completed. One of the questions involved in laying out WQCV facilities on a site is whether to locate a BMP onstream or offstream. Onstream refers to locating a BMP on a drainageway that traverses a site such that all of the runoff from the upstream watershed flows through the facility. A single onstream BMP can treat both site runoff and runoff generated in any upstream offsite catchment areas that are part of that watershed. Locating BMPs offstream requires that all onsite catchment areas flow though a BMP prior to entering the drainageway. Offstream BMPs do not provide treatment of runoff from any upstream drainage catchment areas.

Onstream WQCV facilities are only recommended if the offsite drainage catchment area tributary to the drainageway has less impervious area than the onsite drainage catchment's impervious area tributary to the same drainageway. Nevertheless, onstream WQCV facilities must be designed to serve the entire upstream watershed, including any catchment areas upstream of the development, based on future development conditions. This is true even if upstream developments have installed their own WQCV facilities.

The intent of WQCV facilities is they be located prior to the stormwater runoff being discharged to State Waters. However, see additional information in section 4.1: *Definition of New Development and Significant Redevelopment/BMP Requirements* regarding the acceptability of using downstream BMPs (including WQCV facilities) to serve as BMP controls for upstream development.

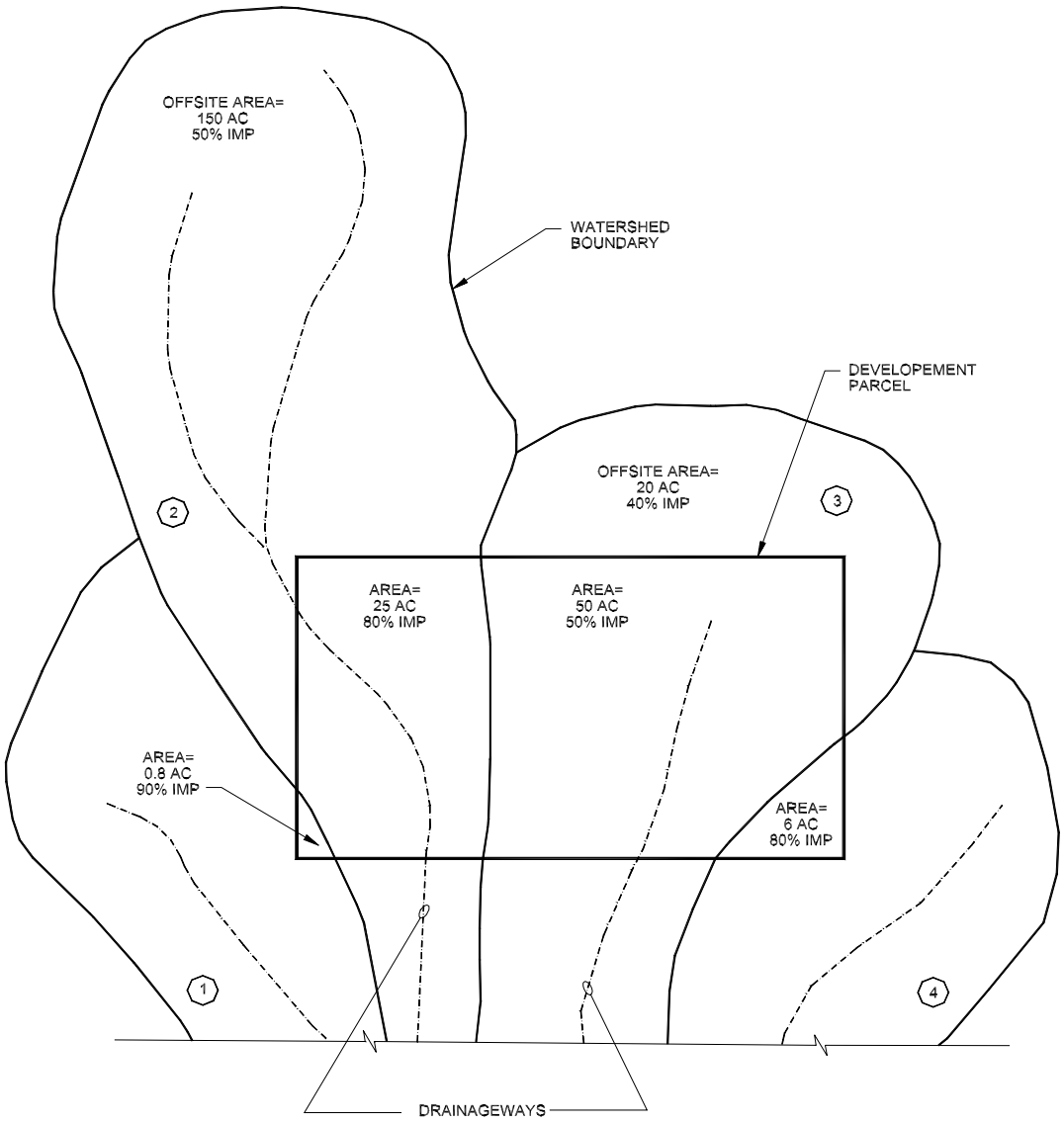
Figure ND-8 provides an illustration of selection and location options for WQCV facilities based on the principles discussed above. Table ND-1 indicates the BMP options for the four watershed areas shown in Figure ND-8.



					Suitable WQCV BMP
○					Porous Pavement Detention (PPD) with Underdrain
	○				Porous Pavement Detention (PPD) with Infiltration
○					Porous Landscape Detention (PLD) with Underdrain
	○				Porous Landscape Detention (PLD) with Infiltration
		○	○	○	Extended Detention Basin (EDB)
		○			Sand Filter Extended Detention Basin (SFB)
				○	Construction Wetland Basin (CWB)
				○	Retention Pond (RP)

Note: Large drainage areas may be subdivided into areas < 20 acres for use of SFD or PLD or <1 acre for use of PPD.

FIGURE ND-7
Decision Tree for WQCV BMP Selection



NOTE: FOR THIS EXAMPLE SUFFICIENT MAKE-UP WATER EXISTS FOR CONSTRUCTED WETLANDS AND RETENTION POND FOR THE WATERSHED AREAS > 50 ACRES THROUGH IRRIGATION RETURN FLOWS.

FIGURE ND-8
Illustration of Selection and Location Options For WQCV Facilities

TABLE ND-1
Illustration of Selection and Location Options for WQCV Facilities for the Development Parcel on Figure ND-8

Watershed Number	Onstream or Offstream	BMP Options	Minimum Number of BMP Installations	Average Drainage Area for Sizing Each BMP, acre
1	Offstream	Porous Pavement Detention	1	0.8
		Porous Landscape Detention	1	0.8
2	Offstream	Porous Pavement Detention	24	1
		Porous Landscape Detention	24	1
		Extended Detention Basin	2	12
		Sand Filter Extended Detention Basin	2	12
3	Offstream	Porous Pavement Detention	49	1
		Porous Landscape Detention	49	1
		Extended Detention Basin	2	24
		Sand Filter Extended Detention Basin	3	16
	Onstream	Extended Detention Basin	1	70
		Constructed Wetland Basin	1	70
		Retention Pond	1	70
4	Offstream	Porous Pavement Detention	6	1
		Porous Landscape Detention	6	1
		Extended Detention Basin	1	6
		Sand Filter Extended Detention Basin	1	6

Incorporating WQCV into Stormwater Quantity Detention Basins

Wherever possible, it is recommended that WQCV facilities be incorporated into stormwater quantity detention facilities. This is relatively straightforward for an extended detention basin, constructed wetland basin, and a retention pond. When combined, the 2-, 5-, 10-, and/or 100-year detention levels are provided above the WQCV and the outlet structure is designed to control two or three different releases. Stormwater quantity detention could be provided above the WQCV for porous pavement and landscape detention provided the drain times for the larger events are kept short.

The following approaches are to be implemented when incorporating WQCV into stormwater quantity detention facilities:

- Water Quality. The full WQCV is to be provided according to the design procedures documented in the *New Development BMP Factsheets*.
- Minor Storm. The full WQCV plus the full minor storm quantity detention volume is to be provided.
- 100-Year Storm. One-half the WQCV plus the full 100-year detention volume is to be provided.

At this time, water quality detention is not to be incorporated into underground detention facilities, such as installations of buried large-diameter pipe sections, stone trenches, underground "infiltrating" devices, etc.

Separate Presedimentation Facilities

The design criteria shown in the *New Development BMP Factsheets* section shows presedimentation forebays at the upstream end of the extended detention basin, constructed wetland basin, and retention pond. The purpose of the forebay is to settle out coarse

sediment and skim off floatables prior to the main body of the facility. An option to this approach is to install a separate facility upstream from the main WQCV facility. If this option is selected, the recommended size is at least 20 percent of the WQCV and the recommended drain time is 1 hour for the presedimentation forebay volume only. Using this approach, the size of the main WQCV facility may be reduced by 10 percent, any requirement for sediment storage in the main facility may be reduced by one-half, and the forebay within the main facility may be eliminated.

It is extremely important that high sediment loading be controlled for porous pavement detention, porous landscape detention, and sand filter extended detention basins. These facilities are best suited to being brought on line at the end of the construction phase where disturbed ground has been established with pavement or vegetation.

Structural BMP Effectiveness

Table ND-2 indicates ranges of removal efficiencies reported in literature for a number of structural BMPs. Although combinations of nonstructural/structural BMPs can improve the overall water quality of the runoff, the effectiveness of several BMPs in their ability to reduce influent pollutant concentrations as a group are not directly additive. Table ND-2 also shows a most probable range of removal efficiencies for structural BMPs recommended in the *New Development BMP* section.

TABLE ND-2
BMP Pollutant Removal Ranges for Stormwater Runoff and Most Probable Range for BMPs

Type of BMP	(1)	TSS	TP	TN	TZ	TPb	BOD	Bacteria
Grass Buffer	LRR:	10-50	0-30	0-10	0-10	N/A	N/A	N/A
	EPR	**10-20**	**0-10**	**0-10**	**0-10**	N/A	N/A	N/A
Grass Swale	LRR:	20-60	0-40	0-30	0-40	N/A	N/A	N/A
	EPR	**20-40**	**0-15**	**0-15**	**0-20**	N/A	N/A	N/A
Modular Block Porous Pavement	LRR:	80-95	65	75-85	98	80	80	N/A
	EPR	**70-90**	**40-55**	**10-20**	**40-80**	**60-70**	N/A	N/A
Porous Pavement Detention	LRR:	8-96	5-92	-130-85	10-98	60-80	60-80	N/A
	EPR	**70-90**	**40-55**	**10-20**	**40-80**	**60-70**	N/A	N/A
Porous Landscape Detention	LRR:	8-96	5-92	-100-85	10-98	60-90	60-80	N/A
	EPR	**70-90**	**40-55**	**20-55**	**50-80**	**60-80**	N/A	N/A
Extended Detention Basin	LRR:	50-70	10-20	10-20	30-60	75-90	N/A	50-90
	EPR	**55-75**	**45-55**	**10-20**	**30-60**	**55-80**	N/A	N/A
Constructed Wetland Basin	LRR:	40-94	-4-90	21	-29-82	27-94	18	N/A
	EPR	**50-60**	**40-80**	**20-50**	**30-60**	**40-80**	N/A	N/A
Retention Pond	LRR:	70-91	0-79	0-80	0-71	9-95	0-69	N/A
	EPR	**80-90**	**45-70**	**20-60**	**20-60**	**60-80**	N/A	N/A
Sand Filter Extended Detention	LRR:	8-96	5-92	-129-84	10-98	60-80	60-80	N/A
	EPR	**80-90**	**45-55**	**35-55**	**50-80**	**60-80**	**60-80**	N/A
Constructed Wetland Channel*	LRR:	20-60	0-40	0-30	0-40	N/A	N/A	N/A
	EPR	**30-50**	**20-40**	**10-30**	**20-40**	**20-40**	N/A	N/A

Ref: Bell et al. (1996), Colorado (1990), Harper & Herr (1992), Lakatos & McNemer (1987), Schueler (1987), Southwest (1995), Strecker et al. (1990), USGS (1986), US EPA (1983), Veenhuis et al. (1989), Whipple and Hunter (1981), Urbonas (1997.

(1)LRR Literature reported range, **EPR**—expected probable range of annual performance by Volume 3 BMPs.
N/A Insufficient data to make an assessment.

*The **EPR** rates for a Constructed Wetland Channel assume the wetland surface area is equal or greater than 0.5% of the tributary total impervious area.

4.2 New Development BMP Factsheets

This chapter provides a description and design information for the following structural BMPs:

1. Grass Buffer (GB).
2. Grass Swale (GS).
3. Modular Block Porous Pavement (MBP).
4. Porous Pavement Detention (PPD).
5. Porous Landscape Detention (PLD).
6. Extended Detention Basin (EDB).
7. Sand Filter Extended Detention Basin (SFB).
8. Constructed Wetlands Basin (CWB).
9. Retention Pond (RP).
10. Constructed Wetlands Channel (CWC).
11. Covering of Storage/Handling Areas.
12. Spill Containment and Control.

Detailed design procedures and criteria are described. Forms that designers can use to document the design procedure are included in Appendix A, *Design Forms*. Typical design details are shown in section 4.3, *Typical Structural Details*.

Grass Buffer (GB)

Description

Grass buffer (GB) strips are an integral part of the MDCIA land development concept. They are uniformly graded and densely vegetated areas of turf grass. They require sheet flow to promote filtration, infiltration and settling to reduce runoff pollutants. GBs differ from grass swales as they are designed to accommodate overland sheet flow rather than concentrated or channelized flow. They can be used to remove larger sediment from runoff off impervious areas.

Whenever concentrated runoff occurs, it should be evenly distributed across the width of the buffer via a flow spreader. This may be a porous pavement strip or another type of structure to achieve uniform sheet-flow conditions. GBs can also be combined with riparian zones in treating sheet flows and in stabilizing channel banks adjacent to major drainageways and receiving waters. GBs can be interspersed with shrubs and trees to improve their aesthetics and to provide shading. Irrigation in the semi-arid climate of Colorado is required to maintain a healthy and dense grass on the GB to withstand the erosive forces of runoff from impervious areas.

General Application

A GB can be used in residential and commercial/industrial areas. They are typically located adjacent to impervious areas. When used, they should be incorporated into site drainage, street drainage, and master drainage planning. Because their effectiveness depends on having an evenly distributed sheet flow over their surface, the size of the contributing area, and the associated volume of runoff have to be limited. Flow can be directly accepted from an impervious area such as from a parking lot and building roofs, provided the flow is distributed uniformly over the strip. GBs provide only marginal pollutant removal and require that follow-up structural BMPs be provided. They do, however, help to reduce some of the runoff volume from small storms.

Advantages/Disadvantages

General

The grass and other vegetation provide aesthetically pleasing green space, which can be incorporated into a development landscaping plan. In addition, their use adds little cost to a development's landscape requirements, and their maintenance should be no different than routine maintenance of the site's landscaping. Eventually, the grass strip next to the spreader or the pavement will have accumulated sufficient sediment to block runoff. At that point in time, a portion of the GB strip will need to be removed and replaced.

Grass and trees within these buffer strips can provide wildlife habitat and help reduce runoff through infiltration. If infiltration occurs, it can reduce the size of downstream drainage facilities. Gravel underdrains can be used where soils are not best suited for infiltration and to help keep the GB's surface dry.

Physical Site Suitability

The site, after final grading, should have a uniform slope and be capable of maintaining an even sheet flow throughout without concentrating runoff into shallow swales or rivulets. The allowable tributary area depends on the width, length, and the soils that lay under the GB. Hydrologic Soil Groups A and B provide the best infiltration capacity, while Soil Groups C and D provide best site stability. The swelling potential of underlying soils should also be taken into account in how the soils may affect adjacent structures and pavement when water is delivered to the grassed areas. Because of the semi-arid nature of Colorado's high plains, an irrigated grass cover is required to be effective.

Pollutant Removal

Pollutant removal depends on many factors such as soil permeability, site slope, the flow path length along the buffer, the characteristics of drainage area, runoff volumes and velocities, and the type of vegetation. The general pollutant removal of both particulate and soluble pollutants is projected to be low to moderate. GBs rely primarily upon the settling and interception of solids, and to only a minor degree, on biological uptake and runoff infiltration. See Table ND-2 for estimated range of pollutant removals.

Design Considerations

Design of GBs are based primarily on maintaining sheet-flow conditions across a uniformly graded, irrigated, dense grass cover strip. When a GB is used over unstable slopes, soils, or vegetation, formation of rills and gullies that disrupt sheet flow will occur. The resultant short-circuiting will invalidate the intended water quality benefits. GBs should be protected from excessive pedestrian or vehicular traffic that can damage the grass cover and affect even sheet-flow distribution. A mixture of grass and trees may offer benefits for slope stability and improved aesthetics.

Design Procedure and Criteria

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

1. Design Discharge

Determine the 2-year peak flow rate of the area draining to the GB. Also, determine the flow control type; sheet or concentrated.

2. Minimum Length

Calculate the minimum length (normal to flow) of the GB. The upstream flow needs to be uniformly distributed over this length. General guidance suggests that the hydraulic load should not exceed 0.05 cfs/linear foot of buffer in the Colorado high plains region during a 2-year storm to maintain a sheet flow of less than 1 inch throughout dense grass that is at least 2 inches high. The minimum design length (normal to flow) is therefore calculated as:

$$L_G = \frac{Q_{2-year}}{0.05}$$

In which:

L_g = Minimum design length (feet)

$Q_{2\text{-year}}$ = Peak discharge supplied to the GBs by a 2-year event (cfs)

Longer lengths may be used.

3. Minimum Width

The minimum width (W_G) (the distance along the sheet flow direction) of the GB shall be determined by the following criteria for onsite and concentrated flow control conditions:

A. Sheet Flow Control (use the larger value)

$$W_G = 0.2L_I \text{ or } 8 \text{ feet}$$

In which:

L_I = The length of flow path of the sheet flow over the upstream impervious surface (feet)

B. Concentrated Flow Control (use the larger value)

$$W_G = 0.15(A_t/L_t) \text{ or } 8 \text{ feet}$$

In which:

A_t = The tributary area (square feet)

L_t = The length of the tributary (normal to flow) upstream of the GB (feet)

The longer the buffer area is relative to the impervious area draining to it, the smaller the effective imperviousness, per Figure ND-1.

A generally rectangular shape strip is preferred and should be free of gullies or rills that concentrate the overland flow.

4. Maximum Slope	Design slopes shall not exceed 4 percent.
5. Flow Distribution	Incorporate a device on the upstream end of the buffer to evenly distribute flows along the design length. Slotted curbing, modular block porous pavement (MBP), or other spreader devices can be used to apply flows. Concentrated flow supplied to the GB must use a level spreader (or a similar concept) to evenly distribute flow onto the buffer.
6. Vegetation	Vegetate the GB with irrigated dense turf in semi-arid areas of Colorado to promote sedimentation and entrapment and to protect against erosion.
7. Outflow Collection	Provide a means for outflow collection. Most of the runoff during significant events will not be infiltrated and will require a collection and conveyance system. A GS can be used for this purpose and can provide another MDCIA type of a BMP. The buffer can also drain to a storm sewer or to a street gutter.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

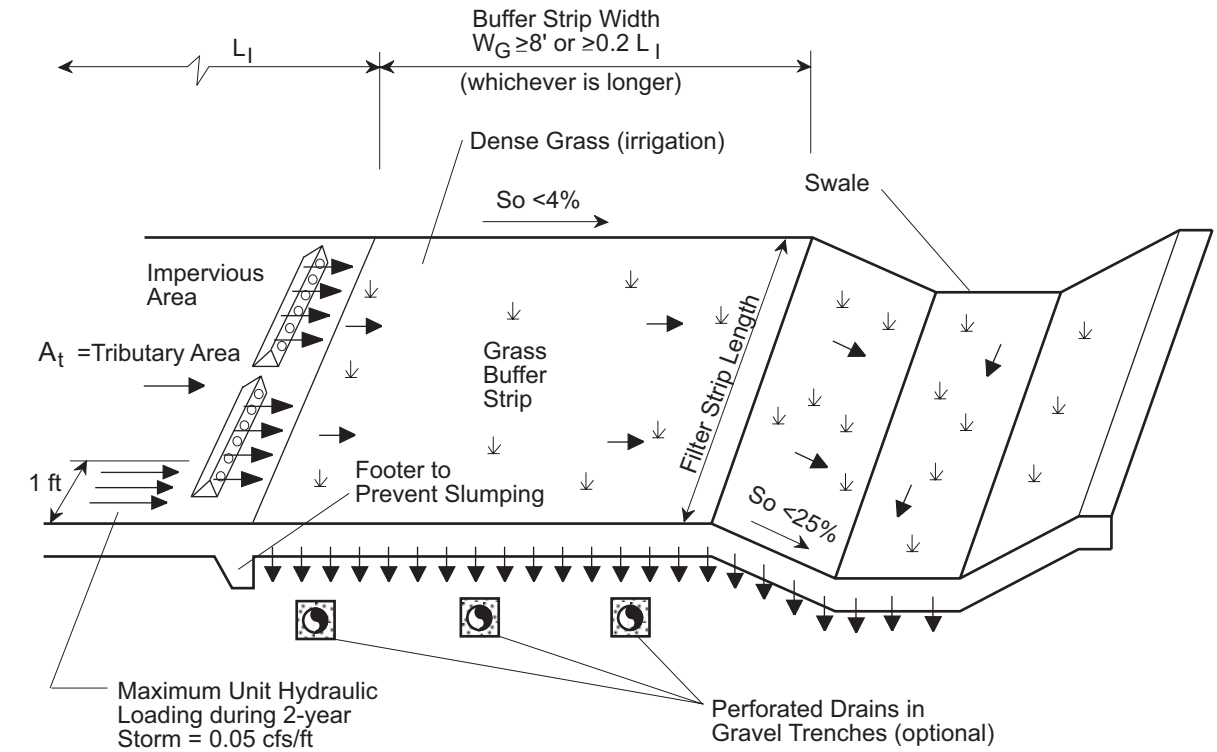
Grass buffers require general maintenance of the turf grass cover and repair of any rill or gully development. Table GB-1 presents a summary of specific maintenance requirements and a suggested frequency of action.

TABLE GB-1
Irrigated Grass Buffer Strip Maintenance Considerations

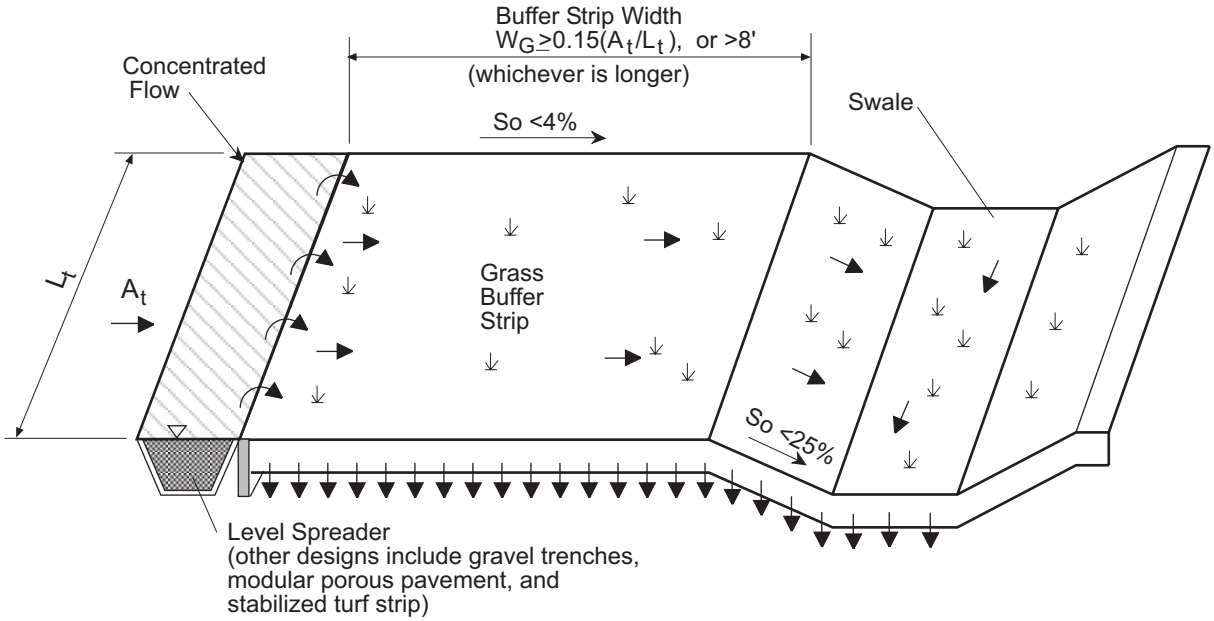
Required Action	Maintenance Objective	Frequency of Action
Lawn mowing	Maintain a dense grass cover at a recommended length of 2 to 4 inches. Collect and dispose of cuttings offsite or use a mulching mower.	Routine – As needed or recommended by inspection.
Lawn care	Use the minimum amount of biodegradable, nontoxic fertilizers and herbicides needed to maintain dense grass cover, free of weeds. Reseed and patch damaged areas.	Routine – As needed.
Irrigation	Adjust the timing sequence and water cover to maintain the required minimum soil moisture for dense grass growth. Do not overwater.	As needed.
Litter removal	Remove litter and debris to prevent gully development, enhance aesthetics, and prevent floatables from being washed offsite.	Routine – As needed by inspection.

TABLE GB-1
Irrigated Grass Buffer Strip Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Inspections	Inspect irrigation, turf grass density, flow distribution, gully development, and traces of pedestrian or vehicular traffic and request repairs as needed.	Annually and after each major storm (that is, larger than 0.75 inches in precipitation).
Turf replacement	To lower the turf below the surface of the adjacent pavement, use a level flow spreader, so that sheet flow is not blocked and will not cause water to back up onto the upstream pavement.	As needed when water padding becomes too high or too frequent a problem. The need for turf replacement will be higher if the pavement is sanded in winter to improve tire traction on ice. Otherwise, expect replacement once every 5 to 15 years.



SHEET FLOW CONTROL



CONCENTRATED FLOW CONTROL

Note: Not to Scale

FIGURE GB-1
Application of Grass Buffers

Design Procedure Form: Grass Buffer (GB)

Designer: _____
Company: _____
Date: **September 21, 1999**
Project: _____
Location: _____

1. 2-Year Design Discharge (Total)	Q_2 = 5.0 cfs
2. Tributary Catchment Flow	
A) Design Length (Normal to runoff flow path): $L_G = Q_2 / 0.05$	L_G = 100 feet
B) Tributary Area in Square Feet (A_t)	A_t= 10,000 square feet
3. Design Width Along Direction of Flow (Use A **or** B)	
A) Sheet Flow Control Upstream	
i) Length of Flow Path Over Upstream Impervious Surface	L_I = _____ feet
ii) Design Width of Buffer: $W_G = 0.2 * L_I$ (8' minimum)	W_G = _____ feet
B) Concentrated (Non-Sheet) Flow Control Upstream (requires a level spreader in step 5 below)	
i) Length of Upstream Flow Level Spreader	L_t = 80 feet
ii) Design Width of Buffer: $W_G = 0.15 * A_t / L_t$ (8' minimum)	W_G = 18.8 feet
4. Design Slope (not to exceed 4%)	S = 4.00 %
5. Flow Distribution (Check the type used or describe "Other") Note: If Method B was Used In Step 3, Level Spreader Must Be Checked Here	_____ Slotted Curbing _____ Modular Block Porous Pavement X Level Spreader _____ Other: _____
6. Vegetation (Check the type used or describe "Other") Note: Irrigated Turf Grass Is Required in Semi-Arid Climates	X Irrigated Turf Grass _____ Non-Irrigated Turf Grass _____ Other: _____
7. Outflow Collection (Check the type used or describe "Other")	X Grass Lined Swale _____ Street Gutter _____ Storm Sewer Inlet X Underdrain Used _____ Other: _____

Notes: _____

Grass Swale (GS) – Sedimentation Facility

Description

A grass swale (GS) sedimentation facility is an integral part of the MDCIA development concept. They are densely vegetated drainageways with low-pitched sideslopes that collect and slowly convey runoff. Design of their longitudinal slope and cross-section size forces the flow to be slow and shallow, thereby facilitating sedimentation while limiting erosion. Berms or check dams should be installed perpendicular to the flow as needed to slow it down and to encourage settling and infiltration.

General Application

A GS can be located to collect overland flows from areas such as parking lots, buildings, residential yards, roadways and grass buffer strips (GBs). They can be made a part of the plans to minimize a directly connected impervious area by using them as an alternative to a curb-and-gutter system. A GS is set below adjacent ground level, and runoff enters the swales over grassy banks. The potential exists for wetland vegetation to become established if the swale experiences standing water or if there is a base flow. If that condition is possible, consider the use of underdrains. A site with a base flow should be managed as either a swale with an unlined trickle channel, or as a wetland bottom channel, the latter providing an additional BMP to stormwater runoff.

Advantages/Disadvantages

General

A GS, which can be more aesthetically pleasing than concrete or rock-lined drainage systems, is generally less expensive to construct. Although limited by the infiltration capacity of local soils, this BMP can also provide some reduction in runoff volumes from small storms. Dense grasses can reduce flow velocities and protect against erosion during larger storm events. Swales in residential and commercial/industrial settings can also be used to limit the extent of directly connected impervious areas.

The disadvantages of using GSs without underdrains include the possibility of soggy and wet areas in front yards, the potential for mosquito breeding areas, and the potential need for more right-of-way than is needed for a storm sewer.

Physical Site Suitability

A GS is practical only at sites with general ground slopes of less than 4 percent and are definitely not practical for sites steeper than 6 percent. The longitudinal slopes of a GS should be kept to less than 1 percent, which often necessitates the use of grade control checks or drop structures. Where the general terrain slope exceeds 4 percent, a GS is often practical only on the upslope side of the adjacent street.

When soils with high permeability (for example, Class A or B) are available, the swale will infiltrate a portion of the runoff into the ground, but such soils are not required for effective application of this BMP. When Class C and D soils are present, the use of a sand/gravel underdrain is recommended.

Pollutant Removal

Removal rates reported in literature vary and fall into the low to medium range. Under good soil conditions and low flow velocities, moderate removal of suspended solids and associated other constituents can be expected. If soil conditions permit, infiltration can remove low to moderate loads of soluble pollutants when flow velocities are very low. As a result, small frequently occurring storms can benefit the most. See Table ND-2 in section 4.1, *New Development Planning* for estimated ranges in pollutant removal rates by this BMP.

Design Considerations and Criteria

Figure GS-1 shows trapezoidal and triangular swale configurations. A GS is sized to maintain a low velocity during small storms and to collect and convey larger runoff events, all for the projected fully developed land use conditions. If the design flows are not based on fully developed land conditions, the swales will be undersized and will not provide the intended pollutant removal, flow attenuation, or flow conveyance capacity.

A healthy turf grass cover must be developed to foster dense vegetation. Permanent irrigation in some cases may be necessary. Judicious use of GSs can replace both the curb-and-gutter systems and greatly reduce the storm sewer systems in the upper portions of each watershed when designed to convey the "initial storm" (for example, a 2- or a 5-year storm) at slow velocities. However, if one or both sides of the GS are also to be used as a GB, the design of the

GB has to follow the requirements for the Grass Buffer (GB) , as listed previously in this section 4.2.

Design Procedure and Criteria

The following steps outline the GS design procedure and criteria.

1. Design Discharge	Determine the 2-year flow rate in the proposed GS using hydrologic procedures described in the Storm Runoff section of the City of Colorado Springs and El Paso County Drainage Criteria Manual.
2. Swale Geometry	Select geometry for the GS. The cross section should be either trapezoidal or triangular with side slopes flatter than 3:1 (Horizontal/ Vertical), preferably 4:1 or flatter. The wider the wetted area of the swale, the slower the flow.
3. Longitudinal Slope	Maintain a longitudinal slope for the GS between 0.2 and 1.0 percent. If the longitudinal slope requirements can not be satisfied with available terrain, grade control checks or small drop structures must be incorporated to maintain the required longitudinal slope. If the slope of the swale exceeds 0.5 percent in semi-arid areas of Colorado, the swale must be vegetated with irrigated turf grass.
4. Flow Velocity and Depth	Calculate the velocity and depth of flow through the swale. Based on Mannings equation and a Mannings roughness coefficient of n=0.05, find the channel velocity and depth using the 2-year flow rate determined in Step 1. Maximum flow velocity of the channel shall not exceed 2.0 feet per second and the maximum flow depth shall not exceed 3 feet at the 2-year peak flow rate. If these conditions are not attained, repeat steps 2 through 4 each time altering the depth and bottom width or longitudinal slopes until these criteria are satisfied.
5. Vegetation	Vegetate the GS with dense turf grass to promote sedimentation, filtration, and nutrient uptake, and to limit erosion through maintenance of low flow velocities.
6. Street and Driveway Crossings	If applicable, small culverts at each street crossing and/or driveway crossing may be used to provide onsite stormwater capture volume in a similar fashion to an EDB (if adequate volume is available).
7. Drainage and Flood Control	Check the water surface during larger storms such as the 5-year through the 100-year floods to ensure that drainage from these larger events is being handled without flooding critical areas or residential, commercial, and industrial structures.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

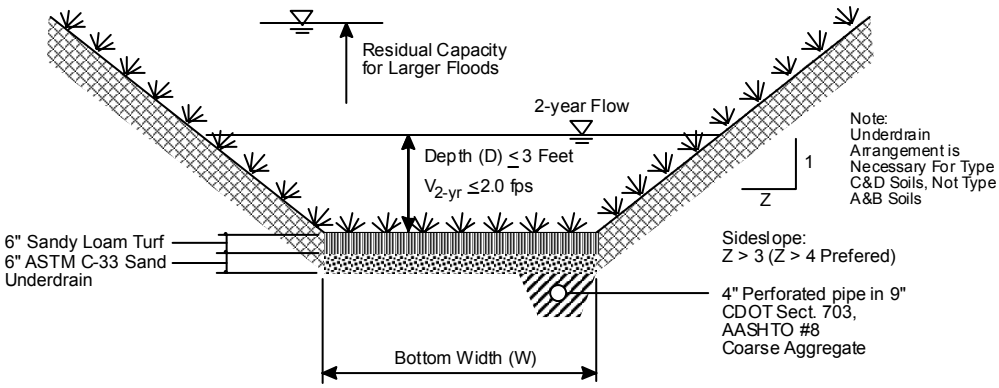
Maintenance Recommendations

Table GS-1 summarizes maintenance needs and related issues and shows the recommended frequency of various maintenance activities.

Healthy grass can generally be maintained without using fertilizers because runoff from lawns and other areas contains the needed nutrients. Occasionally inspecting the grass over the first few years will help to determine if any problems are developing and to plan for long-term restorative maintenance needs.

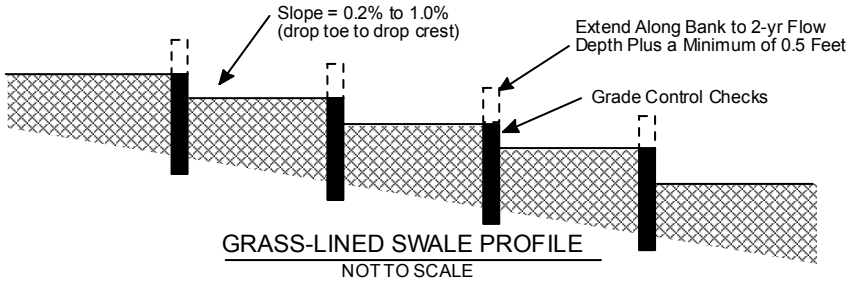
TABLE GS-1
Grass-Lined Swale Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn mowing and lawn care	Maintain irrigated grass at 2 to 4 inches tall and nonirrigated native grass at 6 to 8 inches tall. Collect cuttings and dispose of them offsite or use a mulching mower.	Routine – As needed.
Debris and litter removal	Keep the area clean for aesthetic reasons, which also reduces floatables being flushed downstream.	Routine – As needed by inspection, but no less than two times per year.
Sediment removal	Remove accumulated sediment near culverts and in channels to maintain flow capacity. Replace the grass areas damaged in the process.	Routine – As needed by inspection. Estimate the need to remove sediment from 3 to 10 percent of total length per year, as determined by annual inspection.
Grass reseeding and mulching	Maintain a healthy dense grass in channel and side slope.	Nonroutine – As needed by annual inspection.
Inspections	Check the grass for uniformity of cover, sediment accumulation in the swale, and near culverts.	Routine – Annual inspection is suggested.



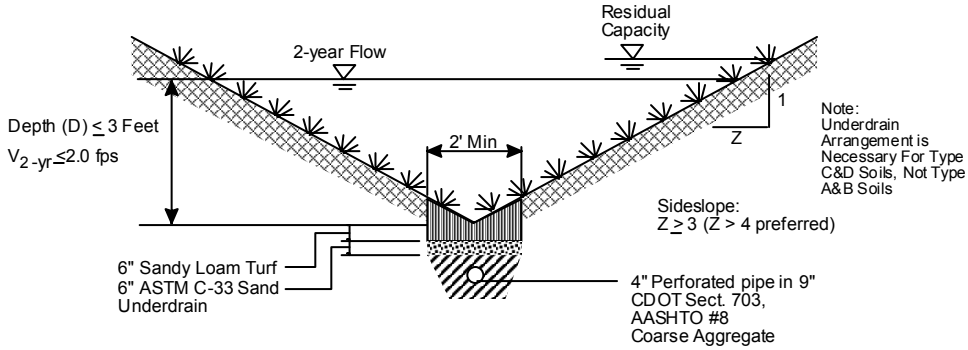
TRAPEZOIDAL GRASS-LINED SWALE SECTION

NOT TO SCALE



GRASS-LINED SWALE PROFILE

NOT TO SCALE



TRIANGULAR GRASS-LINED SWALE SECTION

NOT TO SCALE

FIGURE GS-1
Profile and Sections of a Grass Swale

Design Procedure Form: Grass Swale (GS) Sedimentation Facility

Designer: _____
Company: _____
Date: **May 23, 2002**
Project: _____
Location: _____

1. 2-Year Design Discharge (Total)	Q_2 = 10.0 cfs
2-Year Design Flow Velocity (V_2, 2.0 fps Maximum)	V_2 = 1.30 fps
2. Swale Geometry	
A) Channel Side Slopes (Z, horizontal distance per unit vertical)	Z = 4.00 (horizontal/vertical)
B) 2-Year Design Flow Depth (D_2, 3 feet Maximum)	D_2 = 1.4 feet
C) Bottom Width of Channel (B)	B = 0.0 feet
3. Longitudinal Slope	
A) Froude Number (F, 0.50 maximum, reduce V_2 until F $\leq$ 0.50)	F = 0.28
A) Design Slope (S, Based on Manning's n = 0.05, 0.01 Maximum)	S = 0.0032 feet/feet
B) Number of grade control structures required	5 (number)
4. Vegetation (Check the type used or describe "Other") (Must use irrigated turf grass if S >0.005 in semi-arid areas of Colorado)	___ Dryland Grass X Irrigated Turf Grass ___ Other: _____
5. Outlet (Check the type used or describe "Other")	X Infiltration Trench w/ Underdrain ___ Grated Inlet ___ Other: _____

Notes: _____

Modular Block Porous Pavement (MBP)

Description

Modular block porous pavement (MBP) consists of open void concrete block units laid on a gravel subgrade. The surface voids are filled with sand or sandy loam turf. An alternate approach is to use stabilized-grass porous pavement, consists of grass turf semiforced with plastic rings and filter fabric underlain by gravel. This BMP is intended to be used in low vehicle movement areas to accommodate vehicles while facilitating stormwater infiltration from rain falling directly on the porous pavement. The MBP may be sloped or flat, and functions to decrease the effective imperviousness of a site. An alternate application of MBP provided for a surcharge zone to capture the WQCV and provide water quality detention. This application is entitled *Porous Pavement Detention* and is described later in this chapter. MBP has been in use since the mid-1970s. Although field data that quantify its long-term performance are somewhat limited, the data collected locally and the episodical record from other parts of United States indicate it is reliable and has experienced few problems regardless of the local climatic conditions.

A stabilized (reinforced) sandy loam turf surface (e.g., Invisible Structures, Inc., or equal) may be substituted for the modular concrete block surface if the details below the surface are kept the same as shown in this section of the *Manual*.

General Application

MBP is best used in low vehicle movement zones such as residential driveways and is often used as a parking pad surface. Although MBP is most commonly used as parking pads in a parking lot, the following are other potential applications:

- Low vehicle movement airport zones such as parking aprons and maintenance roads.
- Crossover/emergency stopping/parking lanes on divided highways.

- Residential street parking lanes.
- Residential driveways.
- Maintenance roads and trails.
- Emergency vehicle and fire access lanes in apartment/multi-family/office complex situations (subject to Fire Department approval).

Vehicle movement (i.e., not parking) lanes that lead up to the porous pavement parking pads need to be solid asphalt or concrete pavement.

Grass can be used in the block voids; however, it requires irrigation and lawn care in Colorado's semi-arid climate.

Advantages/Disadvantages

General

Aside from the potential for high particulate pollutant removal and the removal of other constituents similar to what a sand filter would provide, MBP can reduce flooding potential by infiltrating or slowing down runoff. Modular block patterns, colors, and materials can serve functional and aesthetic purposes.

The primary disadvantages for use of MBP are cost and the lack of significant volume of performance data in semi-arid areas that are subject to severe freeze-thaw cycles; however, the limited testing by the Urban Drainage and Flood Control District as well as observation of several sites since 1990 and the episodic descriptions from public works professional from other parts of the country and Canada indicate this type of pavement, when properly installed, functions well in freeze-thaw cycles. Other disadvantages could be associated with uneven driving surfaces and potential traps for the high heels of women's shoes. Also, the cost of restorative maintenance can be somewhat high when the system seals with sediment and no longer functions as permeable pavement.

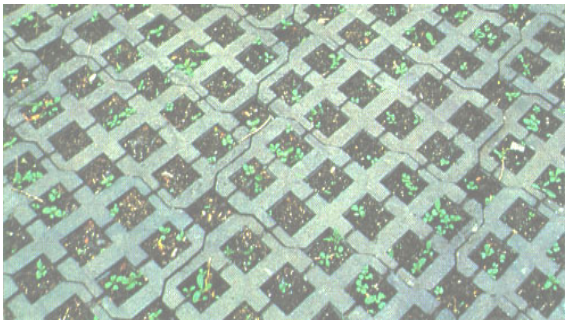
Physical Site Suitability

This BMP may be installed without free draining subsoils when provided with underdrains. An underdrain ensures drainage of the gravel subgrade whenever the subsoils are not free draining. In those cases an impermeable liner should be provided to drain the water in the gravel pack and to mitigate concerns about expansive soils. This BMP should be located far enough from foundations in expansive soils so as to limit damage potential to structures. In addition, when a commercial or an industrial site may be handling chemicals and petroleum products that may spill onto the ground, an impermeable liner with an underdrain is required to prevent groundwater and soil contamination.

Pollutant Removal

See Table ND-2 for estimated ranges in pollutant removals. Specific field data on pollutant removal rates are somewhat limited. Removal rates are projected to be high for both suspended sediment and associated constituents, such as metals, oil, and grease. Runoff filtration through the sand and gravel of the modular block voids and entrapment in the gravel media are the primary removal mechanisms of pollutants along with the filtration, adsorption, and ion exchange that occur as stormwater travels through the underlying soils before the stormwater

reaches groundwater. Removal rates for dissolved constituents are expected to be low to moderate, depending on the filtering media used and on the specific constituent.



Design Considerations

MBP has been tested as a stormwater BMP in the Denver area and the design guidance presented here is based, in part, on those tests. The above photo depicts one type of local available block. Other block patterns are acceptable provided they have at least 40 percent of its surface area as voids. Figures MBP-1 and MBP-2 show cross-sections of modular block installation and its subgrades. Upon installation, every effort should be made to assure even flow distribution over the entire porous surface. Figure MBP-3 depicts typical applications of modular block porous pavement.

For the purpose of sizing downstream drainage systems and follow-up BMPs, assume that the permeable pavement areas are only 35 percent impervious.

Design Procedure and Criteria

The following steps outline the design procedure and criteria.

1. Select Block	Select appropriate modular blocks that have no less than 40 percent of the surface area open. The manufacturer's installation requirements shall be followed with the exception that *Rock Media Pore Volume Inlay Material* and *Base Course* dimensions and requirements in this section shall be adhered with.
2. Select Porous Pavement Infill	The MBP openings should be filled with ASTM C-33 graded sand (fine concrete aggregate).
3. Base Coarses	Provide AASHTO No. 8 (CDOT Section 703) coarse aggregate with all fractured surfaces as called for in Figure MBP-1. Assume 30 percent is open pore space.
4. Design Area Ratio	Calculate the design area ratio which is the contributing impervious area divided by porous pavement area. This ratio cannot exceed 2.0.
5. Perimeter Wall (optional)	Provide a concrete perimeter wall to confine the edges of the MBP block area. The wall should be minimum 6-inch wide and 6 inches deeper than all the porous media and modular block depth combined (see Figure MBP-2).
6. Contained Cells	Provide 20 mil or thicker liner placed vertically or concrete walls to separate individual cells of the porous base course so as to cut-off horizontal flow of water (see Figure MBP-2). Space these cut-offs according to the following equation:

$$L_{MAX} = \frac{0.8}{S_O}$$

in which

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

S_O = Slope of the base course (ft/ft).

7. Subbase — If expansive soils are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane and place the base coarse on top of the membrane. Otherwise, install a non-woven geotextile membrane to encourage infiltration.

8. Subdrain Outlet — When needed due to site and soil conditions, design the subdrain with a permanent restrictor outlet to drain the available pore space volume in the base course in 12 hours. Subdrains are required when the pavement is located on low permeability soils such as clayey silt, sandy clays, clays, etc.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

TABLE MBP-1
Modular Block Porous Pavement Maintenance Considerations

Requires Action	Maintenance Objective	Frequency of Action
Debris and litter removal	Accumulated material should be removed as a source control measure.	Nonroutine – As needed.
Sod maintenance	If sandy loam turf is used, provide lawn care, the irrigation system, and inlay depth maintenance as needed.	Routine – As dictated by inspection.
Inspection	Inspect representative areas of surface filter sand or sandy turf for accumulation of sediment or poor infiltration.	Routine and during a storm event to ensure that water is not bypassing these surfaces by not infiltrating.
Replacement of Surface Filter Layer	Remove, dispose, and replace surface filter media by pulling out turf plugs and by vacuuming out sand media from within the annular spaces of the blocks. Replace with fresh ASTM C-33 sand and, if appropriate, sandy loam turf plugs.	Nonroutine – when it becomes evident that runoff does not rapidly infiltrate into the surface. May be as often as every year or as little as every 5 to 10 years.

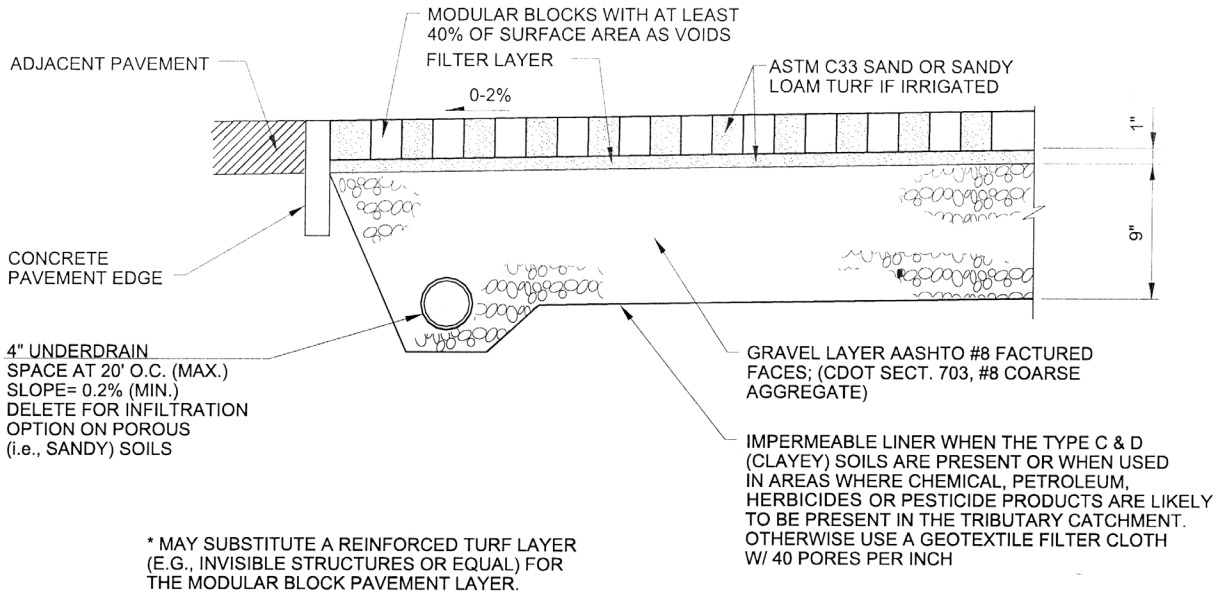
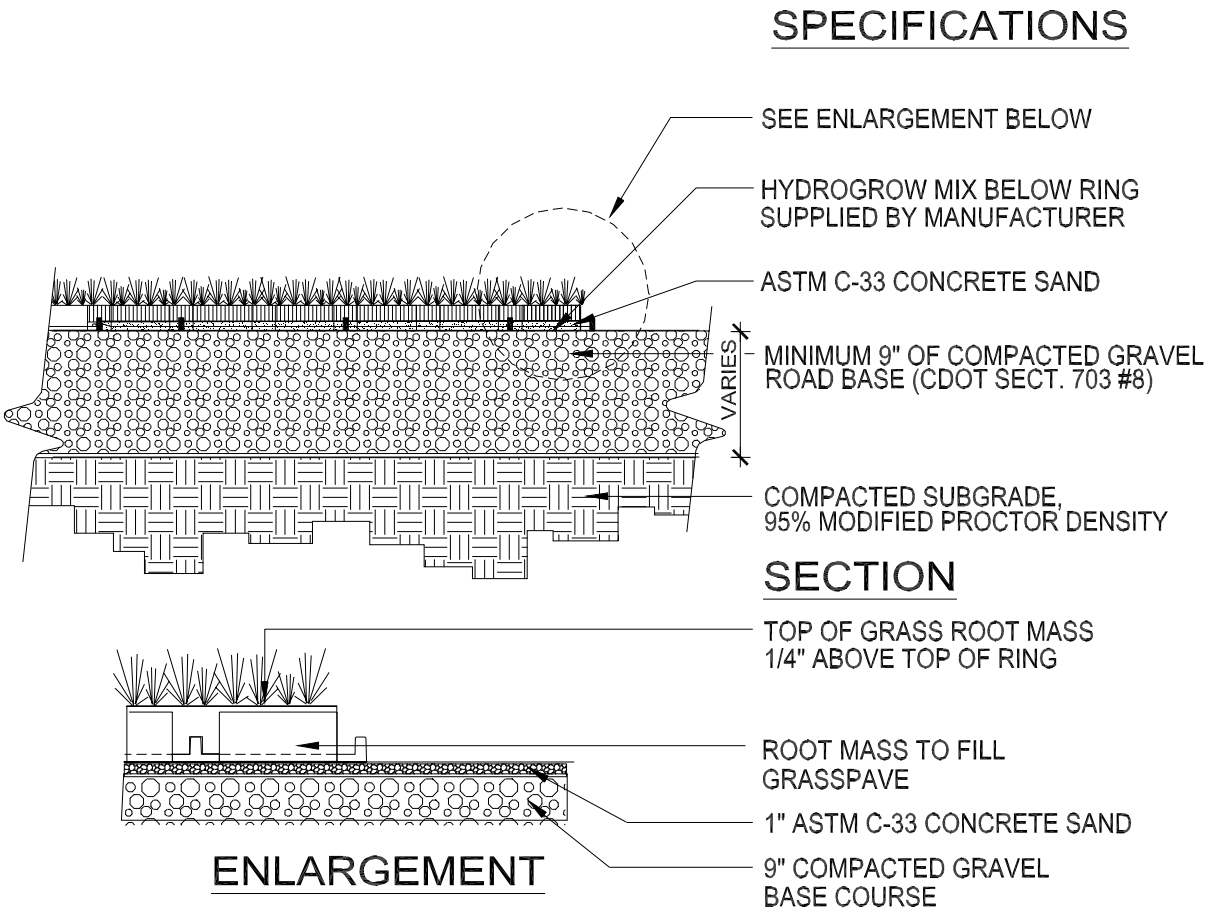


FIGURE MBP-1
Modular Block Porous Pavement Cross Section



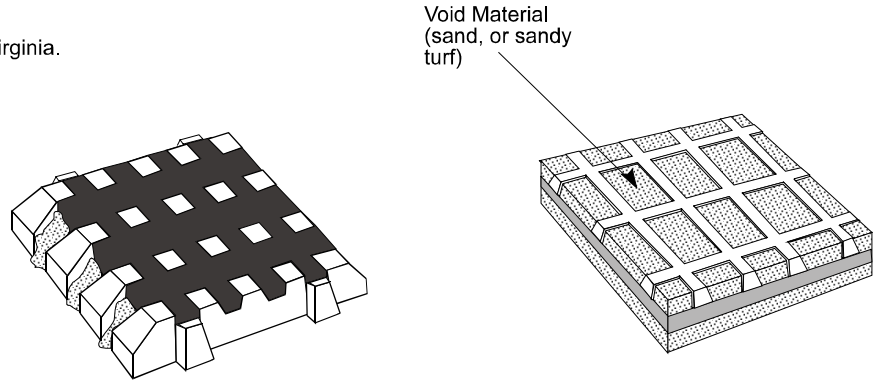
NOTES:

1. INSTALL GRASS TURF REINFORCING LAYER PER MANUFACTURER'S RECOMMENDATIONS

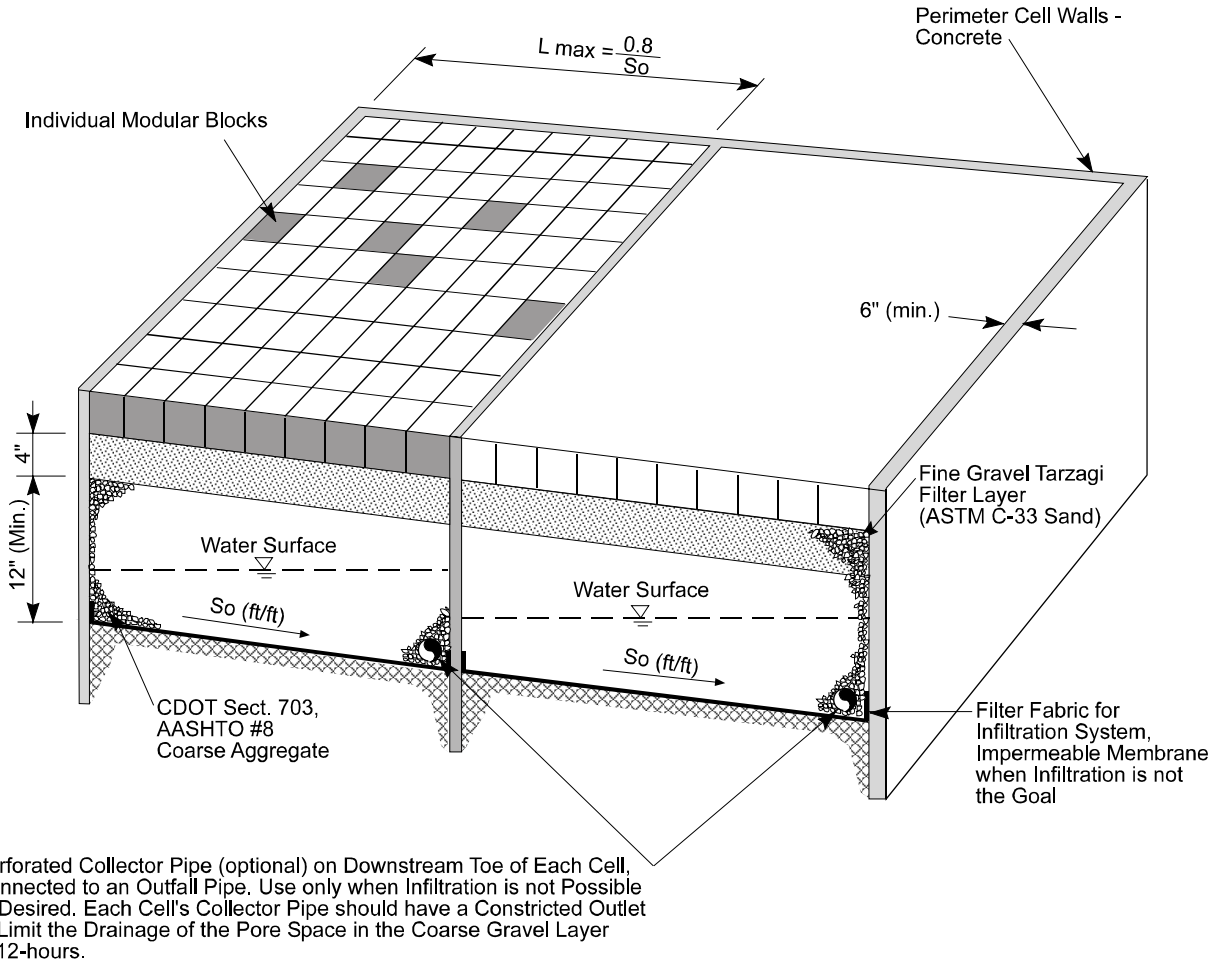
2. DETAIL BASED ON INVISIBLE STRUCTURES, INC., ET AL DETAILS, BUT MODIFIED TO SUIT USDCM REQUIREMENTS.

FIGURE MBP-1A
Typical Grasspave Detail

Source: State of Virginia.

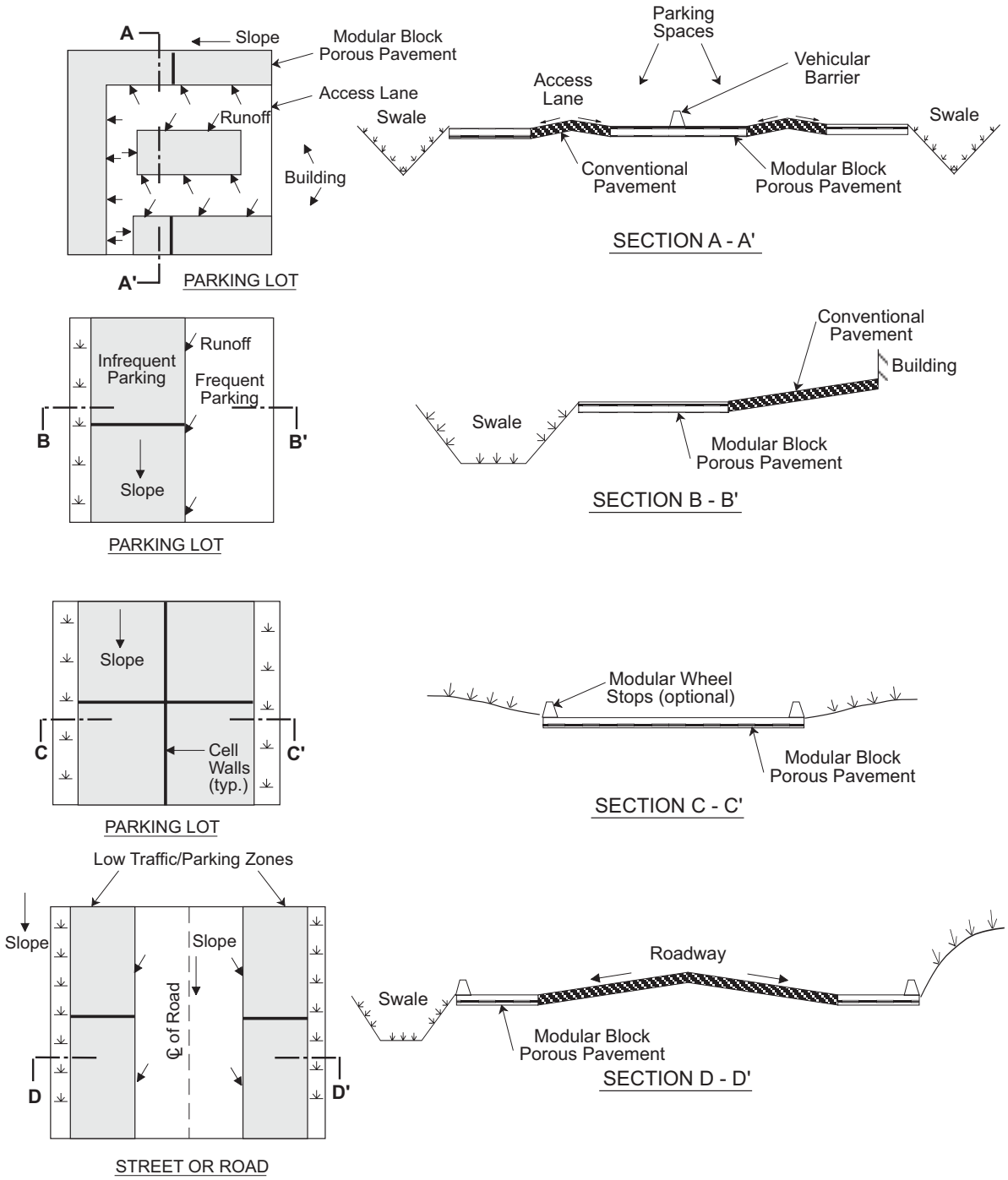


TWO EXAMPLES OF INDIVIDUAL CONCRETE MODULAR PAVING BLOCK



PERSPECTIVE OF SIDE-BY-SIDE MODULAR BLOCK CELLS

FIGURE MBP-2
Modular Block Porous Pavement



NOT TO SCALE

FIGURE MBP-3
Typical Applications of Modular Block Porous Pavement

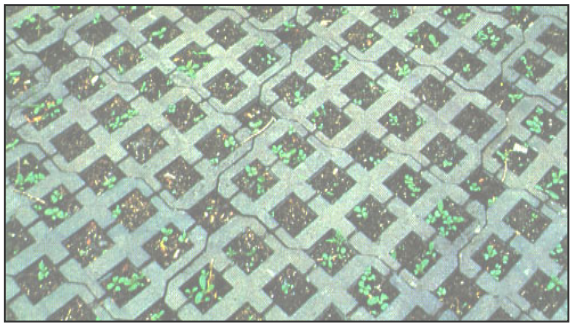
Design Procedure Form: Modular Block Porous Pavement (MBP)

Designer: _____
Company: _____
Date: **September 21, 1999**
Project: _____
Location: _____

1. Modular Block Properties May substitute MBP with reinforced turf pavement such as provided by Invisible Structures (or equal). Note: Blocks shall have no less than 40% open area and shall be no less than 4" thick	Block Name: Uni-Green Manufacturer: Pavestone Open Surface Area = 40 % Thickness = 4.00 inches
2. Porous Pavement Infill (Check the type or describe "Other")	X ASTM C-33 Sand _____ Sandy Loam Sod _____ Other: _____
3. Base Course A) Sand (ASTM C-33)	X 1" Layer ASTM C-33 Sand _____ Other: _____
B) Gravel (AASHTO #8 Coarse Aggregate-CDOT Section 703)	X 9" Layer AASHTO #8 Course Agg. _____ Other: _____
4. Design Impervious Area to Porous Pavement Area Ratio (Not to Exceed 2.0)	Ratio = 1.5 (A_{IMP} / A_{POROUS})
5. Perimeter Wall (6" deeper than base coarse)	X Concrete 4.0 inches thick _____ Other _____
6. Contained Cells A) Type	X 15 mil (min) P.E. Liner _____ Concrete Wall
B) Slope of the base course	S_O = 0.02 ft/ft
C) Minimum distance between cutoffs (normal to flow, L_{MAX}) $L_{MAX} = 0.8 / S_O$	L_{MAX} = 40 feet
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 subgrade is heavy or expansive clay [X] b) Check box if subgrade is silty or clayey sands [ ] c) Check box if subgrade is well-draining soils [ ] 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 Subgrade with Permeable Membrane: 7(c) checked **and** 7(d) = no X Underdrain with Impermeable Membrane: 7(a) checked **or** 7(d) = yes _____ Underdrain with Permeable Membrane: 7(b) checked **and** 7(d) = no _____ Other: _____

Notes: _____

Porous Pavement Detention (PPD)



Description

Porous pavement detention (PPD) consists of an installation of MBP that is flat (i.e., S_o=0.00 percent in all directions) and is provided with a 2-inch deep surcharge zone to temporarily store the WQCV draining from an adjacent drainage area. Runoff will infiltrate into the void spaces of the gravel base course through the sand filter media and sandy loam turf. The latter is not used for the PPD facility to insure more rapid drainage of the parking surface and easy maintenance when the media needs to be replaced to maintain rapid drainage of the ponding areas. The ponded and filtered water slowly exits through an underdrain. The application of MBP without the flat slope (i.e., S_o=0.00 percent) and surcharge zone, described in the MBP factsheet, functions to reduce imperviousness of pavement areas (from 100 percent to 35 percent). However, with the detention features, this BMP has the potential to satisfy the WQCV requirement for a site.

General Application

PPD may be used in the same types of low vehicle movement zones identified above for Modular Block Porous Pavement (MBP) with the driveways leading up to them being solid pavement.

Advantages/Disadvantages

PPD has generally the same advantages and disadvantages as MBP. Its additional advantage is to provide a means to provide WQCV for a site that has little available open area for detention.

Design Considerations

Figure PPD-1 shows a cross-section of modular block installation and its subgrade for PPD.

Design Procedure and Criteria

The following steps outline the PPD design procedure and criteria.

1. Basin Storage Volume — Provide a storage volume equal to the WQCV based on a 12-hour drain time.

   A. Find the required storage volume (watershed inches of runoff):

      Determine the required WQCV (watershed inches of runoff) using Figure PPD-2, based on 12-hour drain time. Assume imperviousness of 100 percent for the PPD area.

   B. Calculate the Design Volume in cubic-feet as follows:

$$Design\ Volume = \left(\frac{WQCV}{12}\right) * Area$$

      In which:

      Area = The watershed area tributary to the PPD pond (square feet)

2. Surface Area — Calculate minimum required surface area as follows:

$$\text{Minimum surface area (FT}^2\text{)} = \frac{\text{Design Volume (ft}^3\text{)}}{\text{0.17 feet}}$$

3. Select Block — Select appropriate modular blocks that have no less than 40 percent of the surface area open. The manufacturer's installation requirements shall be followed with the exception that *Rock Media Pore Volume Inlay Material* and *Base Course* dimension and requirements of this section shall be adhered with.

4. Select Porous Pavement Infill — The MBP openings should be filled with ASTM C-33 graded sand (fine concrete aggregate) and not sandy loam turf.

5. Base Coarses — Provide base courses as shown in Figure PPD-1.

6. Perimeter Wall — Provide a concrete perimeter wall to confine the edges of the PPD area. The wall should be minimum 6 inches wide and at least 6 inches deeper than all the porous media and modular block depth combined.

7. Subbase — If expansive soils are a concern or the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the base coarse. Otherwise install a non-woven geotextile membrane to encourage infiltration.

8. Overflow — Provide an overflow, possibly with an inlet to a storm sewer, set at 2 inches (-0, + ½-inch) above the level of the porous pavement

surface. Make sure the 2-inch ponding depth is contained and does not flow out of the area at ends or sides until the 2-inch ponding depth is reached.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

For an example of where PPD would be applied see Sections A-A and B-B of Figure MBP-3.

Maintenance Recommendations

TABLE PPD-1
Porous Pavement Detention Maintenance Considerations

Requires Action	Maintenance Objective	Frequency of Action
Debris and litter removal	Accumulated material should be removed as a source control measure.	Nonroutine – As needed.
Inspection	Inspect representative areas of surface filter sand accumulation of fine sediment.	Routine and during a storm event to ensure that water is not bypassing these surfaces or taking too long to drain out.
Replacement of Surface Filter Layer	Using a power vacuum remove all sand media within the annular spaces of the concrete blocks. Replace with fresh ASTM C-33 sand, vibrate into place and remove excess.	Nonroutine – when it becomes evident that runoff does not rapidly infiltrate into the surface, namely, the ponded water does not drain within one hour. May be as often as once a year or as little as once every 5 to 10 years.

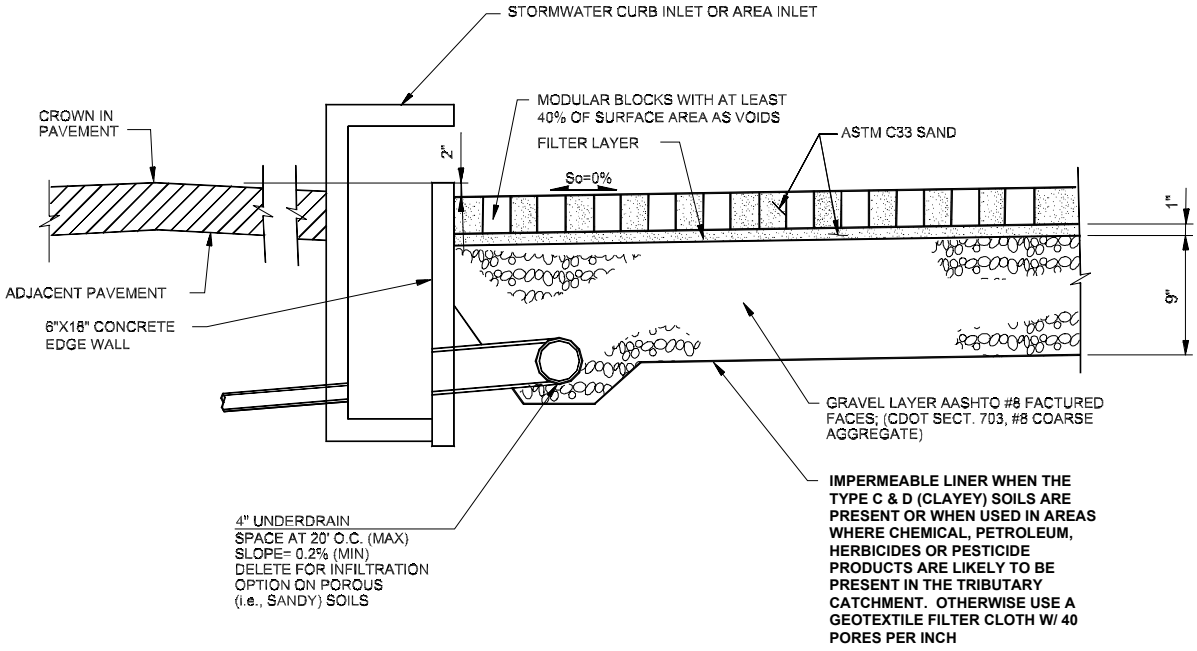


FIGURE PPD-1
Porous Pavement Detention

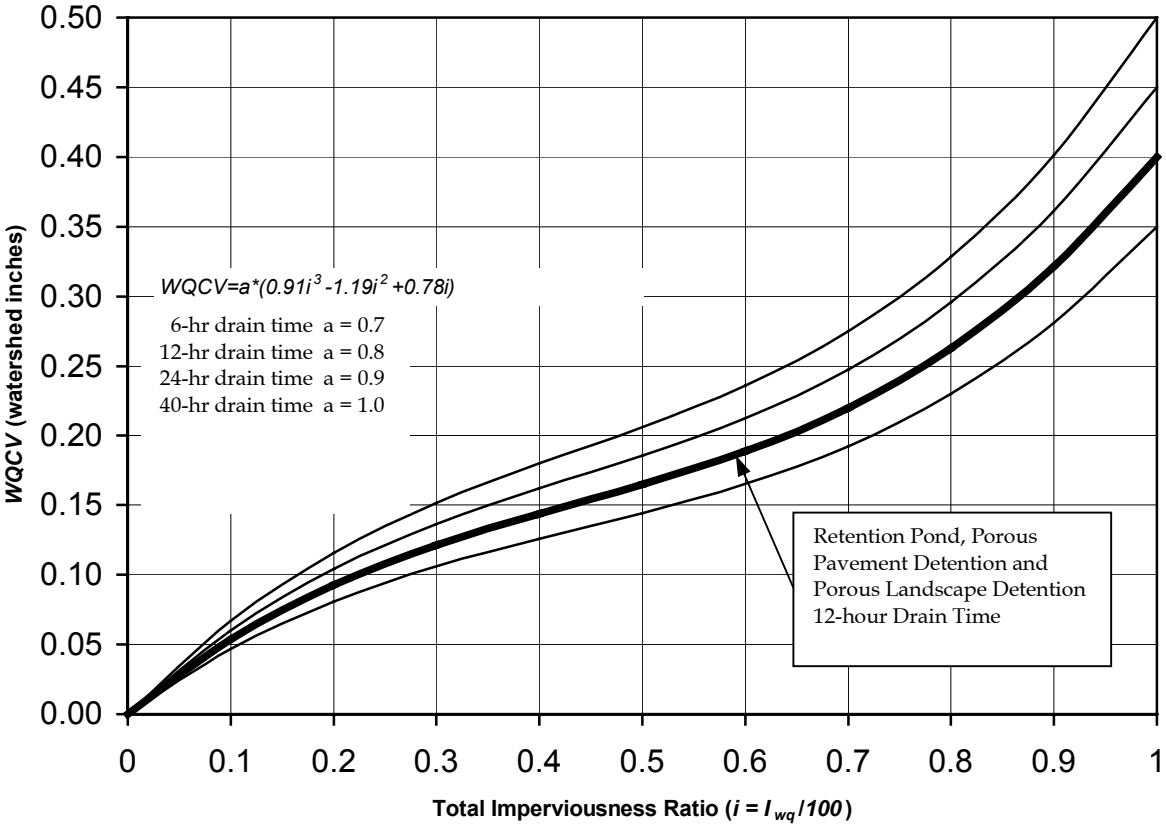


FIGURE PPD-2
Water Quality Capture Volume (WQCV), 80th Percentile Runoff Event

Design Procedure Form: Porous Pavement Detention (PPD)

Designer: _____
Company: _____
Date: **September 22, 1999**
Project: _____
Location: _____

1. Basin Storage Volume	
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$) (I_a = 100% if all paved and roofed areas)	I_a = 100.00 % i = 1.00
B) Contributing Watershed Area, Including PPD Area	Area = 600 square feet
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.8 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = 0.40 watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol = 20.0 cubic feet
E) Porous Pavement Suface Elevation	Elev. = 5,485.50 feet
2. Required Minimum MBP Surface Area: A = Vol / 0.17	A = 118 square feet
Overflow Inlet Elevation: Porous Pavement Elev. + 0.17 feet	Elev. = 5,485.67 feet
3. Modular Block Properties	Block Name: Uni-Green
Note: Blocks shall have no less than 40% open area and shall be no less than 4" thick	Manufacturer: Pavestone
	Open Surface Area = 40 %
	Thickness (4" min.) 4.00 inches
4. Porous Pavement Infill (Check the type used or describe "Other")	X ASTM C-33 Sand _____ Other: _____
5. Base Course	
A) Sand	X 1" Layer ASTM C-33 Sand _____ Other: _____
B) Gravel	X 9" Layer AASHTO #8 Course Agg. _____ Other: _____
6. Perimeter Wall (required)	X Concrete **4.0** inches thick _____ Other: _____
7. Draining of porous pavement (Check a, **or** b, **or** c, **answer** d) Based on answers to 7a through 7d, check the appropriate method	_____ Infiltration to Subgrade with Permeable Membrane: 7(c) checked **and** 7(d) = no
a) Check box if subgrade is heavy or expansive clay [ ] b) Check box if subgrade is silty or clayey sands [X] c) Check box if subgrade is well-draining soils [ ]	_____ Underdrain with Impermeable Membrane: 7(a) checked **or** 7(d) = yes X Underdrain with Permeable Membrane: 7(b) checked **and** 7(d) = no
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]	_____ Other: _____
8. Overflow For Larger Storms	**Yes** Yes / No

Notes: _____

Porous Landscape Detention (PLD) – Sedimentation Facility

Photo: Courtesy Prince Georges County

Description

Porous landscape detention (PLD) consists of a low lying vegetated area underlain by a sand bed with an underdrain pipe. A shallow surcharge zone exists above the PLD for temporary storage of the WQCV. During a storm, accumulated runoff ponds in the vegetated 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, or storm sewer. Like PPD, this BMP allows the WQCV to be provided on a site that has little open area available for stormwater detention.

General Application

Locating

A PLD can be located in just about any of the open areas of a site. It is ideally suited for small installations such as:

- Parking lot islands.
- Street medians.
- Roadside swale features.
- Site entrance or buffer features.

This BMP may also be implemented at a larger scale, serving as an infiltration basin for an entire site if desired provided the water quality capture volume and average depth requirements contained in this section are met.

Vegetation may consist of irrigated bluegrass or natural grasses with shrub and tree plantings if desired.

Example Application

The following photos illustrate an installation of PLD in Prince Georges County, Maryland.

Parking lot island before installation of PLD.

Excavation and installation of underdrain.

Sandy material used as planting medium.

Photos: Courtesy Prince Georges County

Installation of plant materials.

Completed PLD facility during storm event.

Photos: Courtesy Prince GeorgesCounty

Advantages/Disadvantages

General

A primary advantage of PLD is making it possible to provide the WQCV on a site while reducing the impact on developable land. It works well with irrigated bluegrass, whereas experience has shown that conditions in the bottom of extended detention basins (EDBs) become too wet for bluegrass. A PLD provides a natural moisture source for vegetation, enabling "green areas" to exist with reduced irrigation. The adjacent photograph shows an example of a relatively large PLD facility featuring a bluegrass bottom with a putting green.

The primary disadvantage of PLD is a potential for clogging if a moderate to high level of silts and clays is allowed to flow into the facility. Also, this BMP needs to be avoided close to building foundations or other areas where expansive soils are present, although an underdrain and impermeable liner can ameliorate some of this concern. Saturation of soils may also affect adjacent pavement performance.

Physical Site Suitability

If an underdrain system is incorporated into this BMP, PLD is suited for about any site regardless of in-situ soil type. If sandy soils are present, the facility can be installed without an underdrain (infiltration option); sandy subsoils is not a requirement. This BMP has a relatively flat surface area, and may be more difficult to incorporate it into steeply sloping terrain.

Pollutant Removal

Although not tested to date in the Denver or Colorado Springs areas, the amount of pollutant removed by this BMP should be significant and should equal or exceed the removal rates provided by sand filters. In addition to settling, PLD provides for filtering, adsorption, and biological uptake of constituents in stormwater. See Table ND-2 for estimated ranges in pollutant removals.

Design Considerations

Figure PLD-1 shows a cross-section for a PLD. When implemented using multiple small installations on a site, it is increasingly important to accurately account for each upstream drainage area tributary to each PLD site to make sure that each facility is properly sized, and that all portions of the development site are directed to a PLD.

Design Procedure

The following steps outline the PLD design procedure and criteria.

1. Basin Storage Volume — Provide a storage volume based on a 12-hour drain time.

   A. Find the required storage volume (watershed inches of runoff):

   Using the tributary areas imperviousness, determine the required WQCV (watershed inches of runoff) using Figure PLD-2, based on the PLD 12-hour drain time.

   B. Calculate the Design Volume in cubic feet as follows:

$$Design\ \ Volume = \left(\frac{WQCV}{12}\right) * Area$$

   In which:

   Area = The watershed area tributary to the PLD pond (square feet)

2. Surface Area — Calculate the minimum required surface area as follows:

$$Surface\ Area\ = \frac{Design\ Volume\ \ in\ ft^3}{d_{av}}$$

   in which,

   d_{av} = average depth of the PLD basin.

3. Base Coarses — Provide base coarses as shown in Figure PLD-1.

4. Subbase — If expansive soils are a concern, install an impermeable membrane and place the base coarse on top of the membrane. If soils are not expansive, use geotextile fabric to line the entire basin bottom and walls.

5. Average Depth — Maintain the average WQCV depth between 6 inches and 12 inches. Average depth is defined as water volume divided by the water surface area.

6. Sand-Peat Mix Filter Layer — Provide a minimum of a 12-inch thick layer above the base course consisting of a thoroughly mixed ASTMC-3 Sand and Peat for filtration and adsorption of constituents.

7. Irrigated Vegetative Layer — Provide a sandy loam turf layer above the sand-peat mix layer. This layer shall be no less than 6-inches thick, but a thicker layer is recommended to promote healthier vegetation.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

TABLE PLD-1
Porous Landscape Detention Maintenance Considerations

Required Action	Maintenance Objectives	Frequency
Lawn mowing and vegetative care	Occasional mowing of grasses and weed removal to limit unwanted vegetation. Maintain irrigated turf grass as 2 to 4 inches tall and nonirrigated native turf grasses at 4 to 6 inches.	Routine – depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from detention area to minimize clogging of the sand media.	Routine – depending on aesthetic requirements.
Landscaping removal and replacement	The sandy loam turf and landscaping layer will clog with time. This layer will need to be removed and replaced, along with all turf and other vegetation growing on the surface, to rehabilitate infiltration rates.	Every 5 to 10 years, depending on infiltration rates needed to drain the WQCV in 12-hours or less. May need to do it more frequently if exfiltration rates are too low to achieve this goal.
Inspections	Inspect detention area to determine if the sand media is allowing acceptable infiltration.	Routine – bi-annual inspection of hydraulic performance.

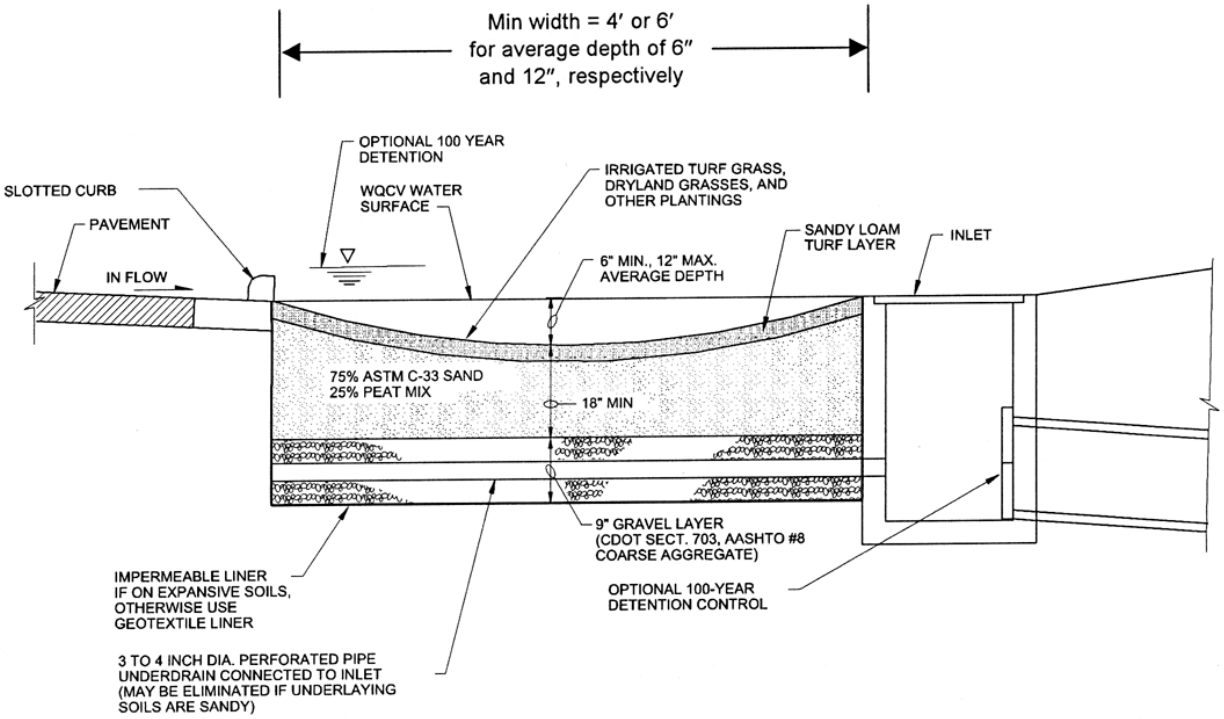


FIGURE PLD-1
Porous Landscape Detention

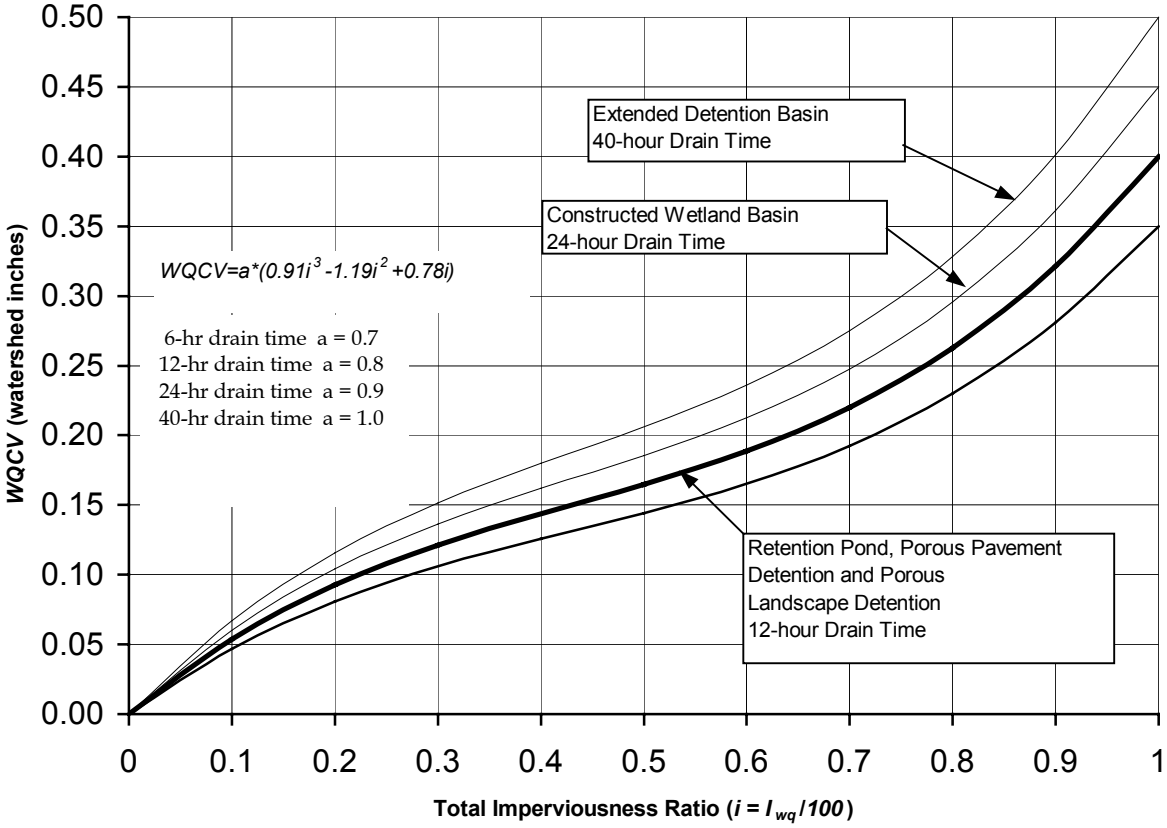


FIGURE PLD-2
Water Quality Capture Volume (WQCV), 80th Percentile Runoff Event

Design Procedure Form: Porous Landscape Detention (PLD)

Designer: _____

Company: _____

Date: **September 22, 1999**

Project: _____

Location: _____

1. Basin Storage Volume (I_a = 100% if all paved and roofed areas u/s of PLD) A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a = 100.00 % i = 1.00
B) Contributing Watershed Area Including the PLD (Area)	Area = 10,000 square feet
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.8 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = 0.40 watershed inches
D) Design Volume: Vol_{PLD} = (WQCV / 12) * Area	Vol = 333.3 cubic feet
2. PLD Surface Area (A_{PLD}) and Average Depth (d_{av}) (d_{av}: = (Vol / A_{PLD}), Min=0.5', Max=1.0')	A_{PLD} = 350 square feet d_{av} = 0.95 feet
3. Base Course (See Figure PLD-1)	X 6" (Min.) Sandy Loam Turf Layer, Plus 18" (Min.) Layer of 25% Peat and 75% Sand Mix, Plus 9" (Min.) Layer of ASSHTO #8 Coarse Aggregate (CDOT Section 703 Specification). _____ Other: _____
5. Draining of porous pavement (Check a, **or** b, **or** c, **answer** d) Based on answers to 5a through 5d, check the appropriate method a) Check box if subgrade is heavy or expansive clay [ ] b) Check box if subgrade is silty or clayey sands [ ] c) Check box if subgrade is well-draining soils [X] 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]	X Infiltration to Subgrade with Permeable Membrane: 5(c) checked **and** 5(d) = no _____ Underdrain with Impermeable Membrane: 5(a) checked **or** 5(d) = yes _____ Underdrain with Permeable Membrane: 5(b) checked **and** 5(d) = no _____ Other: _____

Notes: _____

Extended Detention Basin (EDB)—Sedimentation Facility

Description

An extended detention basin (EDB) is a sedimentation basin designed to totally drain dry sometime after stormwater runoff ends. It is an adaptation of a detention basin used for flood control. The primary difference is in the outlet design. 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 drain time for the brim-full water quality capture volume (i.e., time to fully evacuate the design capture volume) of 40 hours is recommended to remove a significant portion of fine particulate pollutants found in urban stormwater runoff. Soluble pollutant removal can be somewhat enhanced by providing a small wetland marsh or ponding area in the basin's bottom to promote biological uptake. The basins are considered to be "dry" because they are designed not to have a significant permanent pool of water remaining between storm runoff events. However, EDB may develop wetland vegetation and sometimes shallow pools in the bottom portions of the facilities.

General Application

An EDB can be used to enhance stormwater runoff quality and reduce peak stormwater runoff rates. If these basins are constructed early in the development cycle, they can also be used to trap sediment from construction activities within the tributary drainage area. The accumulated sediment, however, will need to be removed after upstream land disturbances cease and before the basin is placed into final long-term use. Also, an EDB can sometimes be retrofitted into existing flood control detention basins.

EDBs can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and are generally used for regional or

follow-up treatment. They can also be used as an onsite BMP and work well in conjunction with other BMPs, such as upstream onsite source controls and downstream infiltration/filtration basins or wetland channels. If desired, a flood routing detention volume can be provided above the water quality capture volume (WQCV) of the basin.

Advantages/Disadvantages

General

An EDB can be designed to provide other benefits such as recreation and open space opportunities in addition to reducing peak runoff rates and improving water quality. They are effective in removing particulate matter and the associated heavy metals and other pollutants. As with other BMPs, safety issues need to be addressed through proper design.

Physical Site Suitability

Normally, the land required for an EDB is approximately 0.5 to 2.0 percent of the total tributary development area. In high groundwater areas, consider the use of retention ponds (RP) instead in order to avoid many of the problems that can occur when the EDB's bottom is located below the seasonal high water table. Soil maps should be consulted, and soil borings may be needed to establish design geotechnical parameters.

Pollutant Removal

The pollutant removal range of an EDB was presented in section 4.1, Table ND-2. Removal of suspended solids and metals can be moderate to high, and removal of nutrients is low to moderate. The removal of nutrients can be improved when a small shallow pool or wetland is included as part of the basin's bottom or the basin is followed by BMPs more efficient at removing soluble pollutants, such as a filtration system, constructed wetlands or wetland channels.

The major factor controlling the degree of pollutant removal is the emptying time provided by the outlet. The rate and degree of removal will also depend on influent particle sizes. Metals, oil and grease, and some nutrients have a close affinity for suspended sediment and will be removed partially through sedimentation.

Aesthetics and Multiple Uses

Since an EDB is designed to drain very slowly, its bottom and lower portions will be inundated frequently for extended periods of time. Grasses in this frequently inundated zone will tend to die off, with only the species that can survive the specific environment at each site eventually prevailing. In addition, the bottom will be the depository of all the sediment that settles out in the basin. As a result, the bottom can be muddy and may have an undesirable appearance to some. To reduce this problem and to improve the basin's availability for other uses (such as open space, habitat or passive recreation), it is suggested that the designer provide a lower-stage basin as suggested in the Two Stage Design procedure. As an alternative, a retention pond (RP) could be used, in which the settling occurs primarily within the permanent pool.

Design Considerations

Whenever desirable and feasible, incorporate the EDB within a larger flood control basin. Also, whenever possible try to provide within the basin for other urban uses such as passive recreation, and wildlife habitat. If multiple uses are being contemplated, consider the multiple-stage detention basin to limit inundation of passive recreational areas to one or two occurrences a year. 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.

Figure EDB-1 shows a representative layout of an EDB. Although flood control storage can be accomplished by providing a storage volume above the water quality storage, how best to accomplish this is not included in this discussion. Whether or not flood storage is provided, all embankments should be protected from catastrophic failure when runoff exceeds the design event. The State Engineer's regulatory requirements for larger dam embankments and storage volumes must be followed whenever regulatory height and/or volume thresholds are exceeded. Below those thresholds, the engineer should design the embankment-spillway-outlet system so that catastrophic failure will not occur.

Perforated outlet and trash rack configurations are illustrated in section 4.3, *Typical Structural Details*. Figure EDB-3 equates the WQCV that needs to be emptied over 40 hours, to the total required area of perforations per row for the standard configurations shown in that section. The chart is based on the rows being equally spaced vertically at 4-inch centers. This total area of perforations per row is then used to determine the number of uniformly sized holes per row (see detail in the *Structural Details* section). One or more perforated columns on a perforated orifice plate integrated into the front of the outlet can be used. Other types of outlets may also be used, provided they control the release of the WQCV in a manner consistent with the drain time requirements and are approved in advance.

Although the soil types beneath the pond seldom prevent the use of this BMP, they should be considered during design. Any potential exfiltration capacity should be considered a short-term characteristic and ignored in the design of the WQCV because exfiltration will decrease over time as the soils clog with fine sediment and as the groundwater beneath the basin develops a mound that surfaces into the basin.

High groundwater should not preclude the use of an EDB. Groundwater, however, should be considered during design and construction, and the outlet design must account for any upstream base flows that enter the basin or that may result from groundwater surfacing within the basin itself.

Stable, all weather access to critical elements of the pond, such as the inlet, outlet, spillway, and sediment collection areas must be provided for maintenance purposes.

Design Procedure and Criteria

The following steps outline the design procedure and criteria for an EDB.

1. Basin Storage Volume

   Provide a storage volume equal to 120 percent of the WQCV based on a 40-hour drain time, above the lowest outlet (i.e., perforation) in the basin. The additional 20 percent of storage volume provides for sediment accumulation and the resultant loss in storage volume.

   A. Determine the WQCV tributary catchment's percent imperviousness. Account for the effects of DCIA, if any, on Effective Imperviousness. Using Figure ND-1, determine the reduction in impervious area to use with WQCV calculations.

   B. Find the required storage volume (watershed inches of runoff):

      Determine the required WQCV (watershed inches of runoff) using Figure EDB-2, based on the EDB's 40-hour drain time.

      Calculate the Design Volume in acre-feet as follows:

$$Design\ Volume = \left(\frac{WQCV}{12}\right) * Area * 1.2$$

      In which:

      Area = The watershed area tributary to the extended detention pond.

      1.2 factor = Multiplier of 1.2 to account for the additional 20 percent of required storage for sediment accumulation.

2. Outlet Works

   The Outlet Works are to be designed to release the WQCV (i.e., not the "Design Volume") over a 40-hour period, with no more than 50 percent of the WQCV being released in 12 hours. Refer to the *Structural Details* section for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type: orifice plate or perforated riser pipe; cutoff collar size and location; and all other necessary components.

   For a perforated outlet, use Figure EDB-3 to calculate the required area per row based on WQCV and the depth of perforations at the outlet. See the *Structural Details* section to determine the appropriate perforation geometry and number of rows. (The lowest perforations should be set at the water surface elevation of the outlet micropool.) The total outlet area can then be calculated by multiplying the area per row by the number of rows.

3. Trash Rack

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 and the selected perforation diameter (or height), Figures 6, 6a or 7 in the *Structural Details* section will help to determine the minimum open area required for the trash rack. If a perforated vertical plate or riser is used as suggested in this manual, 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. Figures 6 and 6a were developed as suggested standardized outlet designs for smaller sites.

4. Basin Shape

Shape the pond whenever possible with a gradual expansion from the inlet and a gradual contraction toward the outlet, thereby minimizing short circuiting. The basin length to width ratio between the inlet and the outlet should be between 2:1 to 3:1, with the larger being preferred. It may be necessary to modify the inlet and outlet points through the use of pipes, swales, or channels to accomplish this.

5. Two-Stage Design

A two-stage design with a pool that fills often with frequently occurring runoff minimizes standing water and sediment deposition in the remainder of the basin. The two stages are as follows:

A. Top Stage: The top stage should be 2 or more feet deep with its bottom sloped at 2 percent toward the low flow channel.

B. Bottom Stage: The active storage basin of the bottom stage should be 1.5 to 3 feet deeper than the top stage and store 5 to 15 percent of the WQCV. Provide a micro-pool below the bottom active storage volume of the lower stage at the outlet point. The pool should be ½ the depth of the upper WQCV depth or 2.5 feet, whichever is the larger.

6. Low-Flow Channel

Conveys low flows from the forebay to the bottom stage. Erosion protection should be provided where the low-flow channel enters bottom stage. Lining the low flow channel with concrete is recommended. Otherwise line its sides with VL Type riprap and bottom with concrete. Make it at least 9 inches deep; at a minimum provide capacity equal to twice the release capacity at the upstream forebay outlet.

7. Basin Side Slopes

Basin side slopes should be stable and gentle to facilitate maintenance and access. Side slopes should be no steeper than 3:1, the flatter, the better and safer.

8. Dam Embankment	The embankment should be designed not to fail during a 100-year and larger storms. Embankment slopes should be no steeper than 3:1, preferably 4:1 or flatter, and planted with turf forming grasses. Poorly compacted native soils should be excavated and replaced. Embankment soils should be compacted to at least 95 percent of their maximum density according to ASTM D 698-70 (Modified Proctor). Spillway structures and overflows should be designed in accordance with the City of Colorado Springs and El Paso County Drainage Criteria Manual and should consider UDFCD drop-structure design guidelines.
9. Vegetation	Bottom vegetation provides erosion control and sediment entrapment. Pond bottom, berms, and side sloping areas may be planted with native grasses or with irrigated turf, depending on the local setting.
10. Access	All weather stable access to the bottom, forebay, and outlet works area shall be provided for maintenance vehicles. Maximum grades should be 10 percent with a solid driving surface of gravel, rock, or concrete.
11. Inlet	Dissipate flow energy at pond's inflow point(s) to limit erosion and promote particle sedimentation. Inlets should be designed in accordance with the City of Colorado Springs and El Paso County Drainage Criteria Manual's drop structure criteria or another type of energy dissipating structure.
12. Forebay Design	Provide the opportunity for larger particles to settle out in the inlet in an area that has a solid surface bottom to facilitate mechanical sediment removal. A rock berm should be constructed between the forebay and the main EDB. The forebay volume of the permanent pool should be 5 to 10 percent of the design water quality capture volume. A pipe throughout the berm to convey water the EDB should be offset from the inflow streamline to prevent short circuiting and should be sized to drain the forebay volume in 5 minutes.
13. Flood Storage	Combining the water quality facility with a flood control facility is recommended. The 10-year, 100-year, or other floods may be detained above the WQCV. See the *New Development Planning* section of this chapter for further guidance.
14. Multiple Uses	Whenever desirable and feasible, incorporate the EDB within a larger flood control basin. Also, whenever possible try to provide for other urban uses such as active or passive recreation, and wildlife habitat. If multiple uses are being contemplated, use the multiple-stage detention basin to limit inundation of passive recreational areas to one or two occurrences a year. 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 EDB level.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

Extended detention basins have low to moderate maintenance requirements. Routine and nonroutine maintenance is necessary to assure performance, enhance aesthetics, and protect structural integrity. The dry basins can result in nuisance complaints if not properly designed or maintained. Bio-degradable pesticides may be required to limit insect problems. Frequent debris removal and grass-mowing can reduce aesthetic complaints. If a shallow wetland or marshy area is included, mosquito breeding and nuisance odors could occur if the water becomes stagnant. Access to critical elements of the pond (inlet, outlet, spillway, and sediment collection areas) must be provided. The basic elements of the maintenance requirements are presented in Table EDB-1.

TABLE EDB-1
Extended Detention Basin Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn mowing and lawn care	Occasional mowing to limit unwanted vegetation. Maintain irrigated turf grass as 2 to 4 inches tall and nonirrigated native turf grasses at 4 to 6 inches.	Routine – Depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from the entire pond to minimize outlet clogging and improve aesthetics.	Routine – Including just before annual storm seasons (that is, April and May) and following significant rainfall events.
Erosion and sediment control	Repair and revegetate eroded areas in the basin and channels.	Nonroutine – Periodic and repair as necessary based on inspection.
Structural	Repair pond inlets, outlets, forebays, low flow channel liners, and energy dissipators whenever damage is discovered.	Nonroutine – Repair as needed based on regular inspections.
Inspections	Inspect basins to insure that the basin continues to function as initially intended. Examine the outlet for clogging, erosion, slumping, excessive sedimentation levels, overgrowth, embankment and spillway integrity, and damage to any structural element.	Routine – Annual inspection of hydraulic and structural facilities. Also check for obvious problems during routine maintenance visits, especially for plugging of outlets.
Nuisance control	Address odor, insects, and overgrowth issues associated with stagnant or standing water in the bottom zone.	Nonroutine – Handle as necessary per inspection or local complaints.

TABLE EDB-1
Extended Detention Basin Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Sediment removal	Remove accumulated sediment from the forebay, micro-pool, and the bottom of the basin.	Nonroutine – Performed when sediment accumulation occupies 20 percent of the WQCV. This may vary considerably, but expect to do this every 10 to 20 years, as necessary per inspection if no construction activities take place in the tributary watershed. More often if they do. The forebay and the micro-pool will require more frequent cleanout than other areas of the basin, say every 1 or 2 years.

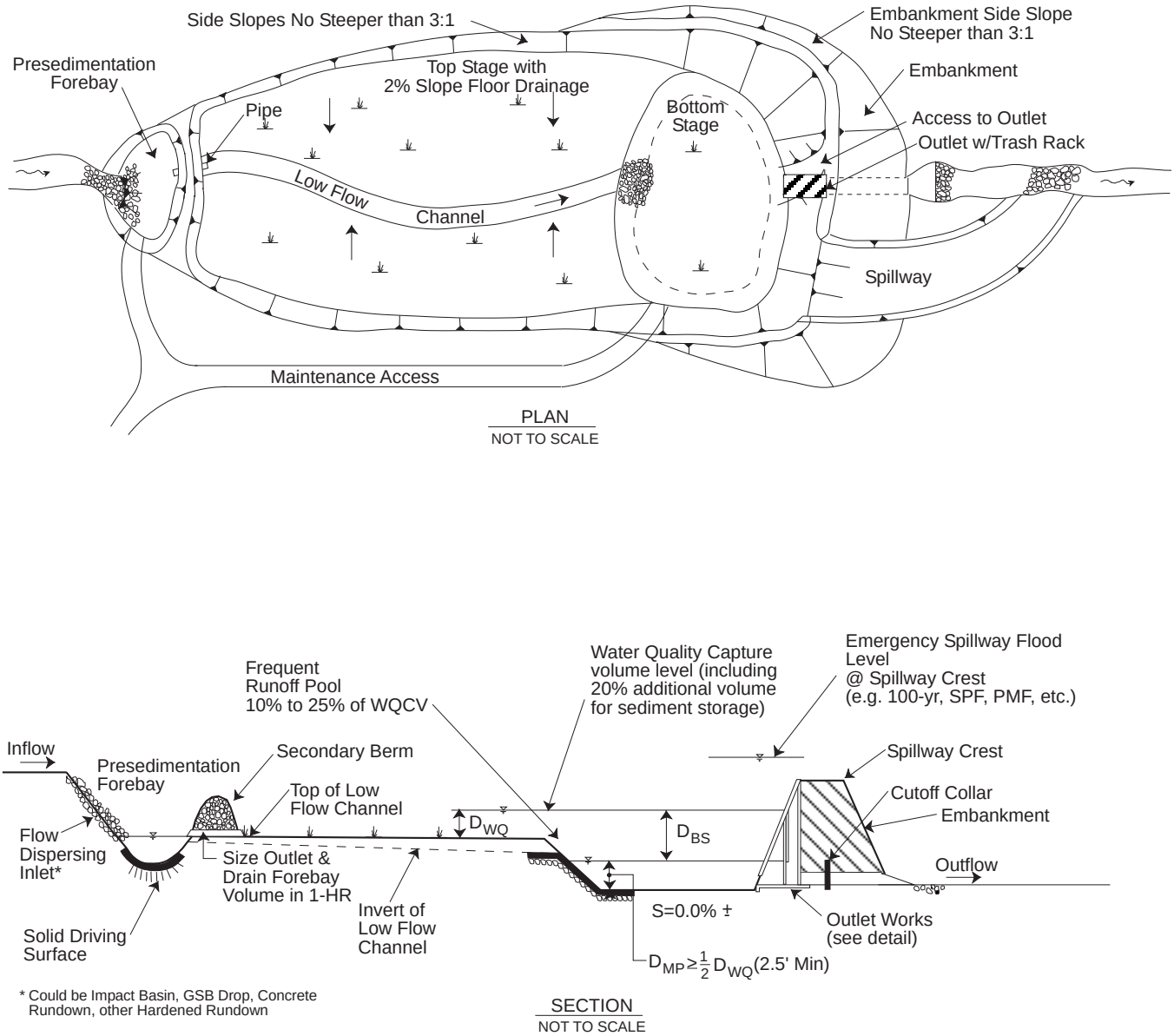


FIGURE EDB-1
Plan and Section of an Extended Detention Basin Sedimentation Facility

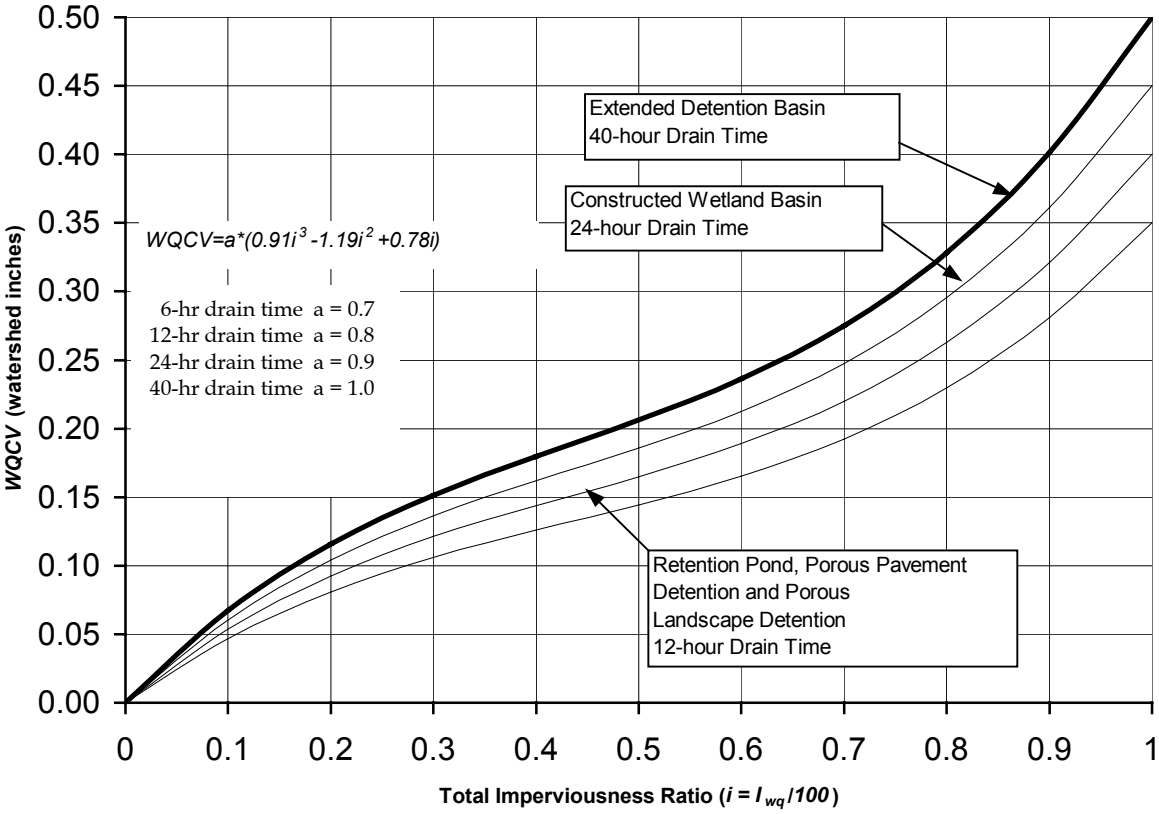
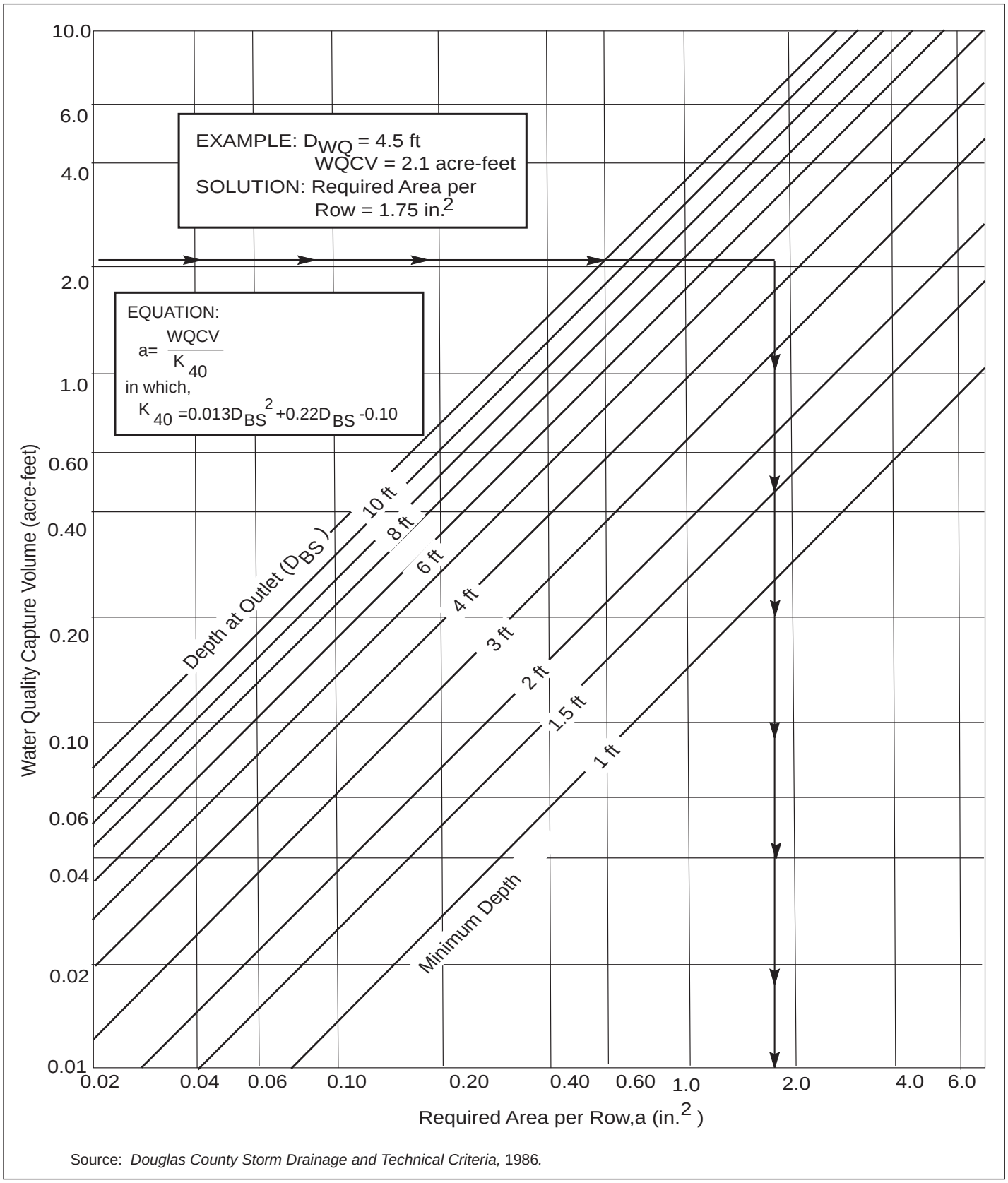


FIGURE EDB-2
Water Quality Capture Volume (WQCV), 80th Percentile Runoff Event



Source: *Douglas County Storm Drainage and Technical Criteria,* 1986.

FIGURE EDB-3
Water Quality Outlet Sizing: Dry Extended Detention Basin with a 40-Hour Drain Time of the Capture Volume

Design Procedure Form: Extended Detention Basin (EDB) - Sedimentation Facility

Sheet 1 of 3

Designer: _____

Company: _____

Date: **September 22, 1999**

Project: _____

Location: _____

1. Basin Storage Volume			
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a =	50.00	%
	i =	0.50	
B) Contributing Watershed Area (Area)	Area =	100.00	acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 1.0 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV =	0.21	watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area * 1.2	Vol =	2.063	acre-feet
2. Outlet Works			
A) Outlet Type (Check One)	X	Orifice Plate	
		Perforated Riser Pipe	
		Other:	
B) Depth at Outlet Above Lowest Perforation (H)	H =	4.00	feet
C) Required Maximum Outlet Area per Row, (A_o)	A_o =	1.74	square inches
D) Perforation Dimensions **(enter one only)**: i) Circular Perforation Diameter **OR**	D =	1.5000	inches, **OR**
ii) 2" Height Rectangular Perforation Width	W =		inches
E) Number of Columns (nc, See Table 6a-1 For Maximum)	nc =	1	number
F) Actual Design Outlet Area per Row (A_o)	A_o =	1.77	square inches
G) Number of Rows (nr)	nr =	12	number
H) Total Outlet Area (A_{ot})	A_{ot} =	21.21	square inches
3. Trash Rack			
A) Needed Open Area: A_t = 0.5 * (Figure 7 Value) * A_{ot}	A_t =	678	square inches
B) Type of Outlet Opening (Check One)	X	≤ 2" Diameter **Round**	
		2" High **Rectangular**	
		Other:	
C) For 2", or Smaller, **Round Opening** (Ref.: Figure 6a):			
i) Width of Trash Rack and Concrete Opening (W_{conc}) from Table 6a-1	W_{conc} =	18	inches
ii) Height of Trash Rack Screen (H_{TR})	H_{TR} =	72	inches

Design Procedure Form: Extended Detention Basin (EDB) - Sedimentation Facility

Designer: _____
Company: _____
Date: **September 22, 1999**
Project: _____
Location: _____

iii) Type of Screen (Based on Depth H), Describe if "Other"	X	S.S. #93 VEE Wire (US Filter)
		Other:
iv) Screen Opening Slot Dimension, Describe if "Other"	X	0.139" (US Filter)
		Other:
v) Spacing of Support Rod (O.C.)	1.00	inches
Type and Size of Support Rod (Ref.: Table 6a-2)	**TE 0.074 in. x 0.50 in.**	
vi) Type and Size of Holding Frame (Ref.: Table 6a-2)	**0.75 in. x 1.00 in. angle**	
D) For 2" High **Rectangular Opening** (Refer to Figure 6b):		
I) Width of Rectangular Opening (W)	W =	inches
ii) Width of Perforated Plate Opening (W_{conc} = W + 12")	W_{conc} =	inches
iii) Width of Trashrack Opening ($W_{opening}$) from Table 6b-1	$W_{opening}$ =	inches
iv) Height of Trash Rack Screen (H_{TR})	H_{TR} =	inches
v) Type of Screen (based on depth H) (Describe if "Other")		Klemp™ KPP Series Aluminum
		Other:
vi) Cross-bar Spacing (Based on Table 6b-1, Klemp™ KPP Grating). Describe if "Other"		inches
		Other:
vii) Minimum Bearing Bar Size (Klemp™ Series, Table 6b-2) (Based on depth of WQCV surcharge)		
4. Detention Basin length to width ratio	2.00	(L/W)
5 Pre-sedimentation Forebay Basin - Enter design values		
A) Volume (5 to 10% of the Design Volume in 1D)	0.200	acre-feet
B) Surface Area	0.069	acres
C) Connector Pipe Diameter (Size to drain this volume in 5-minutes under inlet control)	6	inches
D) Paved/Hard Bottom and Sides	**Yes**	yes/no

Design Procedure Form: Extended Detention Basin (EDB) - Sedimentation Facility

Designer: _____

Company: _____

Date: **September 22, 1999**

Project: _____

Location: _____

6. Two-Stage Design	
A) Top Stage (D_{WQ} = 2' Minimum)	D_{WQ} = 2.00 feet Storage= 1.800 acre-feet
B) Bottom Stage (D_{BS} = D_{WQ} + 1.5' Minimum, D_{WQ} + 3.0' Maximum, Storage = 5% to 15% of Total WQCV)	D_{BS} = 4.00 feet Storage= 0.110 acre-feet Surf. Area= 0.028 acres
C) Micro Pool (Minimum Depth = the Larger of 0.5 * Top Stage Depth or 2.5 Feet)	Depth= 2.50 feet Storage= 0.015 acre-feet Surf. Area= 0.006 acres
D) Total Volume: Vol_{tot} = Storage from 5A + 6A + 6B Must be ≥ Design Volume in 1D	Vol_{tot} = 2.110 acre-feet
7. Basin Side Slopes (Z, horizontal distance per unit vertical) Minimum Z = 3, Flatter Preferred	Z = 5.00 (horizontal/vertical)
8. Dam Embankment Side Slopes (Z, horizontal distance) per unit vertical) Minimum Z = 3, Flatter Preferred	Z = 4.00 (horizontal/vertical)
9. Vegetation (Check the method or describe "Other")	X Native Grass _____ Irrigated Turf Grass _____ Other: _____

Notes: _____

Sand Filter Extended Detention Basin (SFB)

Description

A sand filter extended detention basin (SFB) is a stormwater filter that consists of a runoff storage zone underlain by a sand bed with an underdrain system. During a storm, accumulated runoff ponds 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, or storm sewer.

General Application

A SFB is generally suited to offline, onsite configurations where there is no baseflow and the sediment load is relatively low.

Advantages/Disadvantages

General

Primary advantages of SFBs include effective water quality enhancement through settling and filtering. The primary disadvantage is a potential for clogging if a moderate to high level of silts and clays are allowed to flow into the facility. Such clogging would result in the need for significant maintenance. For this reason, it should **not** be put into operation while construction activities are taking place in the tributary catchment. Also, this BMP should not be located close to building foundations or other areas where expansive soils are a concern, although an underdrain and impermeable liner can ameliorate some of this concern.

Physical Site Suitability

Since an underdrain system is incorporated into this BMP, SFB is suited for about any site; presence of sandy subsoils is not a requirement. This BMP has a relatively flat surface area, so it may be more challenging to incorporate it into steeply sloping terrain.

Pollutant Removal

Although not fully tested to date in the Denver area, the tests on filter vaults in the Denver area and other parts of United States show that the amount of pollutant removed by this BMP should be significant and should at least equal the removal rates by sand filters tested elsewhere. See Table ND-2 for estimated ranges in pollutant removals.

Maintenance Needs

Before selecting this BMP, be sure that the maintenance specified in the Maintenance Requirements chapter of this manual will be provided by either a local government or by the owner. This BMP's performance is critical on having regular maintenance provided.

Design Procedure and Criteria

The following steps outline the design procedure and criteria for an SFB.

1. Basin Storage Volume — Provide a storage volume equal to 100 percent of the WQCV based on a 40-hour drain time, above the sand bed of the basin.

   A. Determine the WQCV tributary catchment's percent imperviousness. Account for the effects of DCIA, if any, on Effective Imperviousness. Using Figure ND-1, determine the reduction in impervious area to use with WQCV calculations.

   B. Find the required storage volume (watershed inches of runoff):

      Determine the Required WQCV (watershed inches of runoff) using Figure SFB-2, based on the SFB's 40-hour drain time.

   C. Calculate the Design Volume in acre-feet as follows:

$$Design\,Volume = \left(\frac{WQCV}{12}\right) * Area$$

      In which:

      Area = The watershed area tributary to the SFB (acres)

2. Basin Depth — Maximum Design Volume depth shall be 2.5 feet.

3. Filter's Surface Area — Calculate the **minimum** sand filter area (A_s) at the basin's bottom with the following equation:

$$A_s = Design\ Volume\ /\ 3 \quad *43{,}560 \text{ (square feet)}$$

4. Outlet Works

An 18 inch layer of sand (ASTM C-33) over a 9 inch gravel layer (AASHTO No. 8; CDOT Section 703, #8) shall line the entire SFB for purposes of draining the WQCV.

If expansive soils are a concern or if the tributary catchment has chemical or petroleum products handled or stored, install an impermeable membrane below the gravel layer.

In addition, an overflow shall be provided to convey flows in excess of the WQCV out of the basin.

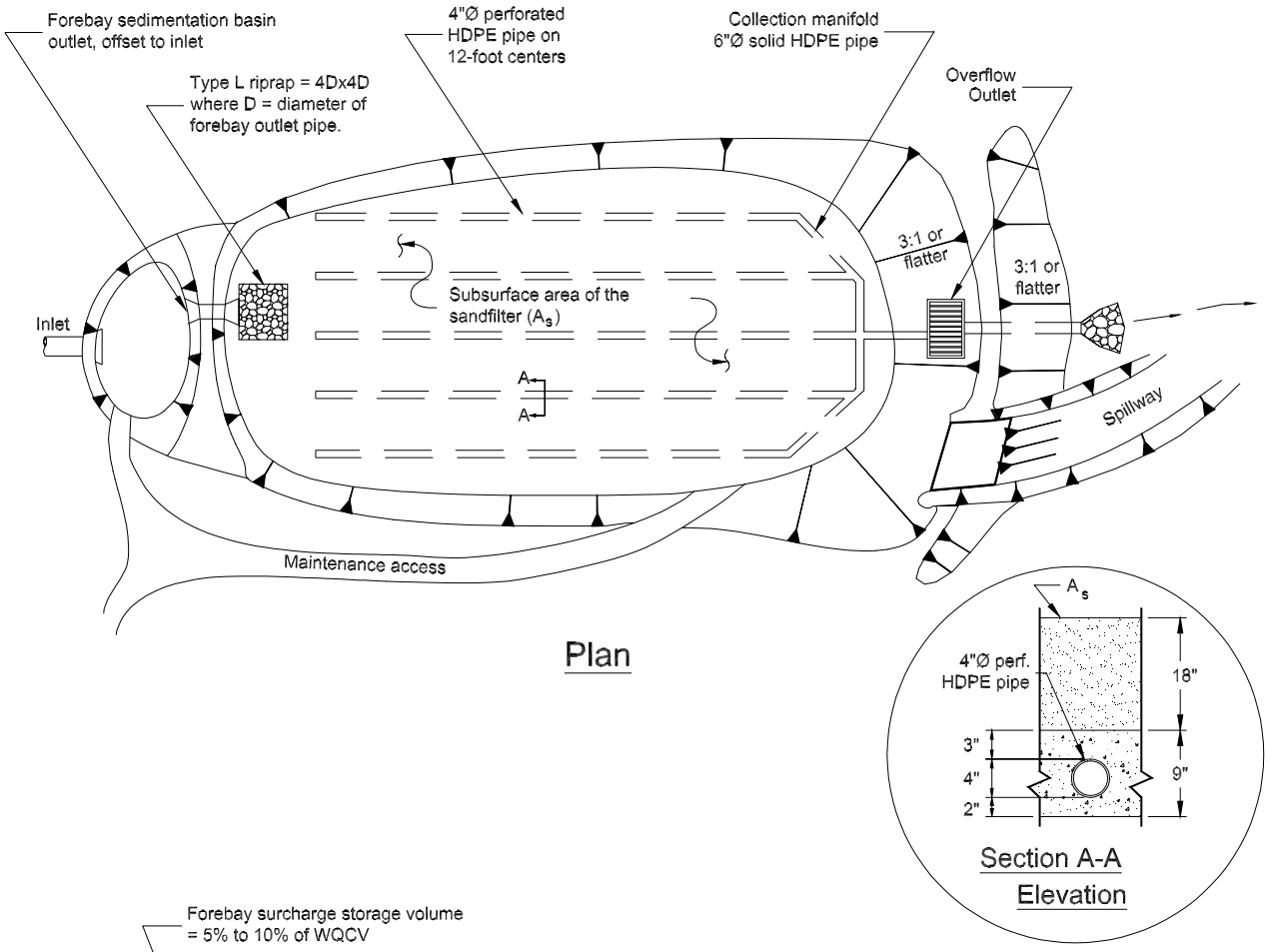
Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

TABLE SFB-1
Sand Filter Detention Basin Maintenance Considerations

Required Action	Maintenance Objectives	Frequency
Debris and litter removal	Remove debris and litter from detention area to minimize clogging of the sand media.	Routine – depending on aesthetic requirements.
Landscaping removal and replacement	If the sand filter is covered with rock mulch, bluegrass, or other landscaping covers, the cover must be removed to allow access to the sand media. Replace landscaping cover after maintenance of sand media is complete.	Every 2 to 5 years.
Scarify filter surface	Scarify top 3 to 5 inches by raking the filter's surface.	Once per year or when needed to promote drainage.
Sand filter removal	Remove the top 3 inches of sand from the sand filter. After a third removal, backfill with 9 inches of new sand to return the sand depth to 18 inches. Minimum sand depth is 12 inches.	If no construction activities take place in the tributary watershed, every 2 to 5 years depending on observed drain times, namely when it takes more than 24 hours to empty 3-foot deep pool. Otherwise more often. Expect to clean out forebay every 1 to 5 years.
Inspections	Inspect detention area to determine if the sand media is allowing acceptable infiltration.	Routine – bi-annual inspection of hydraulic performance, one after a significant rainfall.



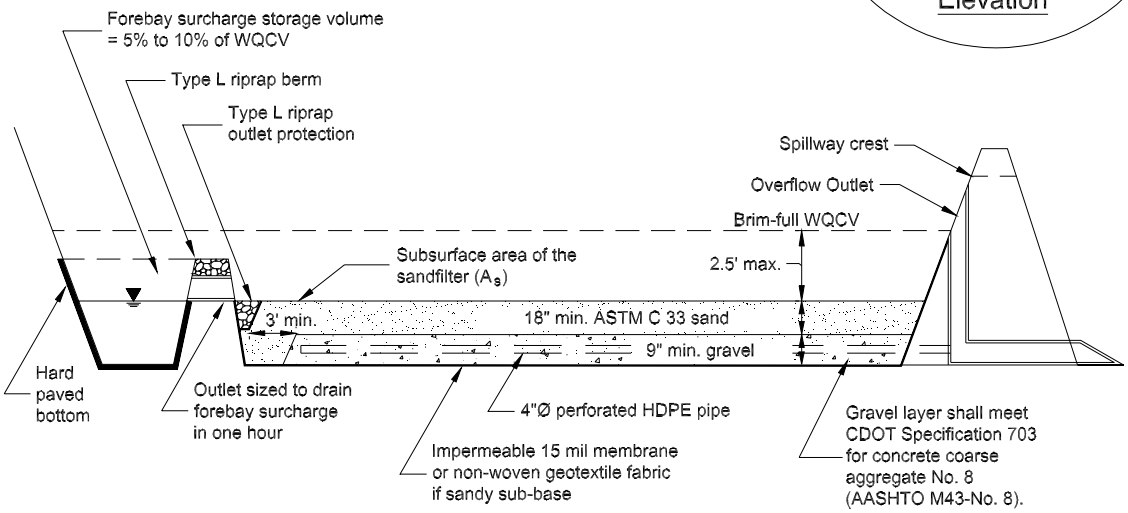


FIGURE SFB-1
Sand Filter Basin

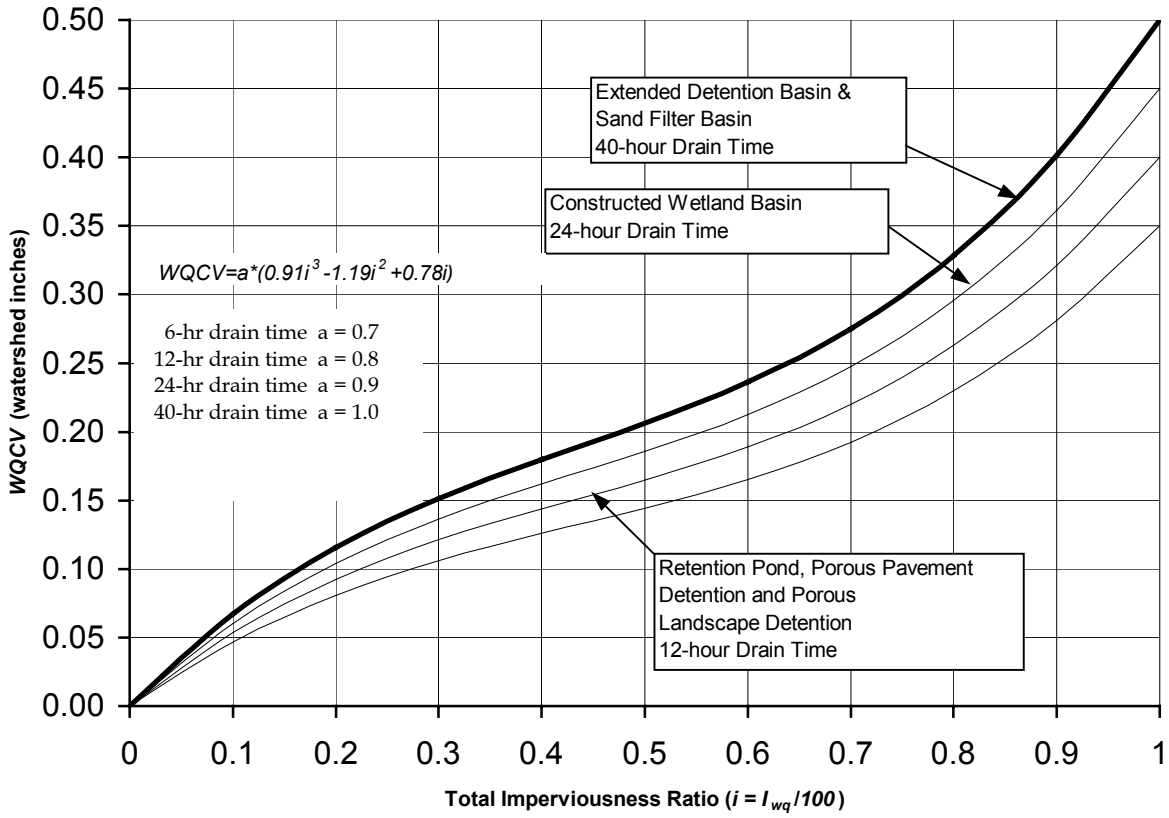


FIGURE SFB-2
Water Quality Capture Volume (WQCV), 80th Percentile Runoff Event

Design Procedure Form: Sand Filter Basin (SFB)

Designer: _____

Company: _____

Date: **September 22, 1999**

Project: _____

Location: _____

1. Basin Storage Volume	
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a = 50.00 % i = 0.50
B) Contributing Watershed Area (Area)	Area = 40.00 acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 1.0 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = 0.21 watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol = 0.688 acre-feet
2. Minimum Filter Surface Area: A_s = (Vol / 3) * 43,560	A_s = 9,983 square feet
Filter Surface Elevation	5478.50 feet
Average Side Slope of the Filter Basin (3:1 or flatter)	Z = 4.0
3. Estimate of Basin Depth (D), based on filter area A_s	D = 2.6 feet
4. Outlet Works	
A) Sand (ASTM C-33) Layer Thickness (18" min.)	18 inches
Gravel (AASHTO No. 8; CDOT Section 703) Layer Thickness (9" min.)	9 inches
B) Overflow Elevation At Top of Design Volume (Filter Surface Elev. + Estimate of Basin Depth (D))	5481.10 feet

5. Draining of porous pavement (Check a, **or** b, **or** c, **answer** d)
Based on answers to 5a through 5d, check the appropriate method

a) Check box if subgrade is heavy or expansive clay	
b) Check box if subgrade is silty or clayey sands	
c) Check box if subgrade is well-draining soils	X

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 Subgrade with Permeable Membrane: 5(c) checked **and** 5(d) = no

X Underdrain with Impermeable Membrane: 5(a) checked **or** 5(d) = yes

_____ Underdrain with Permeable Membrane: 5(b) checked **and** 5(d) = no

_____ Other: _____

6 Describe Provisions for Maintenance _____

Notes: _____

Constructed Wetlands Basin (CWB)—Sedimentation Facility

Description

A constructed wetlands basin (CWB) is a shallow retention pond (RP) which requires a perennial base flow to permit the growth of rushes, willows, cattails, and reeds to slow down runoff and allow time for sedimentation, filtering, and biological uptake. It is a sedimentation basin and a form of a treatment plant.

A CWB differ from "natural" wetlands as they are totally human artifacts that are built to enhance stormwater quality. Sometimes small wetlands that exist along ephemeral drainageways on Colorado's high plains could be enlarged and incorporated into the constructed wetland system. Such action, however, requires the approval of federal and state regulators.

Current regulations intended to protect natural wetlands recognize a separate classification of wetlands constructed for a water quality treatment. Such wetlands generally are not allowed on receiving waters and cannot 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 treatment, such as the CWB, is separate from the disturbance of a natural wetland. Nevertheless, the U.S. Army Corps of Engineers has established maximum areas that can be maintained under a nationwide permit. Thus, 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.

General Application

A CWB can be used as a followup structural BMP in a watershed, or as a stand-alone onsite facility if the owner provides sufficient water to sustain the wetland. Flood control storage can be provided above the CWB's water quality capture volume (WQCV) pool to act as a multiuse facility.

CWB requires a net influx of water to maintain its vegetation and microorganisms. A complete water budget analysis is necessary to ensure the adequacy of the base flow.

Advantages/Disadvantages

General

A CWB offers several potential advantages, such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. It can also provide an effective followup treatment to onsite and source control BMPs that rely upon settling of larger sediment particles. In other words, it offers yet another effective structural BMP for larger tributary catchments.

The primary drawback of the CWB is the need for a continuous base flow to ensure viable wetland growth. In addition, silt and scum can accumulate and unless properly designed and built, can be flushed out during larger storms. In addition, in order to maintain a healthy wetland growth, the surcharge depth for WQCV above the permanent water surface cannot exceed 2 feet.

Along with routine good housekeeping maintenance, occasional "mucking out" will be required when sediment accumulations become too large and affect performance. Periodic sediment removal is also needed for proper distribution of growth zones and of water movement within the wetland.

Physical Site Suitability

A perennial base flow is needed to sustain a wetland, and should be determined using a water budget 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. Also, wetland basins require a near-zero longitudinal slope, which can be provided using embankments.

Pollutant Removal

See Table ND-2 for estimated ranges in pollutant removals. Reported removal efficiencies of constructed wetlands vary significantly. Primary variables influencing removal efficiencies include design, influent concentrations, hydrology, soils, climate, and maintenance. With periodic sediment removal and routine maintenance, removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorous, low to high; and for nitrogen, zero to moderate. Pollutants are removed primarily through sedimentation and entrapment, with some of the removal occurring through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts, and algae can concentrate

in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are washed out.

Researchers still do not agree whether routine aquatic plant harvesting affects pollutant removals significantly. Until research demonstrates and quantifies these effects, periodic harvesting for the general upkeep of wetland, and not routine harvesting of aquatic plants, is recommended.

Design Considerations

Figure CWB-1 illustrates an idealized CWB. An analysis of the 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). Insufficient inflow can cause the wetland to become saline or to die off.

Design Procedure and Criteria

The following steps outline the design procedure for a CWB.

1. Basin Surcharge Storage Volume

   Provide a surcharge storage volume equal to the WQCV based on a 24-hour drain time, above the lowest outlet (i.e., perforation) in the basin.

   A. Determine the WQCV using the tributary catchments percent imperviousness. Account for the effects of DCIA, if any, on Effective Imperviousness. Using Figure ND-1, determine the reduction in impervious area to use with WQCV calculations.

   B. Find the Required Storage Surcharge Volume (watershed inches of runoff) above the permanent pool level.

      Determine the Required Storage (watershed inches of runoff) using Figure CWB-2, based on the constructed wetland basin 24-hour drain time.

      Calculate the Surcharge Volume in acre-feet as follows:

$$Design\ \ Surcharge\ \ Volume = \left(\frac{WQCV}{12}\right) * Area$$

      In which:

      Area = The tributary drainage area tributary to the CWB (acres).

2. Wetland Pond Depth and Volume

   The volume of the permanent wetland pool shall be no less than 75 percent of the WQCV found in Step 1.

Proper distribution of wetland habitat is needed to establish a diverse ecology. Distribute pond area in accordance with the following:

TABLE 1

Components	Percent 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.

3. Depth of Surcharge WQCV

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

4. Outlet Works

Provide outlet works that limit WQCV depth to 2 feet or less. Use a water quality outlet that is capable of releasing the WQCV in no less than a 24-hour period. Refer to the *Structural Details* section for schematics pertaining to structure geometry: grates, trash racks, and screens; outlet type: orifice plate or perforated riser pipe; cutoff collar size and location; and all other necessary components.

For a perforated outlet, use Figure CWB-3 to calculate the required area per row based on WQCV and the depth of perforations at the outlet. See the *tructural Details* section to determine the appropriate perforation geometry and number of rows (The lowest perforations should be set at the water surface elevation of the outlet pool). The total outlet area can then be calculated by multiplying the area per row by the number of rows.

5. Trash Rack

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 and the selected perforation diameter (or height), Figures 6, 6a or 7 in the *Structural Details* section will help to determine the minimum open area required for the trash rack. If a perforated vertical plate or riser is used as suggested in the *Manual*, 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. Figures 6 and 6a were developed as suggested standardized outlet designs for smaller sites.

6. Basin Use — Determine if flood storage or other uses will be provided for above the wetland surcharge storage or in an upstream facility. Design for combined uses when they are to be provided for.

7. Basin Shape — Shape the pond with a gradual expansion from the inlet and a gradual contraction to the outlet, thereby limiting short circuiting. The basin length to width ratio between the inlet and outlet should be 2:1 to 4:1 with 3:1 recommended. It may be necessary to modify the inlet and outlet point through the use of pipes, swales, or channels, to accomplish this.

8. Basin Side Slopes — Basin side slopes are to be stable and gentle to facilitate maintenance and access needs. Side slopes should be no steeper than 3:1, preferably 4:1 or flatter.

9. Base Flow — A net influx of water must be available throughout the year that exceeds all of the losses. The following equation and parameters can be used to estimate the net quantity of base flow available at a site:

$$Q_{net} = Q_{Inflow} - Q_{Evap} - Q_{Seepage} - Q_{E.T.}$$

Where:

Q_{Net} = Net quantity of base flow (acre-ft/year)

Q_{Inflow} = Estimated base flow (acre-ft/year) (Estimate by seasonal measurements and/or comparison to similar watersheds)

Q_{Evap} = Loss attributed to evaporation less the precipitation (acre-ft/year) (Computed for average water surface)

$Q_{Seepage}$ = Loss (or gain) attributed to seepage to groundwater (acre-ft/year)

$Q_{E.T.}$ = Loss attributed to plant evapotranspiration (computed for average plant area above water surface, not including the water surface)

10. Inlet/Outlet Protection — Provide a means to dissipate flow energy entering the basin to limit sediment resuspension. Inlets should correspond to the drop-structure criteria in the Design Criteria section of the City of Colorado Springs and El Paso County Drainage Criteria Manual. Outlets should be placed in an offbay that is at least 3 feet deep. The outlet should be protected from clogging by a skimmer shield that starts at the bottom of the permanent pool and extends above the maximum capture volume depth. Provide for a trash rack also.

11. Forebay Design — Provide the opportunity for larger particles to settle out in an area that has a solid driving surface bottom for vehicles to facilitate sediment removal. The forebay volume of the permanent pool should be 5 to 10 percent of the design water quality capture volume.

12. Vegetation — Cattails, sedges, reeds, and wetland grasses should be planted in the wetland bottom. Berms and side-sloping areas should be planted with native or irrigated turf-forming grasses. Initial establishment of the wetlands requires control of the water depth. After planting wetland species, the permanent pool should be kept at 3 to 4 inches to allow growth and to help establish the plants, after which the pool should be raised to its final operating level.

    Professionals experienced in design of wetlands, including plant selection/diversity/location and scheduling of plantings, need to be involved in the planning, design and construction phases.

13. Maintenance Access — Provide vehicle access to the forebay and outlet area for maintenance and removal of bottom sediments. Maximum grades should not exceed 10 percent, and a stabilized, all-weather driving surface needs to be provided.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

To achieve and maintain a healthy wetland for water quality enhancement, the proper depth and the spatial distribution of growth zones must be maintained. Table CWB-1 summarizes suggested activities and their frequencies to maintain an operational wetland.

TABLE CWB-1
Constructed Wetlands Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn mowing and lawn care	Mow occasionally to limit unwanted vegetation. Maintain irrigated turf grass at 2 to 4 inches tall and nonirrigated native turf grasses at 4 to 6 inches.	Routine – depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from entire pond to minimize outlet clogging and aesthetics. Include removal of floatable material from the pond's surface.	Routine – including just before annual storm seasons (that is, in April and May) and following significant rainfall events.

TABLE CWB-1
Constructed Wetlands Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Sediment removal	Remove accumulated sediment and muck along with much of the wetland growth. Re-establish growth zone depths and spatial distribution. Revegetate with original wetland species.	Nonroutine – every 10 to 20 years as needed by inspection if no construction activities take place in the tributary watershed. More often if they do. Expect to clean out forebay every 1 to 5 years.
Aquatic plant harvesting	Cut and remove plants growing in wetland (such as cattails and reeds) to remove nutrients permanently with manual work or specialized machinery.	Nonroutine until further evidence indicates such action would provide significant nutrient removal. In the meantime, perform this task once every 5 years or less frequently as needed to clean the wetland zone out.
Inspections	Observe inlet and outlet works for operability. Verify the structural integrity of all structural elements, slopes, and embankments.	Routine – at least once a year, preferably once during one rainfall event resulting in runoff.

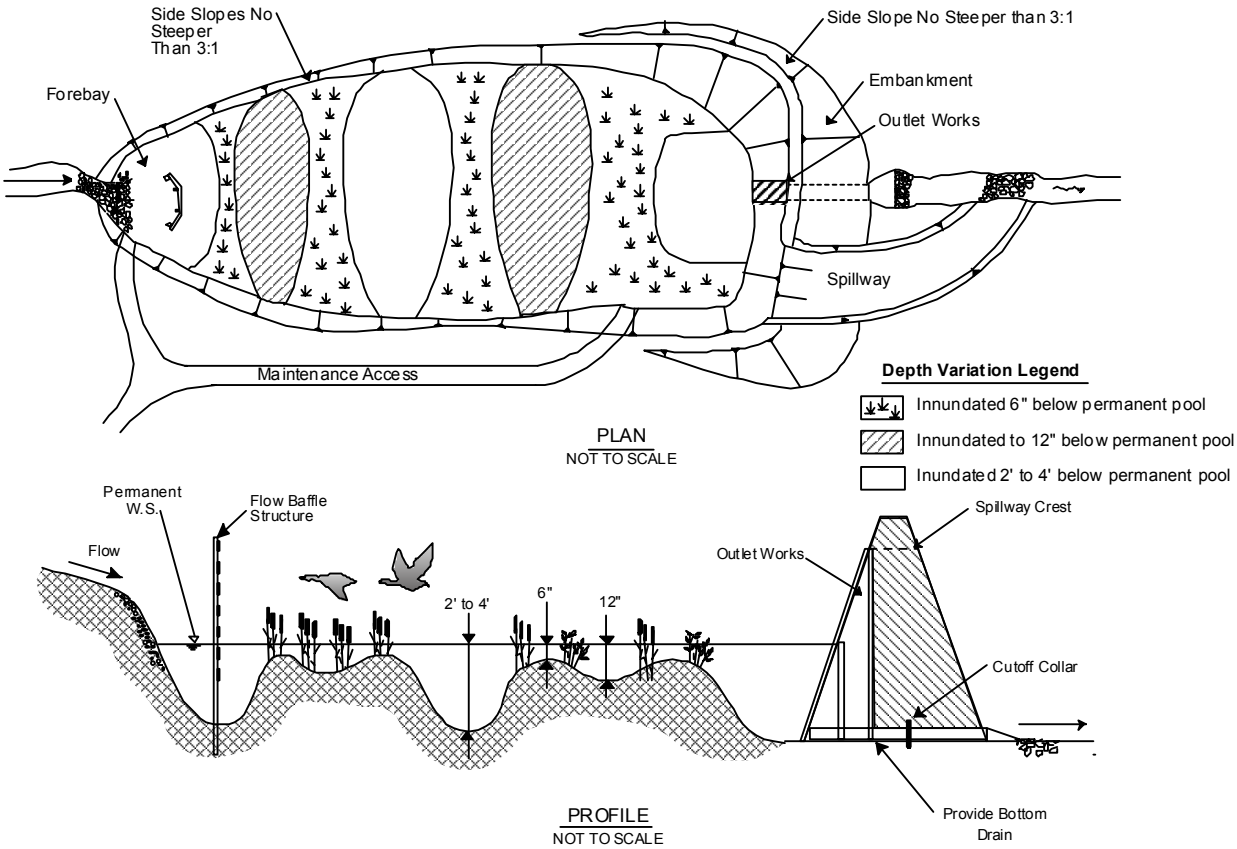


FIGURE CWB-1
Plan and Profile of a Constructed Wetland Basin Sedimentation Facility

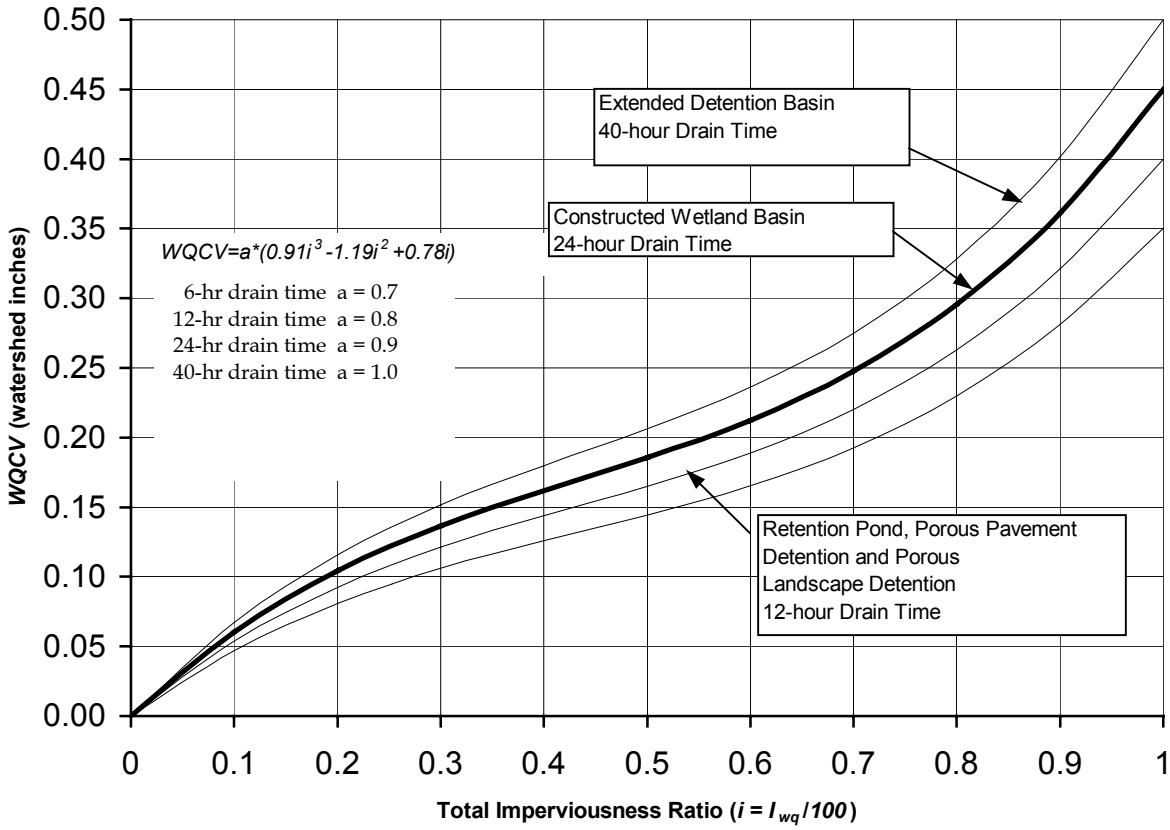
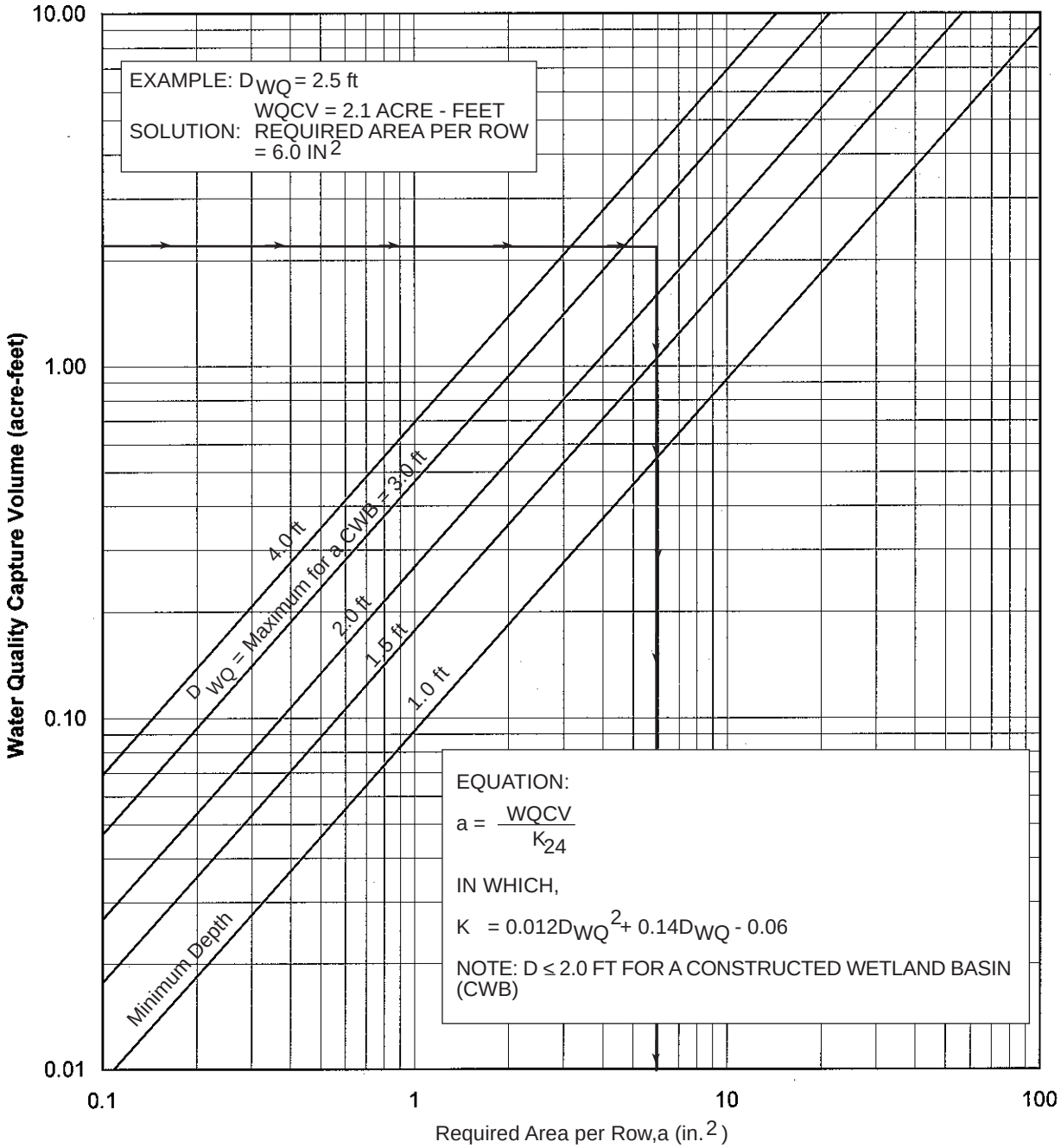


FIGURE CWB-2
Water Quality Capture Volume (WQCV), 80th Percentile Runoff Event



Source: Douglas County Storm Drainage and Technical Criteria, 1986.

FIGURE CWB-3
Water Quality Outlet Sizing: Constructed Wetland Basin With a 24-Hour Drain Time of The Capture Volume

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

Sheet 1 of 3

Designer: _____

Company: _____

Date: **October 2, 2000**

Project: _____

Location: _____

1. Basin Storage Volume			
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a =	50.00	%
	i =	0.50	
B) Contributing Watershed Area (Area)	Area =	50.00	acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.9 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV =	0.19	watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol =	0.77	acre-feet
2. Wetland Pond Volume, Depth, and Water Surface Area			
	Calculated Required Minimums:		
A) Minimum Permanent Pool: $Vol_{Pool} \geq 0.75 * Vol$	$Vol_{Pool} \geq$	0.58	acre-feet
	WS Area =	0.39	acres, estimated
	Enter the Actual Design Values:		
	$Vol_{Pool} \geq$	0.60	acre-feet, final design
	WS Area =	0.40	acres, final design
B) Forebay (Volume $\geq$ 0.05 * Vol in 1D)	Volume=	0.04	acre-feet
Depth minimum = 2.5', maximum = 4.0'	Depth=	3.50	feet
	Area=	0.011	acres, % = 2.86%
C) Outlet Pool (Area > 0.06 * Design WS Area)	Depth=	3.00	feet
Depth minimum = 2.5', maximum = 4.0'	Area=	0.025	acres, % = 6.25%
D) Wetland Zones with Emergent Vegetation (6" to 12" deep)	Depth=	0.75	feet
(Area = 50% to 70% of Design WS Area)	Area=	0.220	acres, % = 55.00%
E) Free Water Surface Areas (2' to 4' deep)	Depth=	3.50	feet
(Area = 30% to 50% of Design WS Area)	Area=	0.144	acres, % = 35.89%
			100.00%
3 Average Side Slope Above Water Surface (3:1 or flatter)	Z =	4.00	
A) Depth of WQCV Surcharge (above permanent pool, 2' max.)		1.8	feet
4. Outlet Works			
A) Outlet Type (Check One)	**X**	Orifice Plate	
		Perforated Riser Pipe	
		Other: _____	
B) Depth at Outlet Above Lowest Perforation (H, 2' max.)	H =	1.80	feet
C) Required Maximum Outlet Area per Row, (A_o)	A_o =	3.35	square inches
D) Perforation Dimensions (Refer to Figure 5 in W.Q. Str. Det.): **(Enter one only)**:			
i) Circular Perforation Diameter **OR**	D =		inches, **OR**
ii) 2" Height Rectangular Perforation Width	W =	1.63	inches

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

Designer: _____
Company: _____
Date: **October 2, 2000**
Project: _____
Location: _____

E) Number of Columns (nc)	nc =	1	Number
F) Actual Design Outlet Area per Row (A_o)	A_o =	3.26	square inches
G) Number of Rows (nr)	nr =	5	Number
H) Total Outlet Area (A_{ot})	A_{ot} =	17.60	square inches

5. Trash Rack

A) Needed Open Area: A_t = 0.5 * (UDFCD Vol. 3 Figure 7 Value) * A_{ot}	A_t =	528.89	square inches
B) Type of Outlet Opening (Check One)			≤ 2" Diameter **Round**
		X	2" High **Rectangular**
			Other:
C) For 2", or Smaller, **Round Opening** (Ref.: Figure 6a):			
i) Width of Trash Rack and Concrete Opening (W_{conc}) from UDFCD Vol. 3, Table 6a-1	W_{conc} =		inches
ii) Height of Trash Rack Screen (H_{TR})	H_{TR} =		inches
iii) Type of Screen (Based on Depth H), Describe if "Other"			S.S. #93 VEE Wire (US Filter)
			Other:
iv) Screen Opening Slot Dimension, Describe if "Other"			0.139" (US Filter)
			Other:
v) Spacing of Support Rod (O.C.)			inches
Type and Size of Support Rod (Ref.: UDFCD Vol. 3 Table 6a-2)			
vi) Type and Size of Holding Frame (Ref.: UDFCD Vol. 3 Table 6a-2)			
D) For 2" High **Rectangular Opening** (Refer to UDFCD Vol. 3 Figure 6b):			
I) Width of Rectangular Opening (W)	W =	1.63	inches
ii) Width of Perforated Plate Opening (W_{conc} = W + 12")	W_{conc} =	13.63	inches
iii) Width of Trashrack Opening ($W_{opening}$) from Table 6b-1	$W_{opening}$ =	24.0	inches
iv) Height of Trash Rack Screen (H_{TR})	H_{TR} =	46	inches
v) Type of Screen (based on depth H) (Describe if "Other")		X	Klemp™ KPP Series Aluminum
			Other:
vi) Cross-bar Spacing (Based on Table 6b-1, Klemp™ KPP Grating). Describe if "Other"		2	inches
			Other:

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

Sheet 3 of 3

Designer: _____

Company: _____

Date: **October 2, 2000**

Project: _____

Location: _____

vii) Minimum Bearing Bar Size (Klemp™ Series, Table 6a-2) (Based on depth of WQCV surcharge)	**1.00 in. x 3/16 in.**
6. Basin Use for Quantity Controls (Check one or describe if "Other")	X Detention within the facility _____ Detention upstream of the facility _____ Other: _____
7. Basin length to width ratio	3.00 (L/W)
8. Basin Side Slopes (Z, horizontal distance per unit vertical)	4.00 (horizontal/vertical)
9 Annual/Seasonal Water Balance (Q_{net} has to be positive)	Q_{inflow} 362.00 acre-feet/year Q_{evap} 1.40 acre-feet/year $Q_{seepage}$ 2.80 acre-feet/year $Q_{E.T.}$ 1.50 acre-feet/year Q_{net} 356.30 acre-feet/year
10 Vegetation (Check the method being applied or describe)	_____ Native Grass X Irrigated Turf Grass Side Slopes X Wetland Species in Pool* _____ Other: _____ *Describe Species Density and Mixl.

Notes: _____

Retention Pond (RP)—Sedimentation Facility

Description

A Retention Pond (RP) is a sedimentation facility and a form of a treatment plant that has a permanent pool of water that is replaced with stormwater, in part or in total, during storm runoff events. In addition, a temporary detention volume is provided above this permanent pool to capture storm runoff and enhance sedimentation. RPs are similar to EDBs because they are designed to capture in total, as a surcharge to the pond, runoff from frequently occurring storms. However, RPs differ from extended detention basins (EDBs) because the influent water mixes with the permanent pool water as it rises above the permanent pool level. The surcharge captured volume above the permanent pool is then released over 12 hours.

RPs require a dry-weather base flow to maintain the permanent pool. They can be very effective in removing pollutants, and, under the proper conditions, can satisfy multiple objectives.

General Application

A RP can be used to improve the quality of urban runoff from roads, parking lots, residential neighborhoods, commercial areas, and industrial sites and is generally used as regional or follow-up treatment because of the base-flow requirements. It can be used as an onsite BMP if the owner provides sufficient water to keep the pond full between storms. A RP works well in conjunction with other BMPs, such as upstream onsite source controls and downstream filter basins or wetland channels.

Advantages/Disadvantages

General

A RP can be cost-effective for larger tributary watersheds. It provides the following:

- Achieves moderate to high removal rates of many urban pollutants.
- Creates wildlife habitat opportunities.
- Provides recreation, aesthetics, and open space opportunities.
- Be a part of a larger flood control basin.

Their primary disadvantages include safety concerns, more difficult maintenance sediment removal than for EDBs, floating litter, scum and algal blooms, possible nuisance odors and possible mosquito problems. Aquatic plant growth can be a factor in clogging outlet works. The permanent pool can attract water fowl, which can add to the nutrient load entering and leaving the pond. Water rights must also be considered.

Physical Site Suitability

Although site suitability concerns are similar to those stated for an EDB, a RP has one primary difference—it requires sufficient continuous base flow to maintain the pool. A complete water budget under the projected urbanized watershed conditions should be performed to assure that the base flow will exceed evaporation, evapotranspiration, and seepage losses.

Pollutant Removal

See Table ND-2 for pollutant removal ranges. A RP achieves moderate to high removal rates for particulate matter through sedimentation during and shortly after the runoff event. During a storm event, a portion or all of the permanent pool water is displaced and the pool becomes a mixture of the former pool water and new runoff. The period between storms allows biological uptake of soluble nutrients and metals from the water column in the permanent pool while also providing time for quiescent settling of fine sediment particles that remain in the pool after a storm. Some of the sediment can resuspend and soluble compounds can remobilize if a large storm event causes intense mixing or when unfavorable chemical conditions exist in the pool (such as low dissolved oxygen [DO] or pH). Also, algal growth and other biological activity can produce suspended solids and increased concentrations of certain forms of phosphates and nitrogen compounds in dry-weather base flow discharges from the pond.

Without a sufficient continuous base flow, a wet pond can concentrate levels of salts and algae between storm events through evaporation. Besides contributing to nuisance problems, the water quality of the pool is very important. A storm event will displace any concentrated pond water, and in some instances, can result in discharges of water with pollutant concentrations exceeding the inflow, exactly the opposite of the intent for providing this BMP.

Aesthetics and Multiple Uses

A RP offers improved aesthetics and multiple-uses beyond those typically found at an EDB. The bulk of the capture volume occurs as a surcharge above the permanent pool, with some of it occurring above the dry-weather bank areas. As a result, most of the sediment deposits are left behind within the permanent pool zone, where they are not seen by the public. Also, the

permanent pool offers some aquatic habitat and is a habitat for water fowl. However, water fowl can be a nuisance because of the fecal matter they deposit on the banks and in the pool.

Design Considerations

The required total basin design volume of a RP facility includes the volume needed for a permanent pool (≥water quality capture volume) plus a water quality capture volume as a surcharge above the permanent pool. If desired, a flood routing detention volume can be provided above the water quality capture volume.

Whenever desirable and feasible, incorporate the RP within a larger flood control basin. Also, whenever possible try to provide for other urban uses such as active or passive recreation, and wildlife habitat. Try to locate recreational areas to limit the frequency of inundation to one or two occurrences a year. Generally, the area within the water quality capture volume is not well suited for active recreation facilities such as ballparks, playing fields, and picnic areas. These should be located above this pool level.

Land requirements are typically 0.5 to 2 percent of the tributary watershed's area. High exfiltration rates can initially make it difficult to maintain a permanent pool in a new RP, but the bottom can eventually seal with fine sediment and become relatively impermeable over time. It is best, however, to seal the bottom and the sides of a permanent pool if the pool is located on permeable soils and to leave the areas above the permanent pool unsealed to promote exfiltration of the stormwater detained in the surcharge water quality capture volume.

There are two primary differences in design between a RP and an EDB:

- The RP requires a base flow to maintain and to flush a permanent pool.
- A RP is designed to empty the surcharge water quality capture volume over a 12-hour period, instead of the longer 40 hours needed for an EDB. The reason for this is that the sediment removal process is more efficient when the outflow occurs above the bottom of the basin. Sediments become trapped below the outlet and sedimentation continues in the pool after the captured surcharge volume is emptied.

Figure RP-1 shows a representative layout for a RP. Although flood storage has not been addressed in these recommendations for the same reasons mentioned under EDBs, it can be easily provided for above the surcharge water quality capture volume. Embankment design and safety design considerations for a RP are identical to those discussed for an EDB, except more attention should be given to cutoff collars on the outlet pipe to safeguard against piping along the outlet.

The amount of construction activity within a basin, the erosion control measures implemented, and the size of the basin will influence the frequency of sediment removal from the pond. It is estimated that accumulated sediment will need to be removed at 5- to 20-year intervals if there are no construction activities within the tributary catchment.

Design Procedure and Criteria

The following steps outline the design procedure and criteria for a RP.

1. Basin Surcharge Storage Volume

Provide a storage volume equal to the WQCV based on a 12-hour drain time, above the lowest outlet (i.e., perforation) in the basin.

A. Determine the WQCV using the tributary catchment's percent imperviousness. Account for the effects of DCIA, if any, on Effective Imperviousness. Using Figure ND-1, determine the reduction in impervious area to use with WQCV calculations.

B. Find the required storage surcharge volume (watershed inches of runoff).

Determine the required water quality capture volume in watershed inches of runoff using Figure RP-2, based on the RP, 12-hour drain time. The water quality capture volume is the surcharge volume above the permanent pool.

Calculate the design surcharge volume in acre-feet as follows:

$$Design\ \ Surcharge\ Volume = \left(\frac{WQCV_i}{12}\right) * Area$$

In which:

$WQCV_i$	=	Water quality capture volume from Figure RP-2 in watershed inches
$Area$	=	The tributary drainage area tributary to the RP (acres).

2. Permanent Pool

The permanent pool provides stormwater quality enhancement between storm runoff events through biochemical processes and continuing sedimentation.

A. Volume of the permanent pool:

$$Permanent\ \ Pool = 1.0\ to\ 1.5\ (WQCV)$$

B. Depth Zones: The permanent pool shall have two depth zones:

1. A littoral zone 6 to 12 inches deep that is between 25 to 40 percent of the permanent pool surface area for aquatic plant growth along the perimeter of the permanent pool, and

2. A deeper zone of 4 to 8 feet average depth in the remaining pond area to promote sedimentation and

nutrient uptake by phytoplankton. Maximum depth in the pond shall not exceed 12 feet.

3. Base Flow

A net influx of water must be available through a perennial base flow and must exceed the losses. The following equation and parameters can be used to estimate the net quantity of baseflow available at a site:

$$Q_{Net} = Q_{Inflow} - Q_{Evap} - Q_{Seepage} - Q_{E.T.}$$

In which:

Q_{net}	=	Net quantity of base flow (acre-ft/year)
Q_{inflow}	=	Estimated base flow (acre-ft/year) (Estimate by seasonal measurements and/or comparison to similar watersheds)
Q_{evap}	=	Loss because of evaporation less the precipitation (acre-ft/year) (Computed for average water surface)
$Q_{Seepage}$	=	Loss (or gain) because of seepage to groundwater (ac-ft/year)
$Q_{E.T.}$	=	Loss because of plant evapotranspiration (additional loss through plant area above water surface not including the water surface)

4. Outlet Works

The Outlet Works are to be designed to release the WQCV (above the permanent pool elevation) over a 12-hour period. Refer to the *Structural Details* section for schematics pertaining to structure geometry; grates, trash racks, and screens; outlet type: orifice plate or perforated riser pipe; cutoff collar size and location; and all other necessary components.

For a perforated outlet, use Figure RP-3 to calculate the required area per row based on WQCV and the depth of perforations at the outlet. See the *Structural Details* section to determine the appropriate perforation geometry and number of rows (The lowest perforations should be set at the water surface elevation of the permanent pool.) The total outlet area can then be calculated by multiplying the area per row by the number of rows.

5. Trash Rack

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 and the selected perforation diameter (or height), Figures 6, 6a or 7 in the *Structural Details* section will help to determine the minimum open area required for the trash rack. If a perforated vertical plate or riser is used as suggested in this manual, 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. Figures 6 and 6a were developed as suggested standardized outlet designs for smaller sites.

6. Basin Shape — Shape the pond with a gradual expansion from the inlet and a gradual contraction toward the outlet, thereby limiting short-circuiting. The basin length to width ratio between the inlet and outlet should be between 2:1 and 3:1, with the larger being preferred. It may be necessary to modify the inlet and outlet point through the use of pipes, swales, or channels to accomplish this.

7. Basin Side Slopes — Side slopes should be stable and sufficiently gentle to limit rill erosion and to facilitate maintenance. Side slopes above the permanent pool should be no steeper than 4:1, preferably flatter. The littoral zone should be very flat (that is, 10:1 or flatter) with the depth ranging from 6 inches near the shore and extending to no more than 12 inches at the furthest point from the shore. The side slope below the littoral zone shall be 3:1 or flatter.

8. Dam Embankment — The embankment should be designed not to fail during a 100-year or larger storm. Embankment slopes should be no steeper than 3:1, preferably 4:1 or flatter, covered with turf-forming grasses to limit erosion. Poorly compacted native soils should be removed and replaced. Embankment soils should be compacted to 95 percent of their maximum density according to ASTM D 698-70 (modified proctor).

9. Vegetation — Vegetation provides erosion control and enhances site stability. Berms and side-sloping areas should be planted with native turf-forming grasses or irrigated turf, depending on the local setting and proposed uses for the pond area. The shallow littoral bench should have a 4- to 6-in. organic topsoil layer and be vegetated with aquatic species.

10. Maintenance Access — Access to the basin bottom, forebay, and outlet area must be provided to maintenance vehicles. Maximum grades should be 10 percent, and a solid driving surface of gravel, rock, or concrete shall be provided.

11. Inlet — Dissipate flow energy at the inlet to limit erosion and to diffuse the inflow plume where it enters the pond. Inlets should be designed in accordance with the drop-structure and energy-dissipating structure criteria in the Design Criteria section of the City of Colorado Springs and El Paso County Drainage Criteria Manual.

12. Forebay Design — To provide an opportunity for larger particles to settle out, install an area that has a solid driving surface bottom to facilitate sediment removal. A berm consisting of rock and topsoil mixture should be part of the littoral bench to create the forebay and have a minimum top width of 8 feet and side slopes no steeper than 4:1. The forebay volume of the permanent pool should be 5 to 10 percent of the design water quality capture volume.

13. Underdrains — Provide underdrain trenches near the edge of the pond. The trenches should be no less than 12 inches wide filled with ASTM C-33 sand to within 2 feet of the ponds permanent pool water surface, and with an underdrain pipe connected through a valve to the outlet. These underdrains will permit the drying out of the pond when it has to be "mucked out" to restore volume lost due to sediment deposition.

Design Example

Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

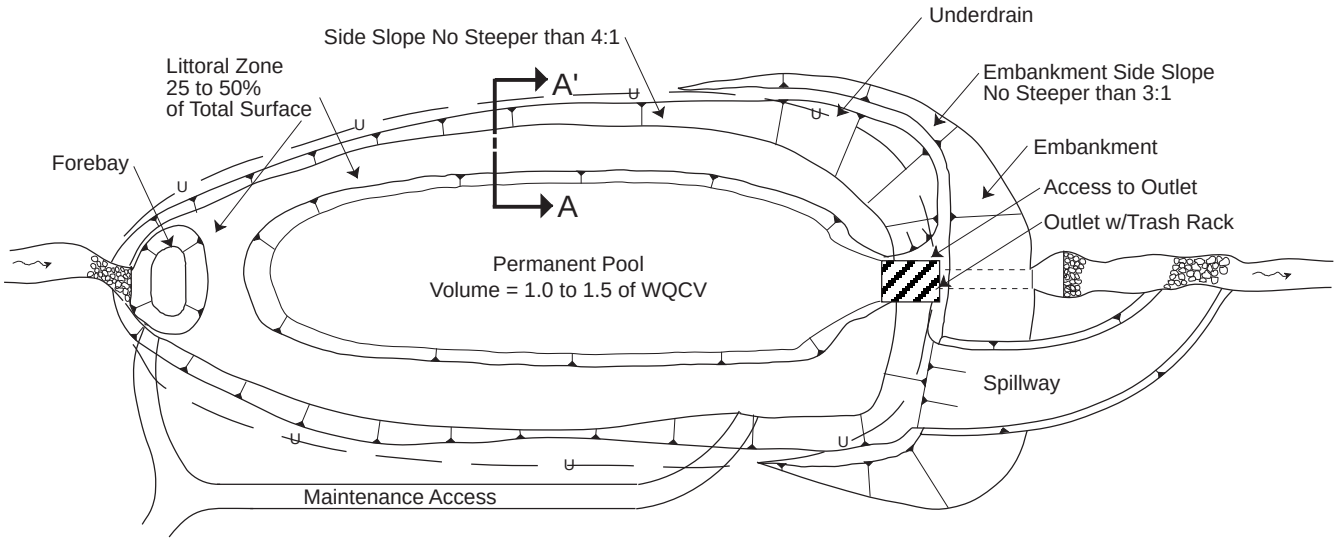
The amount of construction activity within a basin, the erosion control measures implemented, and the size of the basin will influence the frequency of sediment removal from the pond. When aggressive erosion control is practiced in the tributary watershed, it is estimated that accumulated sediment will need to be removed at 5- to 20-year intervals. Table RP-1 summarizes the required maintenance activities and their frequency for retention ponds.

TABLE RP-1
Retention Pond Basin Maintenance Considerations

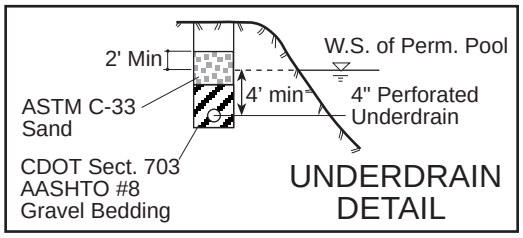
Required Action	Maintenance Objective	Frequency of Action
Lawn mowing and lawn care	Mow occasionally to limit unwanted vegetation. Maintain irrigated turf grass 2 to 4 inches tall and non-irrigated native turf grasses at 4 to 6 inches.	Routine – depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from the entire pond to minimize outlet clogging and aesthetics. Include the removal of floatable material from the pond's surface.	Routine – including just before annual storm seasons (that is, April and May) and following significant rainfall events.

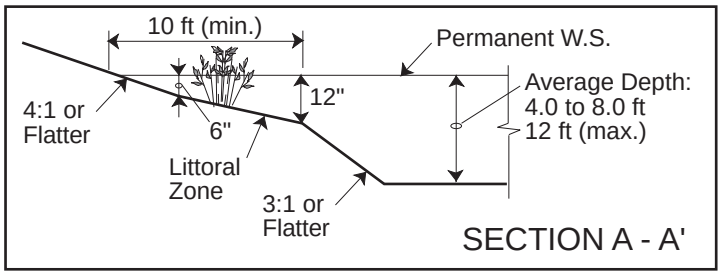
TABLE RP-1
Retention Pond Basin Maintenance Considerations

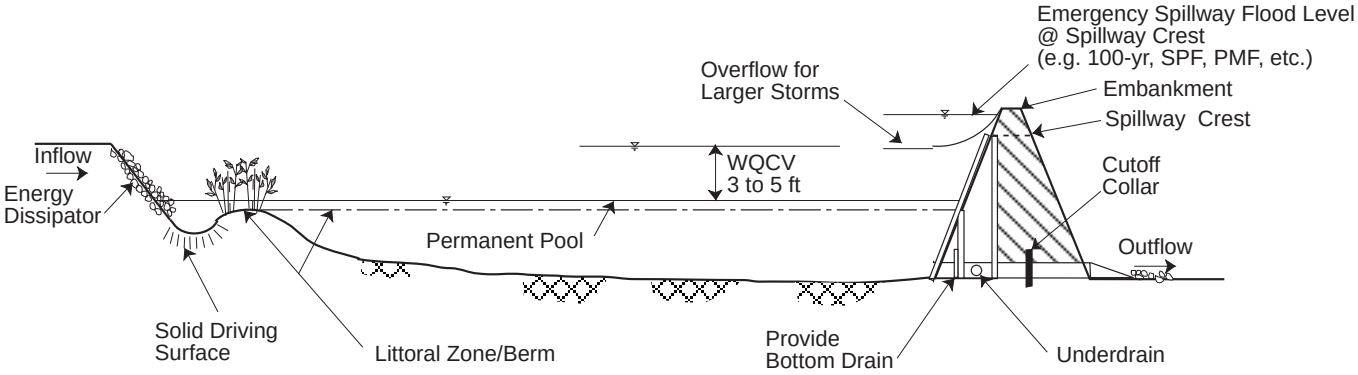
Required Action	Maintenance Objective	Frequency of Action
Erosion and sediment control	Regrade and revegetate eroded and slumped areas above the pond and along channels. Repair damaged inlet and outlet energy dissipators.	Nonroutine – periodic and repair as necessary based on inspection.
Inspections	Inspect the retention pond for functioning as initially intended. Pay attention to outlet clogging. Also note erosion, slumping, sedimentation levels, overgrowth, embankment and spillway integrity, and damage to structural elements of the facility.	Routine – annual inspection of hydraulic and structural facilities. Biannual performance and maintenance inspections.
Nuisance control	Address odor issues, insects, and overgrowth with appropriate measures.	Nonroutine – as necessary per inspection or local complaints.
Structural repairs	Repair such items as inlet/outlet works and energy dissipator liners. Stabilize banks and berms. Repair damage caused by larger storm events.	Nonroutine – as necessary per inspection.
Sediment removal	Empty the pond, divert the base flow, and dry out bottom sediments in fall and winter months to allow access with backhoe. Remove accumulated sediment along with aquatic growth overlaying them. Re-establish original design grades and volumes and replant aquatic vegetation.	Nonroutine – as indicated per inspections and sediment accumulation. Expect to do this every 10 to 20 years if no construction activities take place in the tributary watershed. More often if they do. Expect to clean out the forebay every 1 to 5 years.
Aquatic Growth Harvesting	Remove aquatic plants such as cattails or reeds, which also permanently removes nutrients. Use an aquatic harvester and dispose of the material offsite.	Nonroutine – perform every 5 to 15 years or as needed to control their accumulation.



PLAN
NOT TO SCALE







SECTION
NOT TO SCALE

FIGURE RP-1
Plan And Section Of a Retention Pond - Sedimentation Facility

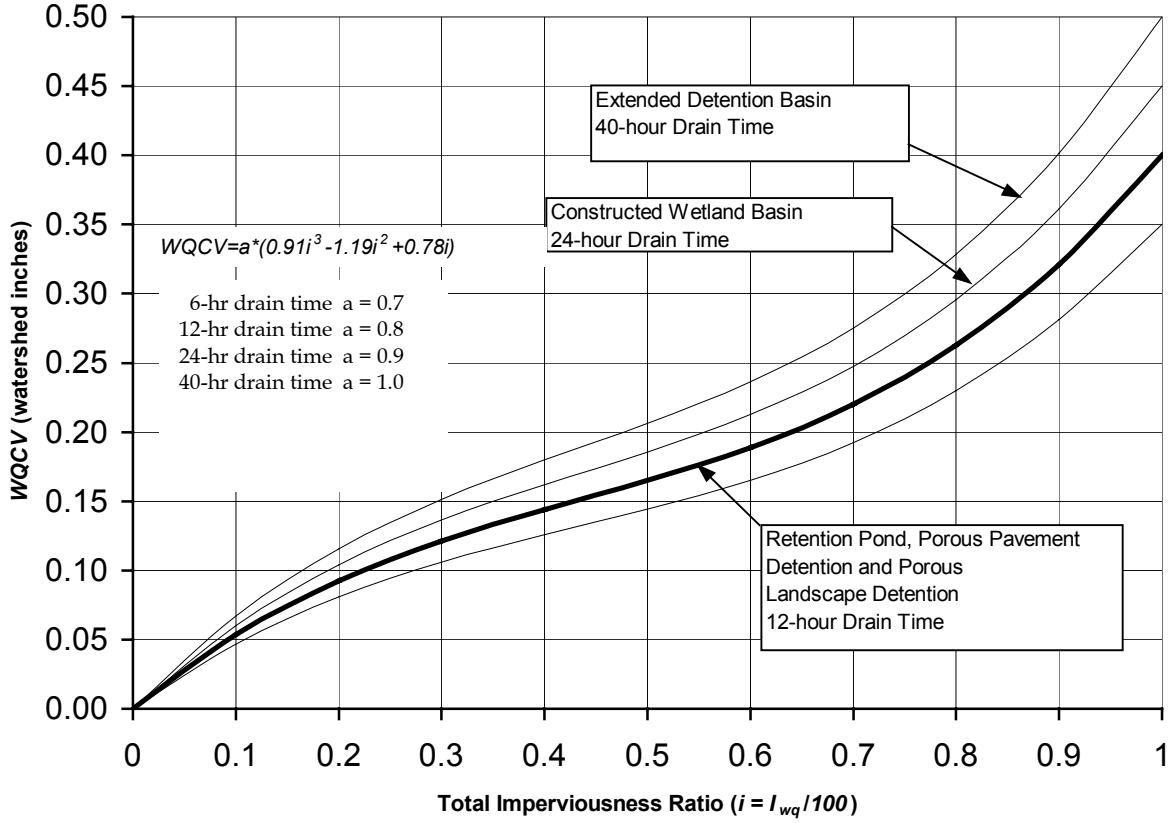
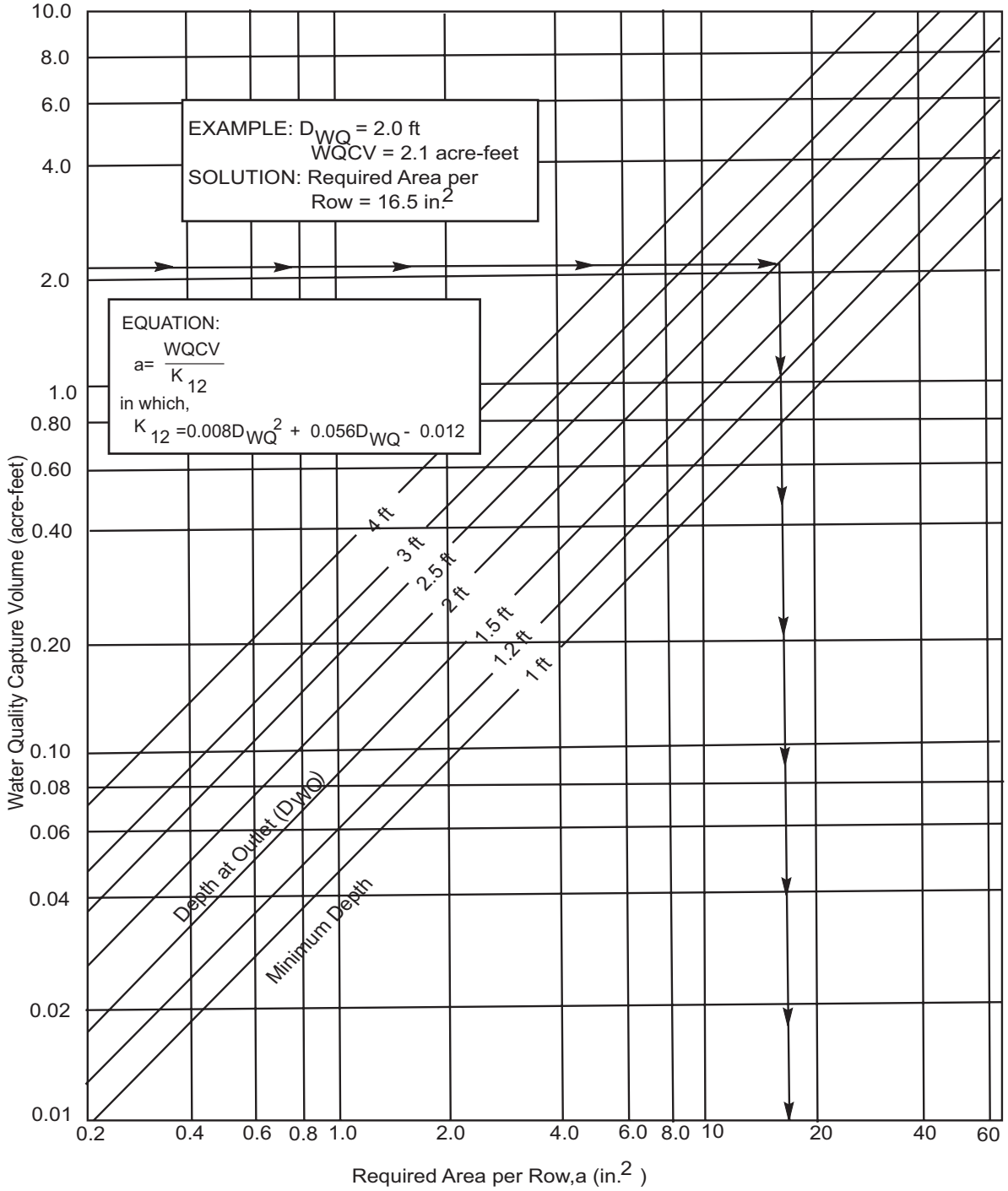


FIGURE RP-2
Water Quality Capture Volume (WQCV), 80th Percentile Runoff Event



Source: *Douglas County Storm Drainage and Technical Criteria*, 1986.

FIGURE RP-3
Water Quality Outlet Sizing: Retention Pond – Sedimentation Facility with a 12-hour Drain Time of Capture Volume

Design Procedure Form: Retention Pond (RP) - Sedimentation Facility (Sheet 1 of 3)

Designer: _____
Company: _____
Date: **September 22, 1999**
Project: _____
Location: _____

1. Basin Storage Volume			
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a =	50.00	%
	i =	0.50	
B) Contributing Watershed Area (Area)	Area =	100.00	acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.8 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV =	0.17	watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol =	1.38	acre-feet
2. Permanent Pool			
A) Volume: Vol_{Pool} = (1.0 to 1.5) * Vol		1.40	acre-feet
B) Average Depth Zone 1 = Littoral Zone - 6 to 12 inches deep		0.75	feet
Zone 2 = Deeper Zone - 4 feet to 8 feet deep	Zone 2	6.00	feet
C) Maximum Zone 2 Pool Depth (not to exceed 12 feet)	Depth =	9.00	feet
D) Permanent Pool Water Surface Area (Estimated Minimum)			
(Zone 1 - Littoral Zone = 25% to 40% of the total surface area)	% =	37.3	acres = 0.129
(Zone 2 - Deeper Zone = 60% to 75% of the total surface area)	% =	62.7	acres = 0.217
Total Estimated Minimum Surface Area (A_{Total})	% =	100.0	acres = 0.346
3. Annual/Seasonal Water Balance (Q_{net} has to be positive)	Q_{inflow}	181.00	acre-feet/year
	Q_{evap}	1.30	acre-feet/year
	$Q_{seepage}$	2.10	acre-feet/year
	$Q_{E.T.}$	0.80	acre-feet/year
	Q_{net}	176.80	acre-feet/year
4. Outlet Works			
A) Outlet Type (Check One)			Orifice Plate
		X	Perforated Riser Pipe
			Other: _____
B) Depth at Outlet Above Lowest Perforation (H)	H =	4.00	feet
C) Required Maximum Outlet Area per Row, (A_o)	A_o =	1.99	square inches
D) Perforation Dimensions **(enter one only)**:			
i) Circular Perforation Diameter **OR**	D =	1.1250	inches, **OR**
ii) 2" Height Rectangular Perforation Width	W =		inches
E) Number of Columns (nc)	nc =	2	Number

Design Procedure Form: Retention Pond (RP) - Sedimentation Facility (Sheet 2 of 3)

Designer: _____
Company: _____
Date: **September 22, 1999**
Project: _____
Location: _____

F) Actual Design Outlet Area per Row (A_o)	A_o = 1.99 square inches
G) Number of Rows (nr)	nr = 12 Number
H) Total Outlet Area (A_{ot})	A_{ot} = 23.86 square inches
5. Trash Rack	
A) Needed Open Area: A_t = 0.5 * (Figure 7 Value) * A_{ot}	A_t = 799 square inches
B) Type of Outlet Opening (Check One)	X ≤ 2" Diameter **Round** 2" High **Rectangular** Other:
C) For 2", or Smaller, **Round Opening** (Ref.: Figure 6a):	
I) Width of Trash Rack and Concrete Opening (W_{conc}) from Table 6a-1	W_{conc} = 24 inches
ii) Height of Trash Rack Screen (H_{TR})	H_{TR} = 72 inches
iii) Type of Screen (Based on Depth H), Describe if "Other"	X S.S. #93 VEE Wire (US Filter) Other:
iv) Screen Opening Slot Dimension, Describe if "Other"	X 0.139" (US Filter) Other:
v) Spacing of Support Rod (O.C.)	1 inches
Type and Size of Support Rod (Ref.: Table 6a-2)	**TE 0.074 in. x 0.75 in.**
vi) Type and Size of Holding Frame (Ref.: Table 6a-2)	**1.00 in. x 1.50 in. angle**
D) For 2" High **Rectangular Opening** (Refer to Figure 6b):	
I) Width of Rectangular Opening form 4.D.ii. (W)	W = _____ inches
ii) Width of Perforated Plate Opening (W_{conc} = W + 12")	W_{conc} = _____ inches
iii) Width of Trash Rack Opening ($W_{opening}$) from Table 6b-1	$W_{opening}$ = _____ inches
iv) Height of Trash Rack Screen (H_{TR})	H_{TR} = _____ inches
v) Type of Screen (based on depth H) (Describe if "Other")	Klemp™ KPP Series Aluminum Other:
vi) Cross-bar Spacing (Based on Table 6b-1, Klemp™ KPP Grating). Describe if "Other"	_____ inches Other: 96.00

Design Procedure Form: Retention Pond (RP) - Sedimentation Facility (Sheet 3 of 3)

Designer: _____
Company: _____
Date: **September 22, 1999**
Project: _____
Location: _____

vii) Minimum Bearing Bar Size (Klemp™ Series, Table 6a-2) (Base on depth of WQCV surcharge)	_____
6. Basin length to width ratio	1.80 (L/W)
7. Basin Side Slopes (Z:1)	
A) Above the Permanent Pool: Z=	5.0 (horizontal/vertical)
B) Below the Permanent Pool Z=	Zone 1= 5.0 (horizontal/vertical)
Z=	Zone 2= 3.0 (horizontal/vertical)
8. Dam Embankment Side Slopes Z=	4.0 (horizontal/vertical)
9. Vegetation (Check the type used or describe if "Other")	_____ Native Grass X Irrigated Turf Grass X Emergent Aquatic Species* _____ Other: _____ *Specify types and densities:
10. Forebay Storage (5% to 10% of Design Volume in 1D)	Storage= 0.12 acre-feet
11. Underdrains	**Yes** yes/no

Notes: _____

Constructed Wetlands Channel (CWC) — Sedimentation Facility

Description

Constructed wetland-bottomed channels takes advantage of dense natural vegetation (rushes, willows, cattails, and reeds) to slow down runoff and allow time for settling out sediment and biological uptake. It is another form of a sedimentation facility and a treatment plant.

Constructed wetlands differ from "natural" wetlands as they are artificial and are built to enhance stormwater quality. 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 a 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.

General Application

Wetland bottom channels can be used in the following two ways:

- A wetland can be established in a totally man-made channel and can act as a conveyance system and water quality enhancement facility. This design can be used along wide and gently sloping channels.

- A wetland bottom channel can be located downstream of a stormwater detention facility (water quality and/or flood control) where a large portion of the sediment load can be removed. The wetland channel then receives stormwater and base flows as they drain from the detention facility, provides water quality enhancement, and at the same time conveys it downstream. This application of a wetland channel is recommended upstream of receiving waters and within lesser (i.e., ephemeral) receiving waters, thereby delivering better quality water to the more significant receiving water system.

A CWC requires a net influx of water to maintain their vegetation and microorganisms. A complete water budget analysis is necessary to ensure the adequacy of the base flow.

Advantages/Disadvantages

General

Constructed wetlands offer several potential advantages, such as natural aesthetic qualities, wildlife habitat, erosion control, and pollutant removal. Constructed wetlands provide an effective follow-up treatment to onsite and source control BMPs that rely upon settling of larger sediment particles. In other words, they offer yet another effective BMP for larger tributary basins.

The primary drawback to wetlands is the need for a continuous base flow to ensure their presence. In addition, salts and scum can accumulate and unless properly designed and built, can be flushed out during larger storms.

Other disadvantages include the need for regular maintenance to provide nutrient removal. Regular harvesting and removal of aquatic plants, cattails, and willows is required if the removal of nutrients in significant amounts has to be assured. Even with that, recent data puts into question the net effectiveness of wetlands in removing nitrogen compounds and some form of phosphates. Periodic sediment removal is also necessary to maintain the proper distribution of growth zones and of water movement within the wetland.

Physical Site Suitability

A perennial base flow is needed to sustain a wetland, and should be determined using a water budget analysis. Loamy soils are needed in wetland bottom to permit plants to take root. Infiltration 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. Wetland bottom channels also require a near-zero longitudinal slope; drop structures are used to create and maintain a flat grade.

Pollutant Removal

Removal efficiencies of constructed wetlands vary significantly. Primary variables influencing removal efficiencies include design, influent concentrations, hydrology, soils, climate, and maintenance. With periodic sediment removal and plant harvesting, expected removal efficiencies for sediments, organic matter, and metals can be moderate to high; for phosphorous, low to moderate; and for nitrogen, zero to low. Pollutants are removed primarily through sedimentation and entrapment, with some of the removal occurring through biological uptake by vegetation and microorganisms. Without a continuous dry-weather base flow, salts and

algae can concentrate in the water column and can be released into the receiving water in higher levels at the beginning of a storm event as they are washed out.

Harvesting aquatic plants and periodic removal of sediment also removes nutrients and pollutants associated with the sediment. Researchers still do not agree that routine aquatic plant harvesting affects pollutant removals. Until research documents these effects, periodic harvesting for the general upkeep of wetland, and not routine harvesting of aquatic plants, is recommended.

Design Considerations

Wetlands can be set into a drainageway to form a wetland bottom channel (see Figure CWC-1). An analysis of the water budget is needed so that the inflow of water throughout the year is sufficient to meet all the projected losses (such as evaporation, evapotranspiration, and seepage). An insufficient base flow could cause the wetland bottom channel to dry out and die.

Design Procedure and Criteria

The following steps outline the Constructed Wetlands Channel design procedure. Refer to Figure CWC-1 for its design components.

1. Design Discharge	Determine the 2-year peak flow rate in the wetland channel *without* reducing it for any upstream ponding or flood routing effects.
2. Channel Geometry	Define the newly-built channel's geometry to pass the design 2-year flow rate at 2.0 feet per second with a channel depth between 2.0 to 4.0 feet. The channel cross-section should be trapezoidal with side slopes of 4:1 (Horizontal/Vertical) or flatter. Bottom width shall be no less than 8.0 feet.
3. Longitudinal Slope	Set the longitudinal slope using Mannings equation and a Mannings roughness coefficient of n=0.03, for the 2-year flow rate. If the desired longitudinal slope can not be satisfied with existing terrain, grade control checks or small drop structures must be incorporated to provide desired slope.
4. Final Channel Capacity	Calculate the final (or mature) channel capacity during a 2-year flood using a Mannings roughness coefficient of n=0.08 and the same geometry and slope used when initially designing the channel with n=0.03. The channel shall also provide enough capacity to contain the flow during a 100-year flood while maintaining one foot of free-board. Adjustment of the channel capacity may be done by increasing the bottom width of the channel. Minimum bottom width shall be 8 feet.
5. Drop Structures	Drop structures should be designed to satisfy the drop structure criteria in the City/County Drainage Criteria Manual

6. Vegetation — Vegetate the channel bottom and side slopes to provide solid entrapment and biological nutrient uptake. Cover the channel bottom with loamy soils upon which cattails, sedges, and reeds should be established. Side slopes should be planted with native or irrigated turf grasses.

7. Maintenance Access — Provide access for maintenance along the channel length. Maximum grades for maintenance vehicles should be 10 percent and provide a solid driving surface.

Design Example

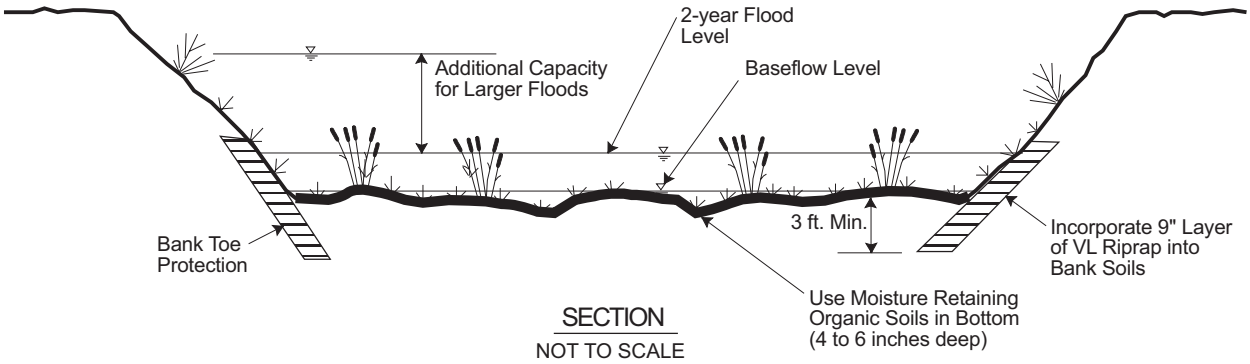
Design forms that provide a means of documenting the design procedure are included in the *Design Forms* section. A completed form follows as a design example.

Maintenance Recommendations

To achieve and maintain a healthy wetland for water quality enhancement, the proper depth and the spatial distribution of growth zones must be maintained. Table CWC-1 summarizes suggested activities and their frequencies to maintain an operational wetland.

TABLE CWC-1
Constructed Wetlands Maintenance Considerations

Required Action	Maintenance Objective	Frequency of Action
Lawn mowing and lawn care	Mow occasionally to limit unwanted vegetation. Maintain irrigated turf grass at 2 to 4 inches tall and nonirrigated native turf grasses at 4 to 6 inches.	Routine – Depending on aesthetic requirements.
Debris and litter removal	Remove debris and litter from the channel.	Routine – Including just before annual storm seasons (that is, in April and May) and following significant rainfall events.
Sediment removal	Remove accumulated sediment and muck along with wetland vegetation growing on top of it. Re-establish growth zone depths and revegetate with original wetland species.	Nonroutine – Every 10 to 20 years as needed by inspection if no construction activities take place in the tributary watershed. More often if they do.
Aquatic plant harvesting	Cut and remove plants growing in wetland (such as cattails and reeds) to remove nutrients permanently with manual work or specialized machinery.	Nonroutine until further evidence indicates such action would provide significant nutrient removal. In the meantime, perform this task once every 5 years or less frequently as needed to clean the wetland zone out.
Inspections	Observe inlet and outlet works for operability. Verify the structural integrity of all structural elements, slopes, and embankments.	Routine – At least once a year, preferably once during one rainfall event resulting in runoff.



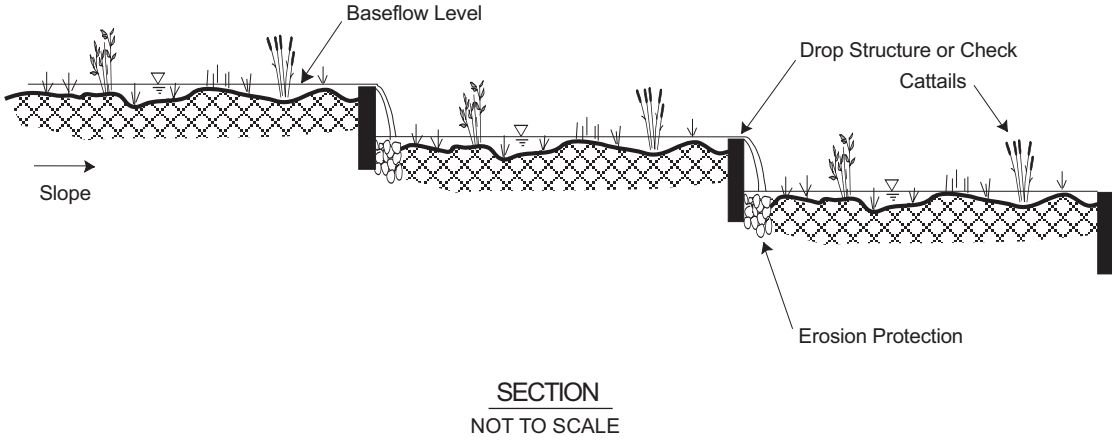


FIGURE CWC-1
Plan and Section of a Constructed Wetland Channel

Design Procedure Form: Constructed Wetlands Channel (CWC) - Sedimentation Facility

Designer: _____
Company: _____
Date: **September 22, 1999**
Project: _____
Location: _____

1. Design Discharge (total)	Q_2 =	200	cfs
	Q_{100} =	1,600	cfs
2. Channel Geometry (New Channel - No Wetland Veg. in Bottom)			
A) Channel Side Slopes (Z:1, i.e., H/V) ($Z \geq 2.5$)	Z =	3.0	(horizontal/vertical)
B) 2-Year Design Flow Depth (D_2) Maximum D_2 = 4', Minimum D_2 = 2'	D_2 =	4.00	feet
C) Bottom width of the channel (B_2) - 8-foot minimum	B_2 =	8.0	feet
D) Top width of the 2-Year Design Water Surface (W_2)	W_2 =	32.0	feet
3. Longitudinal Slope (Based on a Manning's n = 0.03 for the 2-year Channel, velocity set to 2 fps)	S =	0.0005	feet/feet
4. Final Channel Goemetry - Wetland Vegetation in Bottom) (Based on a Manning's n = 0.08)			
A) Calculated channel geometry required to maintain design discharge during a 2-year event with mature vegetation	Z =	3.0	feet
	D_2 =	4.0	feet
	B_2 =	43.5	feet
	W_2 =	67.5	feet
B) Calculated discharge and velocity during a 2-year event with mature vegetation	Q_2 =	200	cfs
	V_2 =	0.9	fps
C) Geometry and velocity to use for the 100-year discharge if composite channel section is used.	D_{100} =	10.2	feet
	B_{100} =	43.5	feet
	W_{100} =	126.2	feet
	V_{100} =	2.2	fps
5. Number of grade control structures required		4	number
6. Vegetation (Check the type or describe "Other")	X	Native Grass	
		Irrigated Turf Grass	
	X	Wetland Species	
		Other:	

Notes: _____

Covering of Storage/Handling Areas

Description

Covering of areas for storage and for handling facilities associated with potential industrial or commercial pollutants, such as salt piles, oil products, pesticides, fertilizers, etc. will reduce the likelihood of storm water contamination and will prevent loss of material from wind or rainfall erosion. Coverings can be permanent or temporary and consist of tarpaulins, plastic sheeting, roofing, enclosed structures, or any other device that prevent rain and wind from spreading possible contamination.

General Application

Covering is appropriate for areas where solids (gravel, salt, compost, building materials, etc.) or liquids (oil, gas, tar, etc.) are stored, prepared, or transferred.

Advantages/Disadvantages

General

Coverings can be inexpensive and easy to install. When an enclosed structure is built, ventilation, lighting, and other issues must be accounted for. Less expensive coverings (tarpaulins, plastic sheeting, etc.) may require frequent inspection and maintenance.

Physical Site Suitability

The size of the area to be covered will determine the most efficient and cost effective type of covering. If the area is too large to be entirely covered, at a minimum the critical areas should be covered.

Pollutant Removal

Spill containment berming can be installed around the covered area to contain spills until proper removal and disposal can occur.

Spill Containment And Control

Description

Spill containment within industrial and some commercial sites consists of berming and gates that allow for the control of spilled material. Berming consists 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 may be made concrete, earthen material, metal, synthetic liners, or any material that will safely contain the spill. A potential spill site is one that allows the storage or transfer of potential spill material. Spill material is that which is not allowed into surface waters or storm sewer systems according to local, state, or federal regulations. Spill control devices include valves, slide gates, or any other device which can contain material when required and then release the spilled material in a controlled fashion.

General Application

Two methods of berming can be used: 1) containment berming that contains an entire spill and 2) curbing that routes spill material to a collection basin. Containment berming should be of sufficient size 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 small collection basin should be provided for removal of storm water and leaked material.

Curbing is used to route spill material to a large collection basin. The curb should be of sufficient size to safely route a spill from the largest storage tank, rail car, tank truck, or other containment device located inside the possible spill area. A containment device must be provided to safely store the spilled material until removal is possible.

If the capacity of the containment berming or the collection basin are exceeded, a spill control device must be used. The spill control device ideally would convey flow into a portable containment device for removal of the material. However, if material is escaping the berming area through the spill control device, two available means of controlling a spill

are to use sorbents (adsorption and absorption through chemical processes) or gelling agents (physically or chemically gel the spill material; solidification eventually occurs).

Advantages/Disadvantages

General

The spill containment berm is an effective means to prevent spill material from entering surface waters or storm sewer systems. In some cases, the spill material may be collected and recycled. The cost of installation and maintenance will be a function of the type of berm used.

Physical Site Suitability

The spill area must have an impermeable floor (asphalt or concrete) so that contamination of groundwater does not occur. If the existing conditions are insufficient to prevent seepage, an impermeable floor or liner must be installed.

Pollutant Removal

In the event of a spill, a method of removal must be provided, such as application of sorbent materials and the use of a pump or vacuum truck. Any material removed from the spill site must be disposed of according to local, state, and federal standards. Recycling of the spill material may be possible if contact or uptake of foreign material is minimal. Water that collects within the berming due to rainfall or snowmelt must be treated to meet standards before release from the spill area.

4.3 Typical Structural Details

The drawings in this section were taken with permission from the *Urban Storm Drainage Criteria Manual – Volume 3*, and have not been modified from the way they appear in that manual.

Typical Outlet Structure Notes:

1. The details shown are intended to show design concepts. Preparation of final design plans, addressing details of structural adequacy, excavation, foundation preparation, concrete work, reinforcing steel,backfill, metalwork, and appurtenances, including preparation of technical specifications, are the responsibility of the design engineer.

2. Alternate designs to the typical outlet structures shown may be considered; however, alternate designs must address the hydraulic and trash handling functional elements of the structures shown in the *Manual*.

3. Wingwalls shown are intended to enable the structure to be backfilled to be flush with the side slopes of the basin, which is the recommended geometry. Other geometries may be considered if their designs related to public safety, aesthetics, maintainability, and function are equal to or better than the designs shown in the *Manual*.

4. Permanent Water Surface shown refers to micro–pool for Extended Detention Basin or permanent pool for Constructed Wetland Basin or Retention Pond.

5. An orifice plate is shown as the outflow control; however, an upturned pipe, with orifices may also be used. See Figure 4 for orifice design information.

6. A Vertical Trash Rack option is generally shown; however, an Adverse–Slope Trash Rack may also be used. Continuous–Slope Trash Racks for use with WQCV outlets are not recommended. See figure 6 for trash rack design information.

7. References are made to 2– or 10–year detention above the WQCV; however, detention above the WQCV may be sized for any storm event, according to local criteria.

8. The underdrain, including a shutoff valve, from the perimeter of the pond is required for a Wetland Basin and a Retention Pond. An underdrain, without a shutoff valve, is optional for the micro–pool and may be used to help dry the micro–pool during dry–weather periods.

9. When outlet designs differ from those shown herein:

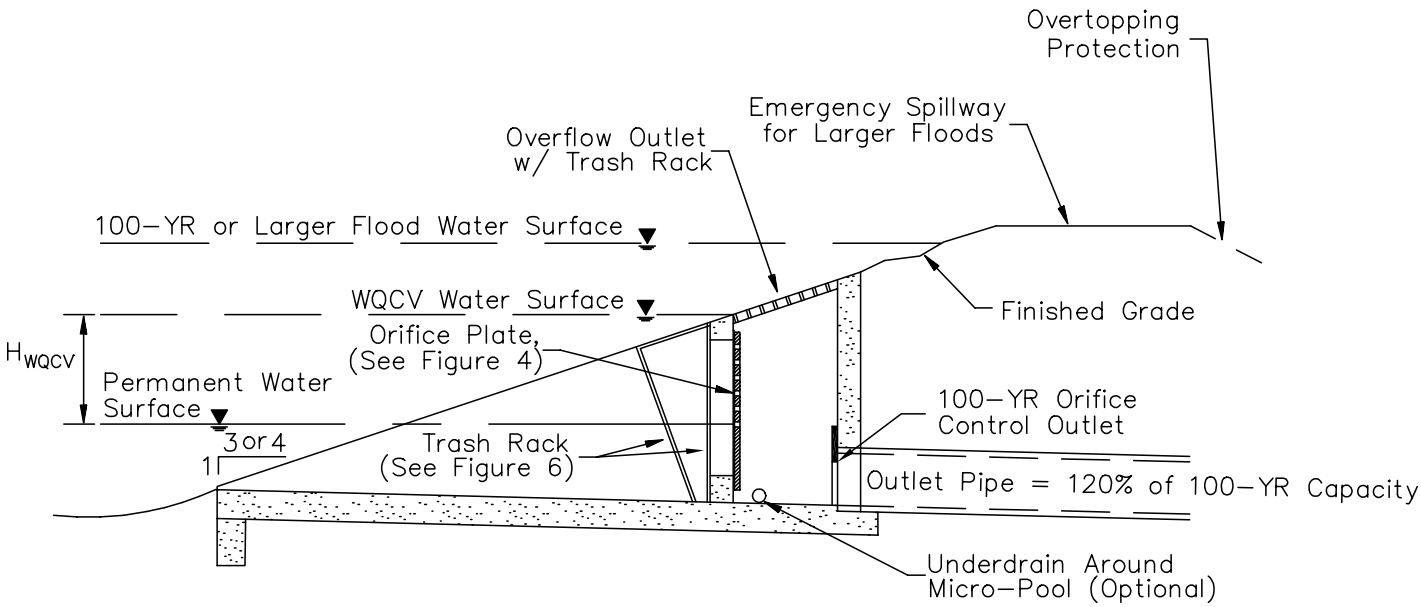
   a) Provide needed orifices that are distributed over the vertical height of the WQCV, with the lowest orifice located at 2'–6" or more above the bottom of the micro–pool.

   b) Provide full hydraulic calculations demonstrating that the outlet will provide no less than the minimum required drain time of the Water Quality Capture Volume for the BMP type being designed.

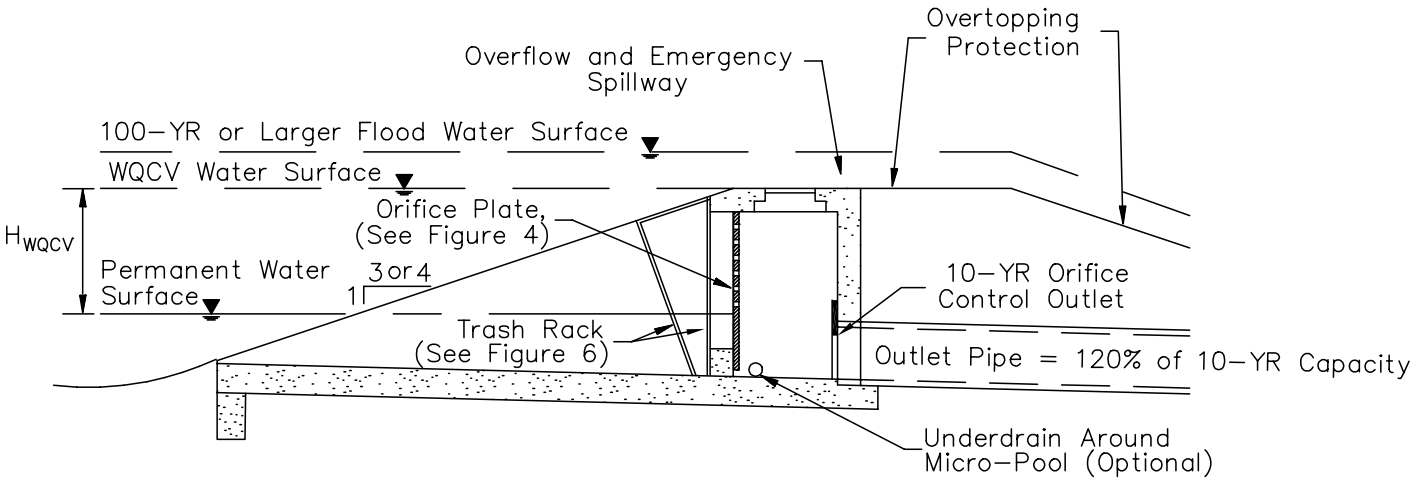
   c) All outlet openings (i.e., orifices) shall be protected by a trash rack sized to provide a minimum net opening area called for by Figure 7, and all trash rack opening dimensions shall be smaller than the smallest dimension of the outlet orifices.

   d) Trash racks shall be manufactured from stainless steel or aluminum alloy structurally designed to not fail under a full hydrostatic load on the upstream side.

Note: Size 2– through 100–year overflow trash racks with the aid of figure 7.

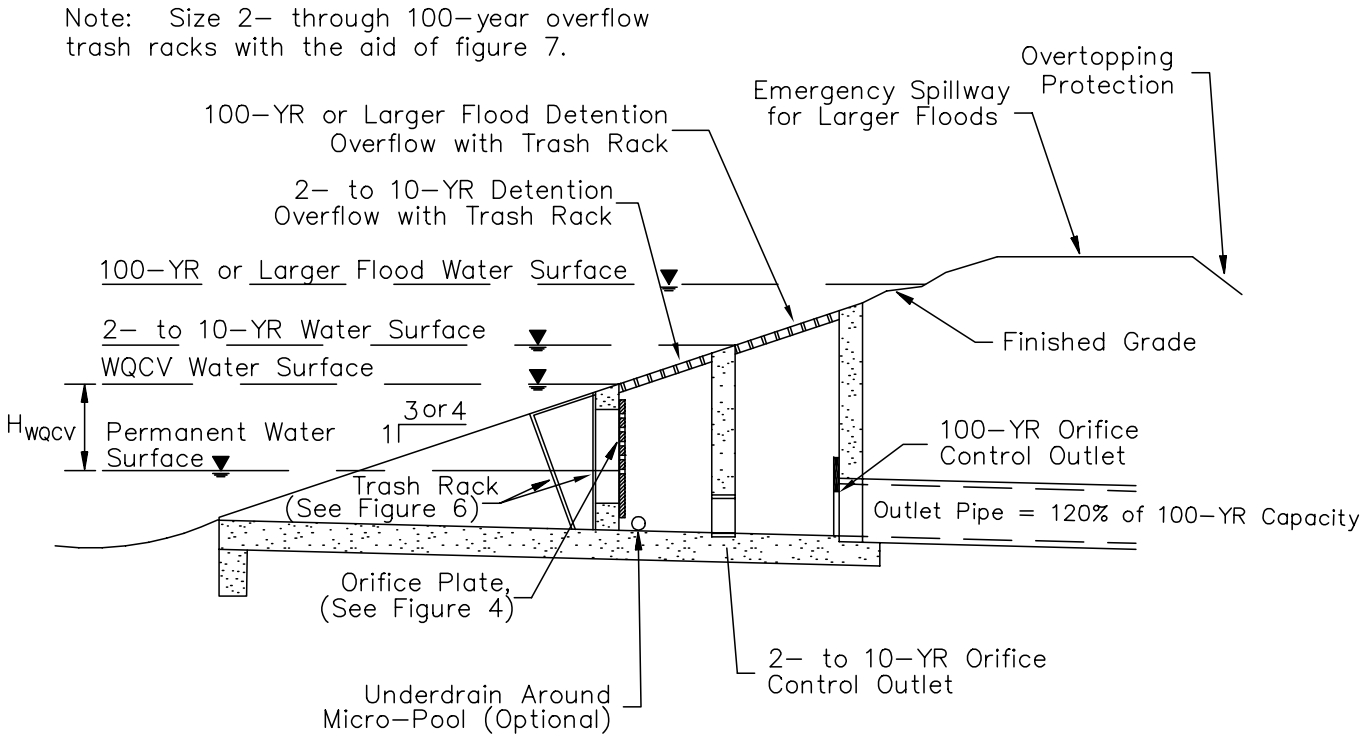


Drop Box Outlet Option

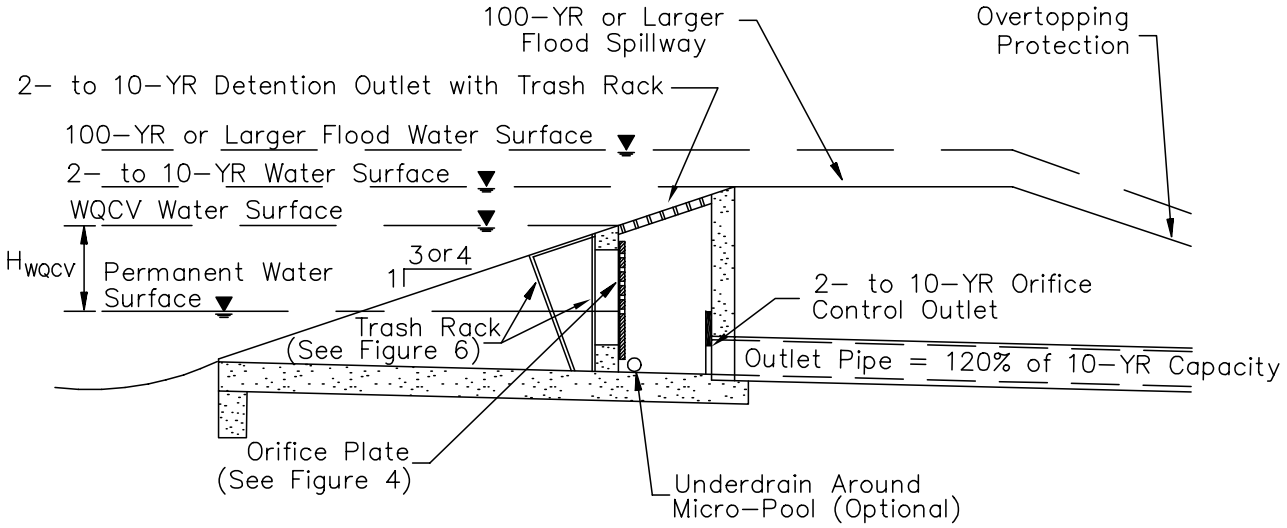


Overtopping Spillway Option

Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 1 Typical WQCV Outlet Structure Profiles Including 100–Year Detention



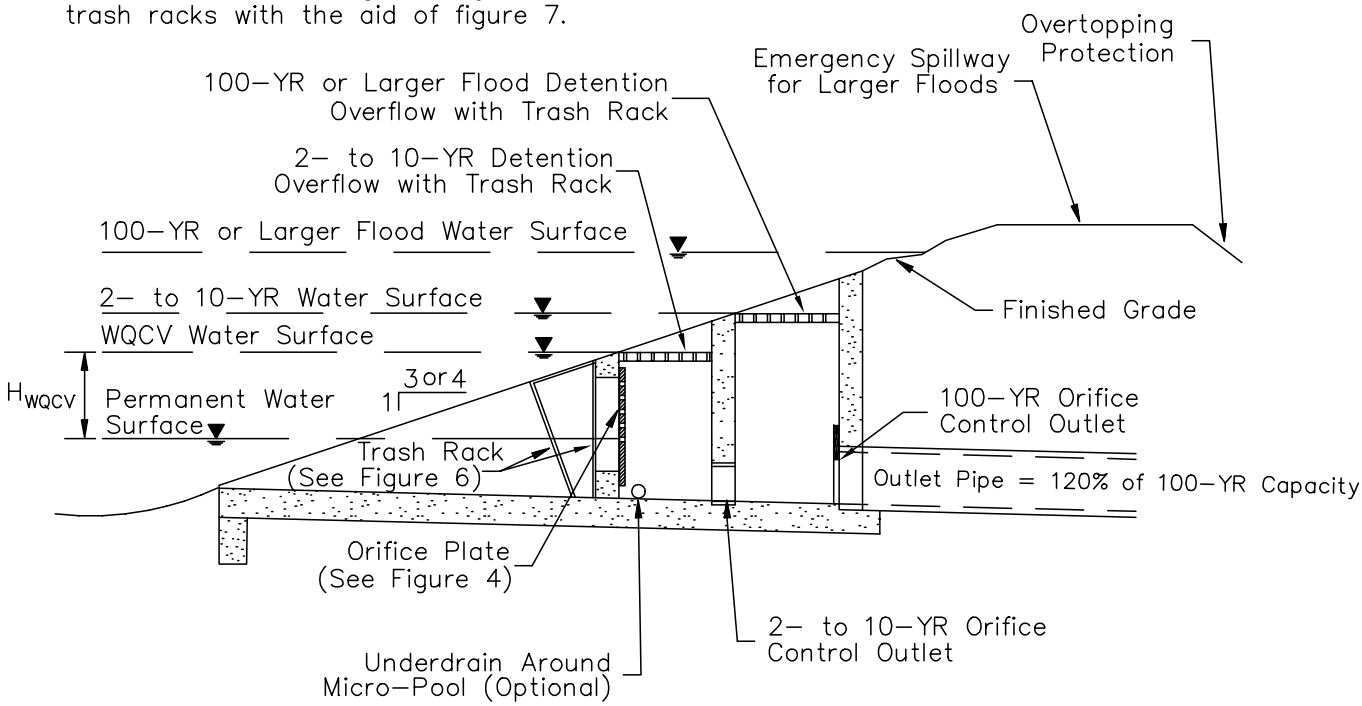
Drop Box Outlet Option



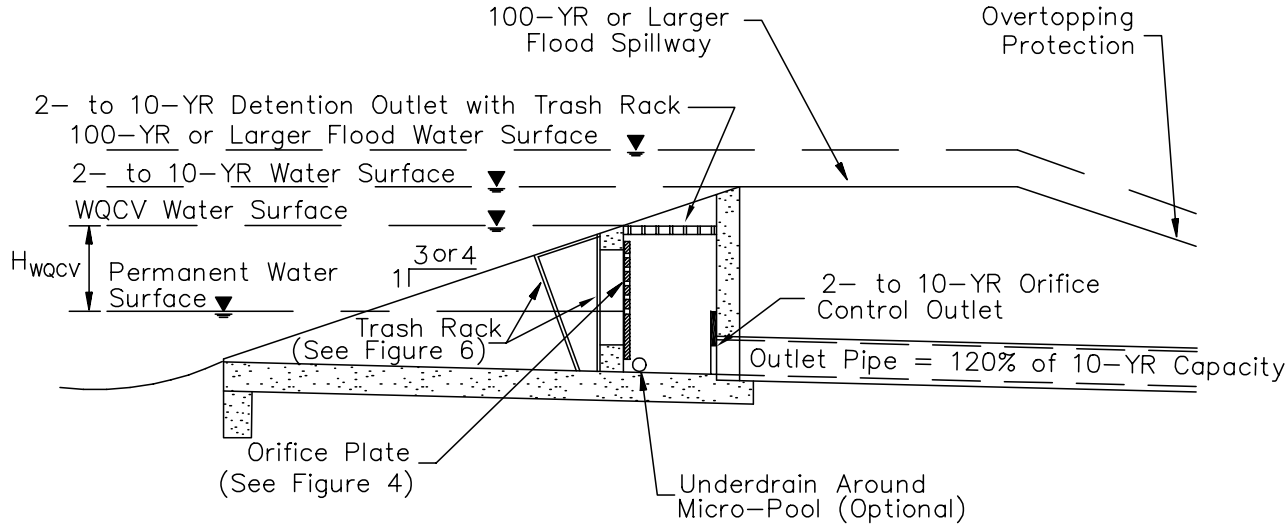
Overtopping Spillway Option

Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 2 Typical WQCV Outlet Structure Profiles Including 2– to 10–Year and 100–Year Detention

Note: Size 2– through 100–year overflow trash racks with the aid of figure 7.

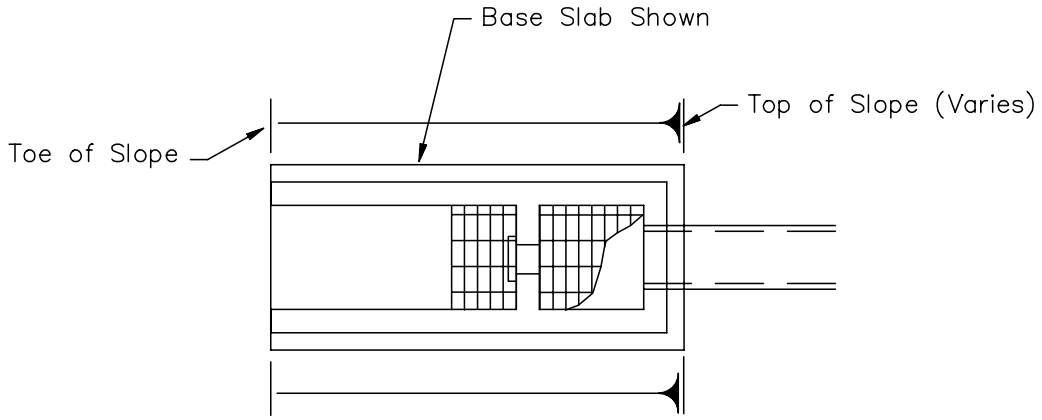


Drop Box Outlet Option

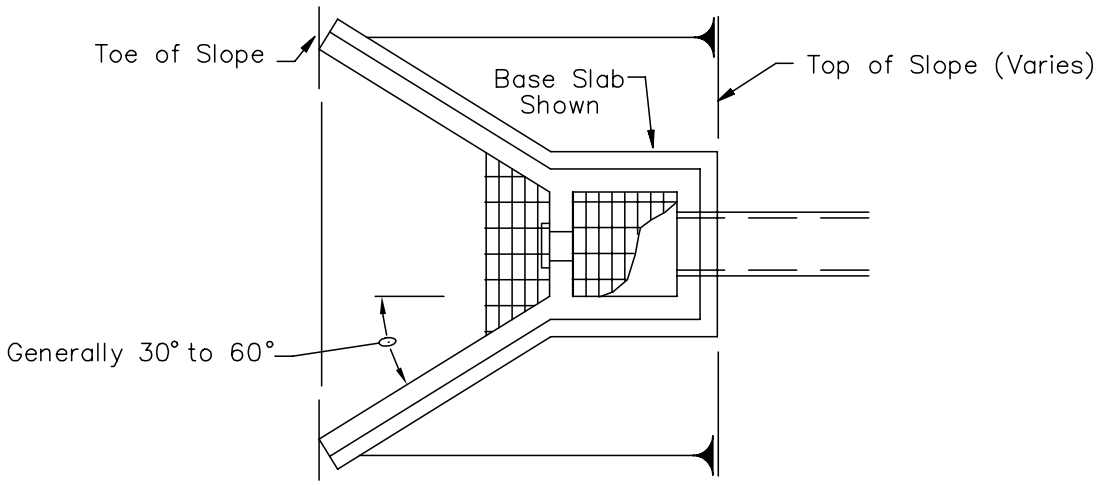


Overtopping Spillway Option

Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 2–a Alternate Typical WQCV Outlet Structure Profiles Including 2– to 10–Year and 100–Year Detention



Plan View—Straight Wingwall Option

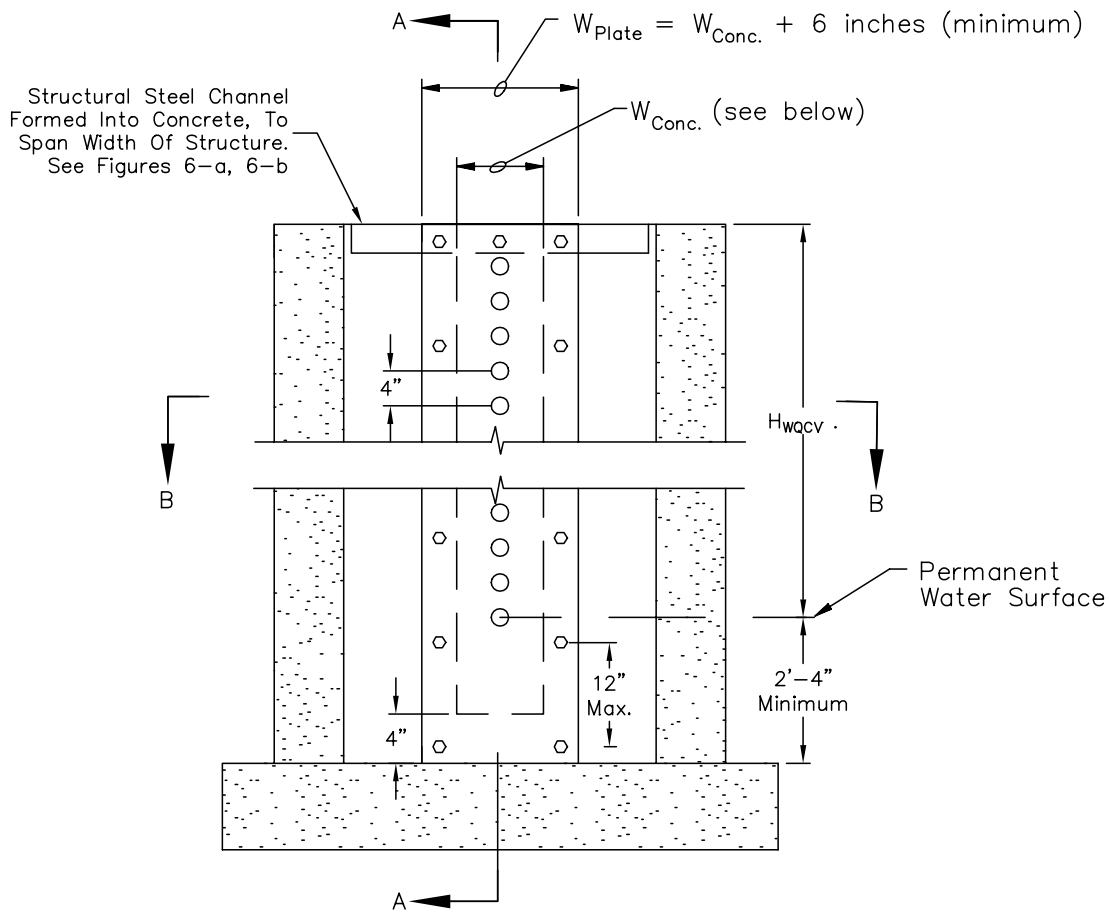


For either a Vertical or Adverse—Slope Trash Rack
a handrail may be required.

Plan View—Flared Wingwall Option

Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 3 Typical WQCV Outlet Structure Wingwall Configurations

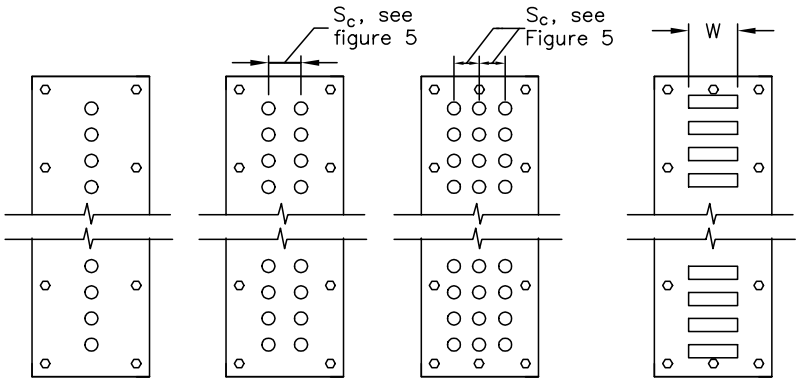
Orifice Perforation Details



Circular Openings: $W_{Conc.}$ Obtained From Table 6a–1

Rectangular Openings: $W_{Conc.}$ = (Width of Rectangular Perforation W) + 12"

Rectangular Openings: $W_{Opening}$ (see Figure 6–b) Obtained From Table 6b–1



Example Perforation Patterns

Note: The goal in designing the outlet is to minimize the number of columns of perforations that will drain the WQCV in the desired time. Do not, however, increase the diameter of circular perforations or the height of the rectangular perforations beyond 2 inches. Use the allowed perforation shapes and configurations shown above along with Figure 5 to determine the pattern that provides an area per row closest to that required without exceeding it.

Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 4 Orifice Details for Draining WQCV

Orifice Plate Perforation Sizing

Circular Perforation Sizing

Chart may be applied to orifice plate or vertical pipe outlet.

Hole Dia (in) *	Hole Dia (in)	Min. S_c (in)	Area per Row (sq in)		
			n=1	n=2	n=3
1/4	0.250	1	0.05	0.10	0.15
5/16	0.313	2	0.08	0.15	0.23
3/8	0.375	2	0.11	0.22	0.33
7/16	0.438	2	0.15	0.30	0.45
1/2	0.500	2	0.20	0.39	0.59
9/16	0.563	3	0.25	0.50	0.75
5/8	0.625	3	0.31	0.61	0.92
11/16	0.688	3	0.37	0.74	1.11
3/4	0.750	3	0.44	0.88	1.33
13/16	0.813	3	0.52	1.04	1.56
7/8	0.875	3	0.60	1.20	1.80
15/16	0.938	3	0.69	1.38	2.07
1	1.000	4	0.79	1.57	2.36
1 1/16	1.063	4	0.89	1.77	2.66
1 1/8	1.125	4	0.99	1.99	2.98
1 3/16	1.188	4	1.11	2.22	3.32
1 1/4	1.250	4	1.23	2.45	3.68
1 5/16	1.313	4	1.35	2.71	4.06
1 3/8	1.375	4	1.48	2.97	4.45
1 7/16	1.438	4	1.62	3.25	4.87
1 1/2	1.500	4	1.77	3.53	5.30
1 9/16	1.563	4	1.92	3.83	5.75
1 5/8	1.625	4	2.07	4.15	6.22
1 11/16	1.688	4	2.24	4.47	6.71
1 3/4	1.750	4	2.41	4.81	7.22
1 13/16	1.813	4	2.58	5.16	7.74
1 7/8	1.875	4	2.76	5.52	8.28
1 15/16	1.938	4	2.95	5.90	8.84
2	2.000	4	3.14	6.28	9.42
n = Number of columns of perforations					
Minimum steel plate thickness			1/4 "	5/16 "	3/8 "

* Designer may interpolate to the nearest 32nd inch to better match the required area, if desired.

Rectangular Perforation Sizing

Only one column of rectangular perforations allowed.

Rectangular Height = 2 inches

$$\text{Rectangular Width (inches)} = \frac{\text{Required Area per Row (sq in)}}{2''}$$

Rectangular Hole Width	Min. Steel Thickness
5"	1/4 "
6"	1/4 "
7"	5/32 "
8"	5/16 "
9"	11/32 "
10"	3/8 "
>10"	1/2 "

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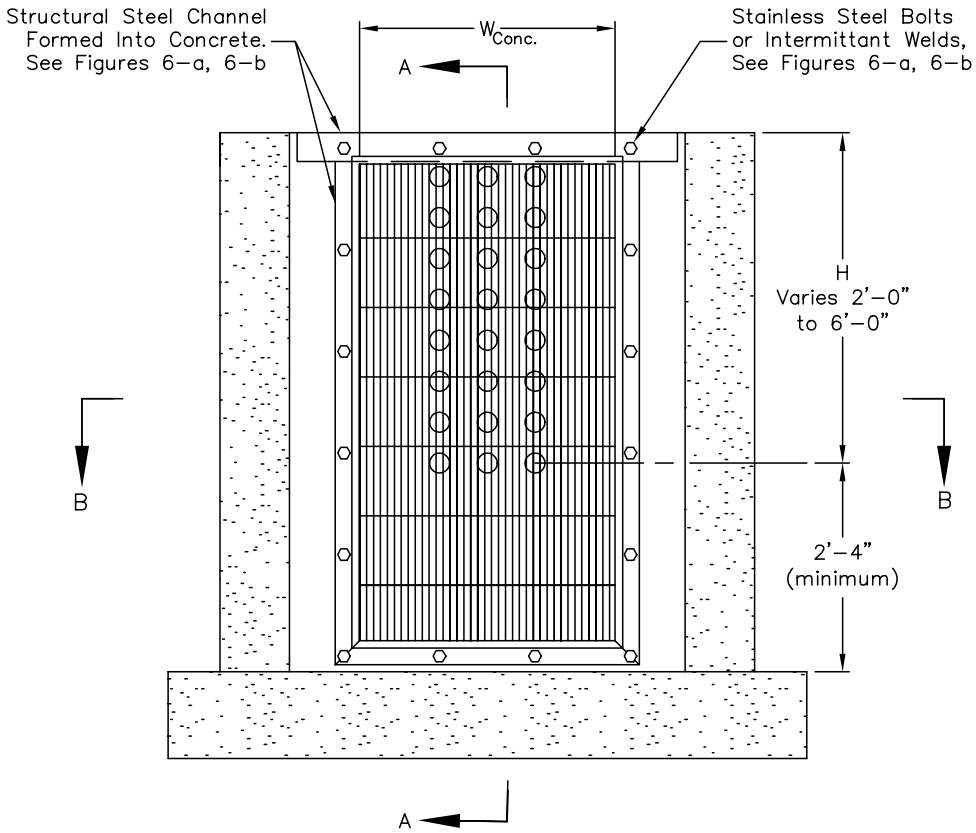
Figure 5

WQCV Outlet Orifice Perforation Sizing

Note: Vertical WQCV Trash Racks are shown in Figures 6, 6–a, and 6–b for suggested standardized outlet design. Adverse–Slope Trash Rack design may be used for non–standardized designs, but must meet minimum design criteria.



Elevation

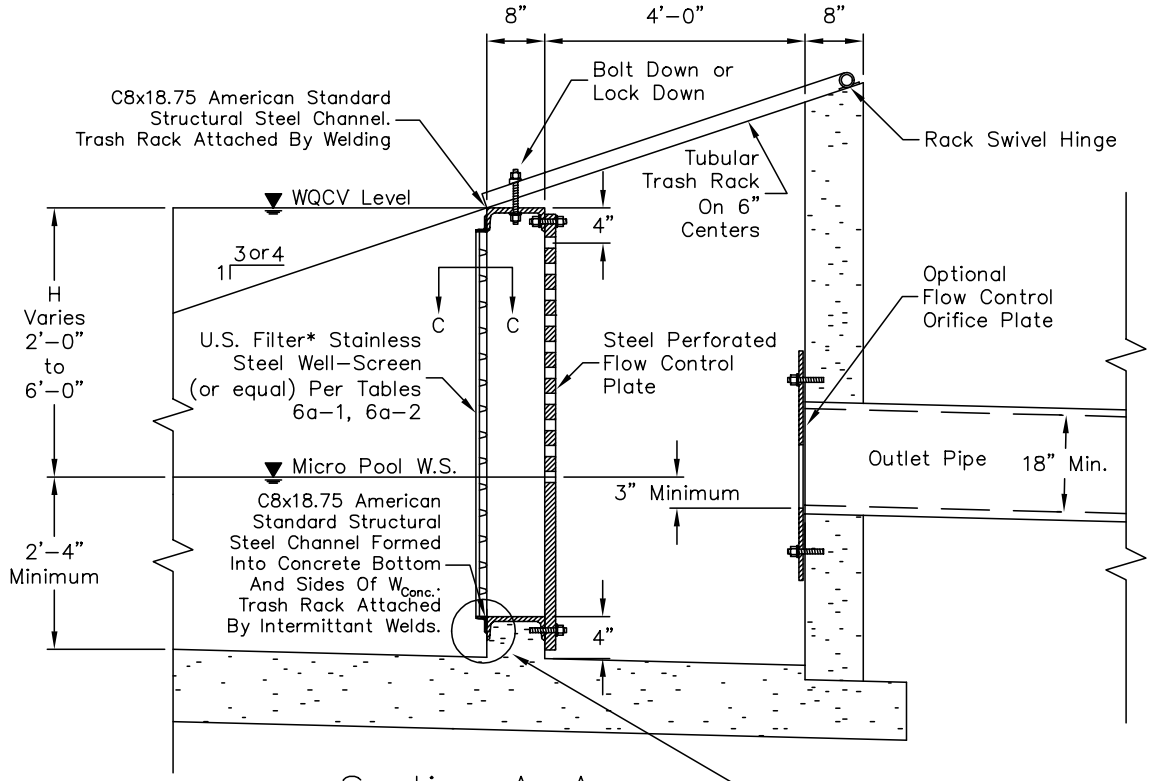
WQCV Trash Racks:

1. Well–screen trash racks shall be stainless steel and shall be attached by intermittant welds along the edge of the mounting frame.
2. Bar grate trash racks shall be aluminum and shall be bolted using stainless steel hardware.
3. Trash Rack widths are for specified trash rack material. Finer well–screen or mesh size than specified is acceptable, however, trash rack dimensions need to be adjusted for materials having a different open area/gross area ratio (R value)
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

Overflow Trash Racks:

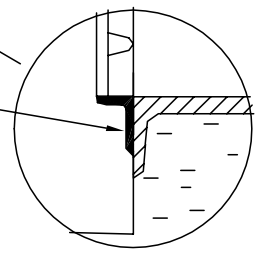
1. All trash racks shall be mounted using stainless steel hardware and provided with hinged and lockable or boltable access panels.
2. Trash racks shall be stainless steel, aluminum, or steel. Steel trash racks shall be hot dip galvanized and may be hot powder painted after galvanizing.
3. Trash Racks shall be designed such that the diagonal dimension of each opening is smaller than the diameter of the outlet pipe.
4. Structural design of trash rack shall be based on full hydrostatic head with zero head downstream of the rack.

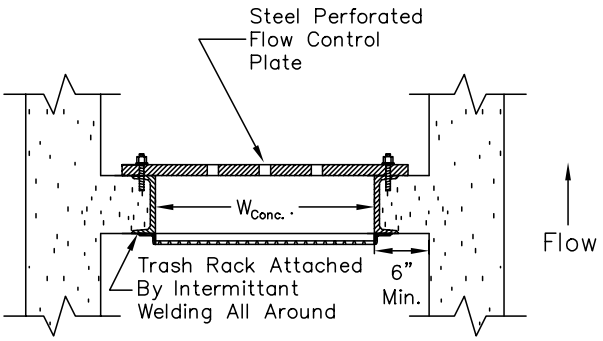
Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 6 Suggested WQCV Outlet Standardized Trash Rack Design



Section A–A

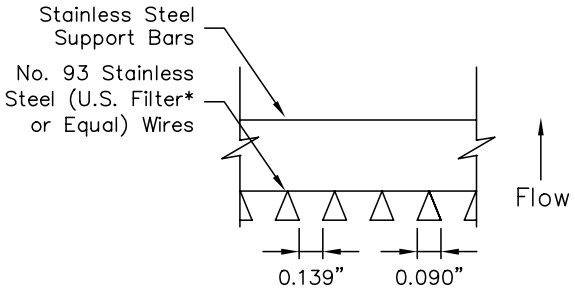
From Figure 6, Circular Openings Only





Section B–B – Plan View

From Figure 6, Circular Openings Only



Section C–C

From Figure 6, Circular Openings Only

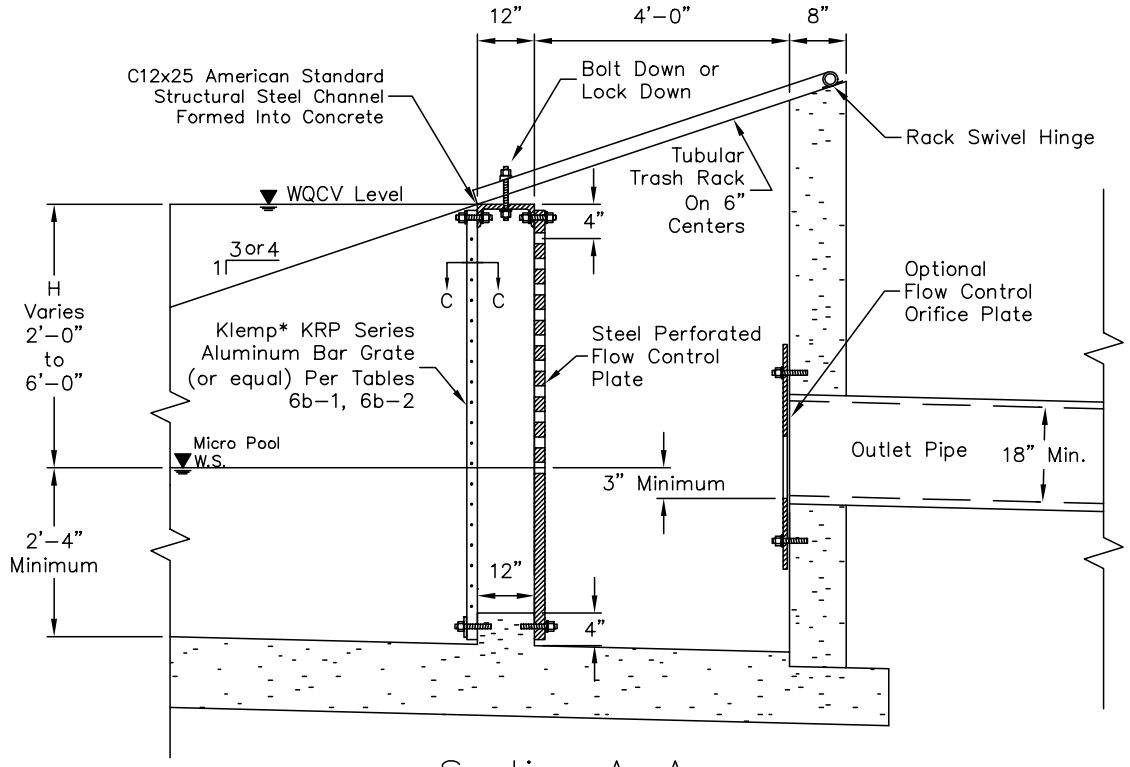
R Value = (net open area)/(gross rack area)
= 0.60

Limits for this Standardized Design:

1. All outlet plate openings are circular.
2. Maximum diameter of opening = 2 inches.

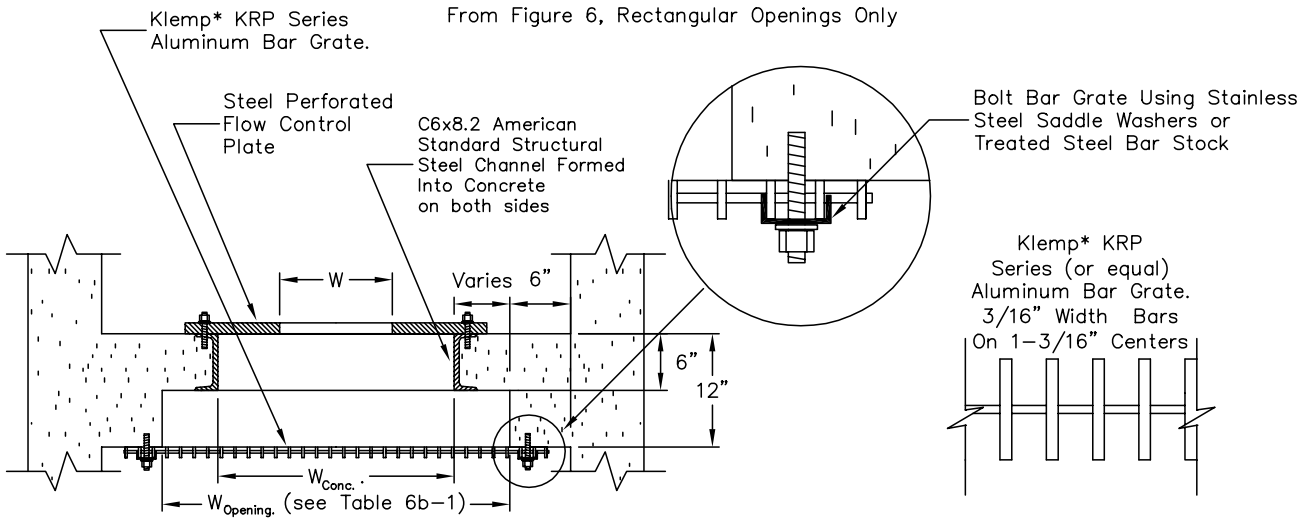
*U.S. Filter, St. Paul, Minnesota, USA

Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 6–a Suggested Standardardized Trash Rack and Outlet Design For WQCV Outlets With Circular Openings



Section A–A

From Figure 6, Rectangular Openings Only



Section B–B – Plan View

From Figure 6, Rectangular Openings Only

Section C–C

From Figure 6, Rectangular Openings Only

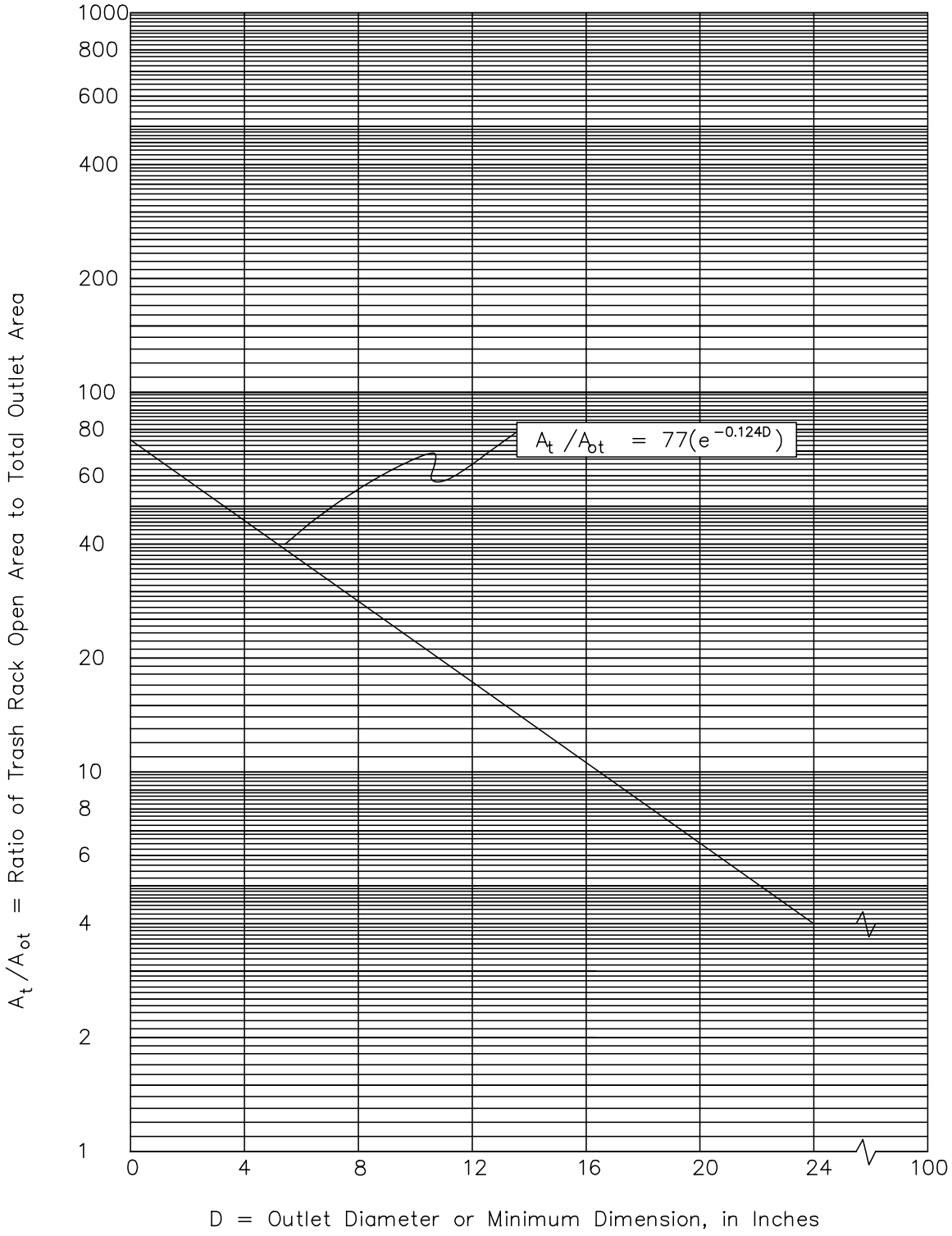
Limits for this Standardized Design:

1. All outlet plate openings are rectangular.
2. Height of all rectangular openings = 2 inches.
3. For trash rack opening width ($W_{Opening}$), see Table 6b–1
4. Concrete opening for outlet plate ($W_{Conc.}$) = W + 12 inches

R Value = (net open area)/(gross rack area)
= 0.71 for cross rods on 2" centers
= 0.77 for cross rods on 4" centers

*Klemp Corporation, Orem, Utah, USA

Urban Drainage and Flood Control District Drainage Criteria Manual (V.3) File: Details.dwg	Figure 6–b Suggested Standardardized Trash Rack and Outlet Design For WQCV Outlets With Rectangular Openings



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File: Details.dwg

Figure 7

Minimum Trash Rack Open
Area – Extended Range

Table 6a-1: Standardized WQCV Outlet Design Using 2" Diameter Circular Openings.
Minimum Width ($W_{conc.}$) of Concrete Opening for a Well-Screen-Type Trash Rack.
See Figure 6-a for Explanation of Terms.

Maximum Dia. of Circular Opening (inches)	Width of Trash Rack Opening ($W_{conc.}$) Per Column of Holes as a Function of Water Depth H					
	H=2.0'	H=3.0'	H=4.0'	H=5.0'	H=6.0'	Maximum Number of Columns
≤ 0.25	3 in.	3 in.	3 in.	3 in.	3 in.	14
≤ 0.50	3 in.	3 in.	3 in.	3 in.	3 in.	14
≤ 0.75	3 in.	6 in.	6 in.	6 in.	6 in.	7
≤ 1.00	6 in.	9 in.	9 in.	9 in.	9 in.	4
≤ 1.25	9 in.	12 in.	12 in.	12 in.	15 in.	2
≤ 1.50	12 in.	15 in.	18 in.	18 in.	18 in.	2
≤ 1.75	18 in.	21 in.	21 in.	24 in.	24 in.	1
≤ 2.00	21 in.	24 in.	27 in.	30 in.	30 in.	1

Table 6a-2: Standardized WQCV Outlet Design Using 2" Diameter Circular Openings.
US Filter™ Stainless Steel Well-Screen[1] (or equal) Trash Rack Design Specifications.

Max. Width of Opening	Screen #93 VEE Wire Slot Opening	Support Rod Type	Support Rod, On-Center, Spacing	Total Screen Thickness	Carbon Steel Frame Type
9"	0.139	#156 VEE	¾"	0.31'	3/8"x1.0"flat bar
18"	0.139	TE .074"x.50"	1"	0.655	¾" x 1.0 angle
24"	0.139	TE .074"x.75"	1"	1.03"	1.0" x 1½" angle
27"	0.139	TE .074"x.75"	1"	1.03"	1.0" x 1½" angle
30"	0.139	TE .074"x1.0"	1"	1.155"	1 1/4"x 1½" angle
36"	0.139	TE .074"x1.0"	1"	1.155"	1 1/4"x 1½" angle
42"	0.139	TE .105"x1.0"	1"	1.155"	1 1/4"x 1½" angle

[1] US Filter, St. Paul, Minnesota, USA

DESIGN EXAMPLE:

Given: A WQCV outlet with three columns of 5/8 inch (0.625 in) diameter openings.
Water Depth H above the lowest opening of 3.5 feet.

Find: The dimensions for a well screen trash rack within the mounting frame.

Solution: From Table 6a-1 with an outlet opening diameter of 0.75 inches (i.e., rounded up from 5/8 inch actual diameter of the opening) and the Water Depth H = 4 feet (i.e., rounded up from 3.5 feet). The minimum width for each column of openings is 6 inches. Thus, the total width is $W_{conc.}$ = 3•6 = 18 inches. The total height, after adding the 2 feet below the lowest row of openings, and subtracting 2 inches for the flange of the top support channel, is 64 inches. Thus, Trash rack dimensions within the mounting frame = 18 inches wide x 64 inches high

From Table 6a-2 select the ordering specifications for an 18", or less, wide opening trash rack using US Filter (or equal) stainless steel well-screen with #93 VEE wire, 0.139" openings between wires, TE 074" x 50" support rods on 1.0" on-center spacing, total rack thickness of 0.655" and ¾" x 1.0" welded carbon steel frame.

Table 6b-1: Standardized WQCV Outlet Design Using 2" Height Rectangular Openings.
Minimum Width ($W_{opening}$) of Opening for an Aluminum Bar Grate Trash Rack.
See Figure 6-b for Explanation of Terms.

Maximum Width W of 2" Height Rectangular Opening (inches)	Minimum Width of Trash Rack Opening ($W_{opening}$) as a Function of Water Depth H					
	H=2.0 ft.	H=3.0 ft.	H=4.0 ft.	H=5.0 ft.	H=6.0 ft.	Spacing of Bearing Bars, Cross Rods
≤ 2.0	2.0 ft.	2.5 ft.	2.5 ft.	2.5 ft.	3.0 ft.	1-3/16", 2"
≤ 2.5	2.5 ft.	3.0 ft.	3.0 ft.	3.5 ft.	3.5 ft.	1-3/16", 2"
≤ 3.0	3.0 ft.	3.5 ft.	3.5 ft.	4.0 ft.	4.0 ft.	1-3/16", 2"
≤ 3.5	3.5 ft.	4.0 ft.	4.5 ft.	4.5 ft.	5.0 ft.	1-3/16", 2"
≤ 4.0	3.5 ft.	4.5 ft.	5.0 ft.	5.0 ft.	5.5 ft.	1-3/16", 2"
≤ 4.5	4.0 ft.	4.5 ft.	5.0 ft.	5.5 ft.	5.5 ft.	1-3/16", 4"
≤ 5.0	4.0 ft.	5.0 ft.	5.5 ft.	6.0 ft.	6.0 ft.	1-3/16", 4"
≤ 5.5	4.5 ft.	5.5 ft.	6.0 ft.	6.5 ft.	7.0 ft.	1-3/16", 4"
≤ 6.0	5.0 ft.	6.0 ft.	6.5 ft.	7.0 ft.	7.5 ft.	1-3/16", 4"
≤ 6.5	5.5 ft.	6.5 ft.	7.0 ft.	7.5 ft.	8.0 ft.	1-3/16", 4"
≤ 7.0	6.0 ft.	7.0 ft.	7.5 ft.	8.5 ft.	8.5 ft.	1-3/16", 4"
≤ 7.5	6.0 ft.	7.5 ft.	8.5 ft.	9.0 ft.	9.5 ft.	1-3/16", 4"
≤ 8.0	6.5 ft.	8.0 ft.	9.0 ft.	9.5 ft.	10.0 ft.	1-3/16", 4"
≤ 8.5	7.0 ft.	8.5 ft.	9.5 ft.	10.0 ft.	N/A	1-3/16", 4"
≤ 9.0	7.5 ft.	9.0 ft.	10.0 ft.	N/A	N/A	1-3/16", 4"
≤ 9.5	8.0 ft.	9.5 ft.	N/A	N/A	N/A	1-3/16", 4"
≤ 10.0	8.5 ft.	10.0 ft.	N/A	N/A	N/A	1-3/16", 4"
≤ 10.5	8.5 ft.	N/A	N/A	N/A	N/A	1-3/16", 4"
≤ 11.0	9.0 ft.	N/A	N/A	N/A	N/A	1-3/16", 4"
≤ 11.5	9.5 ft.	N/A	N/A	N/A	N/A	1-3/16", 4"
≤ 12.0	10.0 ft.	N/A	N/A	N/A	N/A	1-3/16", 4"

Table 6b-2: Standardized WQCV Outlet Design Using 2" Height Rectangular Openings.
Klemp™ KRP Series Aluminum Bar Grate[1] (or equal) Trash Rack Design Specifications.

Water Depth Above Lowest Opening, H	Minimum Bearing Bar Size, Bearing 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"

[1] Klemp Corporation, Orem, Utah, USA

DESIGN EXAMPLE:

Given: A WQCV outlet with 2" height by 6.5" width openings.
Water Depth H above the lowest opening of 4.5 feet.

Find: The dimensions for an aluminum bar grate trash rack.

Solution: Using Table 6b-1for openings having a width of 6.5 inches and Water Depth H = 5 feet (i.e., rounded up from 4.5 feet). The minimum width is 7'-6". The net height, after accounting for the 2 feet below the lowest opening, is 6'-6". An additional 6" must be added to the width and an additional 4" to the height to allow for mounting hardware. Thus,

Trash rack dimensions = 8'-0" wide by 6'-10" high

Note also from Table 6b-1, that for orifice plate rectangular openings wider than 4", cross rod spacing of 4" is allowed.

From Table 6b-2, select the ordering specifications for H = 5.0 feet or less, a 8.0' wide by 6'-10" high trash rack using Klemp Corporation aluminum bar grate (or equal) with 2" by 3/16" bearing bars spaced 1-3/16" on-center, cross rods spaced 4" on-center. **Bearing bars are to be aligned vertically.**

4.4 Procedures for Assessment of Structural Controls for Retrofitting Water Quality Features

The CDPS Municipal Stormwater Discharge Permit for the City states,

> *"Existing structural control projects shall be evaluated to determine if retrofitting the structure to provide for additional pollutant removal from stormwater is feasible."*

1. The permittee shall develop procedures to be used in evaluating existing structural controls. The evaluation procedures shall be complete within 36 months of the permit effective date, and a report on this submitted to the Division.
2. Existing structural controls shall be evaluated for potential retrofitting of the structure to provide additional pollutant removal from stormwater in conjunction with developing each new DBPS [Drainage Basin Planning Study]."

The purpose of this document is to outline the procedures for these evaluations. These procedures would then be utilized in conjunction with developing each new DBPS to determine the potential and feasibility for retrofitting existing structural controls (detention/retention basins).

The analysis of the structures involves three possible levels of review. The first is a qualitative review to determine if retrofitting of the structure is acceptable. The second element is quantitative to determine the pollutant removal effectiveness of the structure, both with and without water quality elements. Total Suspended Solids (TSS) will normally be the only constituent evaluated, unless other pollutants of concern are specified by City Engineering, based on site-specific information. A third element of review involves developing a cost estimate for retrofitting to determine the economic feasibility.

A qualitative assessment evaluates the changes that would occur if the flood-control detention facility was modified for water quality purposes, and determines the extent to which the changes would affect these functions, and if these changes in function are acceptable. The detention pond must first be acceptable under the qualitative criteria, or the evaluation will conclude and not continue to the second level of review. A quantitative analysis involves a determination of whether the percent removal of TSS (or other specified constituent of concern) is significant. For purposes of this assessment, a significant change is defined as the percent removal of the constituent after retrofitting the detention pond is estimated to be at least 20 percent greater than the percent removal of the constituent for the detention pond without the water quality element incorporated. If a significant change is estimated, then the third element of analysis, a cost estimate of the economic feasibility, is conducted. If a significant change is not estimated, then the option to retrofit the detention pond is eliminated.

Retrofit Screening – Qualitative Criteria

Qualitative criteria were developed based on the functions and operations of the existing structural controls. The criteria are:

1. Are there any environmental concerns associated with the retrofitting of the structure? If so, can the concerns be mitigated cost effectively. (Examples of this include the filling in or destroying of wetlands, habitat alteration or elimination, disturbance of contaminated sediment.) Items that would result in an immediate determination of an infeasible retrofit, would include a determination that modifications would impact a threatened or endangered species or that mitigation measures would be more costly than construction of the water quality improvements.

2. Is there a history of maintenance or operational problems with the structure? Can equipment access the site? Examples would include frequent sediment removal or overtopping of the structure. If the basin is not functioning properly, the inclusion of water quality elements could result in little or no effect or even aggravate the situation. A pond with operational problems is not a good candidate for retrofitting. Such retrofitting would be considered infeasible.

3. Can the structure be modified without compromising the flood control function of the structure? It is still important to have the ability to detain the required size storms. The question is whether there is sufficient additional capacity to include detention for storm water quality or if cost effective modifications can be made to incorporate water quality elements and still meet flood control requirements. Retrofitting which compromises its flood protection capabilities would be considered infeasible.

4. Are hazards created by retrofitting the structure? It is important to ensure that the addition of volume to the pond or standing water will not present an unacceptable risk or safety hazard. Examples of risks and hazards to be analyzed include steepness of slopes, depth of standing waters, or adequacy of overflow/outlet/inlet devices.

5. Will the modifications be acceptable to the community? Will the inclusion of the water quality elements eliminate the dual use of a basin for recreational purposes such as a baseball or football field? Are there unacceptable aesthetic or nuisance conditions that will occur? Will the facility "fit" with the location? Will the modifications result in an increase in the presence of mosquitoes or other undesirable insects? Public input on these issues will be necessary during the Drainage Basin Planning Study process and used as a part of the decision-making process.

6. Will future plans for development be impacted? Will the modifications result in the inability of a nearby landowner to develop his land?

7. Are there any effects on water rights that would preclude retrofitting? Incorporation of water quality elements usually results in the longer containment of waters and water loss due to infiltration or evaporation. A pond which affects water rights is not a good candidate for retrofitting. Retrofitting would be considered infeasible.

For each of these items it will need to be determined whether there is a problem, and if so, can it be mitigated. If any one of the above concerns can not be mitigated then the structure is considered not to be feasible for retrofitting and the evaluation will end.

Quantitative Assessment

The second stage of the process is to evaluate the effectiveness of the modifications. This involves the review of the current pollutant removal capacities of the structure compared to the increase in removal from the addition of water quality elements. One procedure for conducting the quantitative analysis is provided below. Other methods and procedures are available or likely to be improved on in the future. Such assessment methods and procedures may be used if adequate documentation of procedures and reliability is provided and accepted by the City. This flexibility will allow for improvements to be made to the assessment procedures as conditions and technical enhancements change in the future.

1. Determine the expected runoff quality. This is done by looking at the land uses in the watershed, determining the approximate acreage dedicated to the different uses, and obtaining a weighted average. Unless specific information is available on the quality of the runoff, the following default concentrations can be used for TSS. This data resulted from wet weather monitoring conducted by the City of Colorado Springs as part of its Municipal Stormwater Discharge Permit Application.

   - Industrial Land Use 408 mg/L
   - Commercial Land Use 565 mg/L
   - Residential Land Uses 472 mg/L
   - Rural Land Uses 400 mg/L

2. Calculate the removal efficiencies expected from the existing detention pond. The following equation should be used.

$$E_c = (k_t * k_d * E_I) * (1 - r_{pf})$$

Where:

E_c = average annual constituent's event mean concentration (EMC) downstream of the facility, mg/L

E_I = average annual constituent's EMC in the runoff inflow to the system, mg/L

r_{pf} = fraction of the average annual runoff volume from the watershed that flows through the basin. It is equal to the Volume of the basin (VB)/ mean storm runoff volume (VR). VR = V*R_v*Area* 3630 where V is the mean storm event in inches, R_v is the runoff coefficient and the Area is that which is tributary to the basin in acres.

k_d = fraction of the original constituent in the runoff that remains in the overflow water. This value is based on actual monitoring data where available. In lieu of actual data, a value of 0.3 to 0.5 should be used. These values are based on literature.

k_t = coefficient of the report constituent EMC that represents the "post-first-flush" fraction of the average EMC in stormwater runoff. This value is usually based on a review of monitoring data. In lieu of actual data a literature value of 0.7 to 0.9 is recommended.

The percent removal to be expected is:

$$\% \text{ Removal} = [(E_I - E_c)/E_I]*100$$

It should be noted that if the pond size exceeds the mean storm event volume, VB/VR > 1, then the pond retains the storm event, since this would be equivalent to 100 percent removal of the pollutant and retrofitting the pond is not desired.

3. Calculate the removal efficiencies from the pond with the desired water quality element incorporated. One of the following equations should be used depending on whether the element is incorporated on- or offline.

For online BMPs: $E_c = (k_t*k_d* E_I)*(1-r_{pf}) + (E_f * r_{pf})$

For offline BMPs: $E_c = (k_t* E_I)*(1-r_{pf}) + (E_f * r_{pf})$

Where:

E_c = average annual constituent's EMC downstream of the facility, mg/L

E_I = average annual constituent's EMC in the runoff inflow to the system, mg/L

E_f = average annual constituent concentration in the effluent from the water quality element. $E_f = E_I*(1-R_{bmp})$ where R_{bmp} is the value from the following table divided by 100.

TABLE ND-3
BMP Removal Ranges for TSS (%)

BMP	Literature Reported Range (LRR)	Expected Probable Range (EPR)
Grass Buffer	10 – 50	10 – 20
Grass Swale	20 – 60	10 – 40
Extended Detention Basin	50 – 70	55 – 75
Constructed Wetland Basin	40 – 94	50 – 60
Retention Pond	70 – 91	80 – 90
Sand Filter Extended Detention	8 – 96	80 – 90
Constructed Wetland Channel*	20 – 60	30 –50

From Table SQ-6, "*Urban Storm Drainage Criteria Manual* – Volume 3: Best Management Practices", Urban Drainage and Flood Control District, Denver, Colorado, September 1, 1999

LRR – Literature reported range. EPR – expected probable range of annual performance by Volume 3 BMPs.

* Assumes the wetland surface area is equal or greater than 0.5% of the tributary total impervious area.

r_{pf} = fraction of the average annual runoff volume from the watershed that flows through the basin. It is equal to the volume of the basin (VB)/mean storm runoff volume (VR). $VR = V*R_v*Area* 3630$ where V is the mean storm event in inches, R_v is the runoff coefficient and the area is that which is tributary to the basin in acres.

k_d = fraction of the original constituent in the runoff that remains in the overflow water. This value is based on actual monitoring data where available. In lieu of actual data, a value of 0.3 to 0.5 should be used. These values are based on literature.

k_t = coefficient of the report constituent EMC that represents the "post-first-flush" fraction of the average EMC in stormwater runoff. This value is usually based on a review of monitoring data. In lieu of actual data a literature value of 0.7 to 0.9 is recommended.

The percent removal to be expected is:

$$\% \text{ Removal} = [(E_I - E_c)/E_f]*100$$

4. Determine if the increase in % removal is significant. A comparison is made of the % removal anticipated before and after the inclusion of water quality elements. If the estimated percent removed increases in absolute value by greater than 20 percent by incorporating a water quality element, the change is deemed significant (e.g. % removal goes from 55 percent to 76 percent). A cost estimate will then be prepared to determine the economic feasibility of the project. If the change is less than 20 percent, the potential retrofitting is deemed to be impractical. Retrofitting will not be required.

Economic Feasibility

If the qualitative and quantitative analyses result in a potential feasible and practical retrofit, a cost estimate for a retrofitted structural control option will be developed. The cost will be evaluated in conjunction with overall water quality benefits, the level of benefit in relation to the overall area affected by the retrofitted structural control, and other factors. In addition, the economic feasibility should consider other options such as the need for new structural controls that may be able to provide similar overall pollutant removal effectiveness at lower total costs. When comparing a retrofit option vs. a new structural control option, protection of water quality in the intervening stretch between the old and new structural control shall be one factor given consideration.

Final Alternative Selection

The final alternative selection process for drainage improvement options in any new Drainage Basin Planning Study is based on the evaluation of many factors including costs, safety, environmental issues including water quality, public input, etc. If the selected alternative includes retrofitting structural controls to provide additional pollutant removal, responsibility for implementation would need to be outlined in the study. If the responsibility was determined to be a public (City) responsibility, consideration for funding any such drainage improvement project would be made by the City Council during its annual budget approval process in conjunction with all other budget requests. If the responsibility was determined to be a private development responsibility, City Engineering would decide when implementation would be required in conjunction with the timing of future developments

Appendix A New Development Design Forms

ATTENTION TO PERSONS USING THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT SUPPLIED DESIGN FORM WORKSHEETS

The Design Form Worksheets with the accompanying Visual Basic macros have been developed using a high standard of care, including professional review for identification of errors, bugs, and other problems related to the software. Minor modifications have been made by the City of Colorado Springs. However, as with any initial release of software driven products, it is likely that some nonconformities, defects, bugs, and errors with the software program will be discovered as they become more widely used. The developers of these products welcome user feedback in helping to identify these potential problems so that improvements can be made to future releases of the Design Form Worksheets.

The Design Form Worksheets are intended to streamline the preliminary design process. Preparation of final design plans, addressing details of structural adequacy, public safety, hydraulic functionality, maintainability, and aesthetics, remain the sole responsibility of the designer.

BY THE INSTALLATION AND USE OF THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT SUPPLIED DESIGN FORM WORKSHEETS, AS MODIFIED BY THE CITY OF COLORADO SPRINGS, THE USER AGREES TO THE FOLLOWING:

NO LIABILITY FOR CONSEQUENTIAL DAMAGES

To the maximum extent permitted by applicable law, in no event shall the Urban Drainage and Flood Control District or the City of Colorado Springs, their contractors, advisors, reviewers, or their member governmental agencies, be liable for any incidental, special, punitive, exemplary, or consequential damages whatsoever (including, without limitation, damages for loss of business profits, business interruption, loss of business information or other pecuniary loss) arising out of the use or inability to use these products, even if the Urban Drainage and Flood Control District or the City of Colorado Springs, their contractors, advisors, reviewers, or their member governmental agencies have been advised of the possibility of such damages. In any event, the total liability of the Urban Drainage and Flood Control District or the City of Colorado Springs, their contractors, advisors, reviewers, or their member governmental agencies, and your exclusive remedy, shall not exceed the amount of fees paid by you to the Urban Drainage and Flood Control District for the Product.

NO WARRANTY

The Urban Drainage and Flood Control District or the City of Colorado Springs, their contractors, advisors, reviewers, or their member governmental agencies do not warrant that the Design Form Worksheets will meet your requirements, or that the use of this product will be uninterrupted or error free.

THIS PRODUCT IS PROVIDED “AS IS” AND THE URBAN DRAINAGE AND FLOOD CONTROL DISTRICT OR THE CITY OF COLORADO SPRINGS, THEIR CONTRACTORS, ADVISORS, REVIEWERS, AND THEIR MEMBER GOVERNMENTAL AGENCIES DISCLAIM ALL WARRENTIES OF ANY KIND, EITHER EXPRESSED OR IMPLIED, INCLUDING BUT NOT LIMITED TO, ANY WARRENTY OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, PERFORMANCE LEVELS, COURSE OF DEALING OR USAGE IN TRADE.

Modifications made to UDFCD Design Form Worksheets by the City of Colorado Springs, CO:

Design Procedure Form: Grass Swale (GS) Sedimentation Facility

1. 2-Year design flow velocity changed from 1.5 fps to 2.0 fps Maximum
2. 2-year Design Flow Depth, D2 changed from 2 feet maximum to 3 feet Maximum

Design Procedure Form: Extended Detention Basin (EDB) – Sedimentation Facility

1. Basin Side Slopes (Z, horizontal distance per unit vertical), Z changed from 4 Minimum to 3 Minimum
2. Dam Embankment Side Slopes (Z, horizontal distance per unit vertical), Z changed from 4 Minimum to 3 Minimum

Design Procedure Form: Sand Filter Basin (SFB)

1. Average Side Slope of the Filter Basin changed from 4:1 or flatter to 3:1 or flatter.

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

1. Average Side Slope Above Water Surface changed from 4:1 or flatter to 3:1 or flatter.

Design Procedure Form: Grass Buffer (GB)

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. 2-Year Design Discharge (Total)	Q_2 = _____ cfs
2. Tributary Catchment Flow A) Design Length (Normal to runoff flow path): $L_G = Q_2 / 0.05$ B) Tributary Area in Square Feet (A_t)	 L_G = _____ feet A_t= _____ square feet
3. Design Width Along Direction of Flow (Use A **or** B) A) Sheet Flow Control Upstream i) Length of Flow Path Over Upstream Impervious Surface ii) Design Width of Buffer: $W_G = 0.2 * L_I$ (8' minimum) B) Concentrated (Non-Sheet) Flow Control Upstream (requires a level spreader in step 5 below) i) Length of Upstream Flow Level Spreader ii) Design Width of Buffer: $W_G = 0.15 * A_t / L_t$ (8' minimum)	 L_I = _____ feet W_G = _____ feet L_t = _____ feet W_G = _____ feet
4. Design Slope (not to exceed 4%)	S = _____ %
5. Flow Distribution (Check the type used or describe "Other") Note: If Method B was Used In Step 3, Level Spreader Must Be Checked Here	_____ Slotted Curbing _____ Modular Block Porous Pavement _____ Level Spreader _____ Other: _____
6. Vegetation (Check the type used or describe "Other") Note: Irrigated Turf Grass Is Required in Semi-Arid Climates	_____ Irrigated Turf Grass _____ Non-Irrigated Turf Grass _____ Other: _____
7. Outflow Collection (Check the type used or describe "Other")	_____ Grass Lined Swale _____ Street Gutter _____ Storm Sewer Inlet _____ Underdrain Used _____ Other: _____

Notes: _____

Design Procedure Form: Grass Swale (GS) Sedimentation Facility

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. 2-Year Design Discharge (Total)	Q_2 = _____ cfs
2-Year Design Flow Velocity (V_2, 2.0 fps Maximum)	V_2 = _____ fps
2. Swale Geometry	
A) Channel Side Slopes (Z, horizontal distance per unit vertical)	Z = _____ (horizontal/vertical)
B) 2-Year Design Flow Depth (D_2, 3 feet Maximum)	D_2 = _____ feet
C) Bottom Width of Channel (B)	B = _____ feet
3. Longitudinal Slope	
A) Froude Number (F, 0.50 maximum, reduce V_2 until F $\leq$ 0.50)	F = _____
A) Design Slope (S, Based on Manning's n = 0.05, 0.01 Maximum)	S = _____ feet/feet
B) Number of grade control structures required	_____ (number)
4. Vegetation (Check the type used or describe "Other") (Must use irrigated turf grass if S >0.005 in semi-arid areas of Colorado)	_____ Dryland Grass _____ Irrigated Turf Grass _____ Other: _____
5. Outlet (Check the type used or describe "Other")	_____ Infiltration Trench w/ Underdrain _____ Grated Inlet _____ Other: _____

Notes: _____

Design Procedure Form: Modular Block Porous Pavement (MBP)

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Modular Block Properties May substitute MBP with reinforced turf pavement such as provided by Invisible Structures (or equal). Note: Blocks shall have no less than 40% open area and shall be no less than 4" thick	Block Name: _____ Manufacturer: _____ Open Surface Area = _____ % Thickness = _____ inches
2. Porous Pavement Infill (Check the type or describe "Other")	_____ ASTM C-33 Sand _____ Sandy Loam Sod _____ Other: _____
3. Base Course A) Sand (ASTM C-33) B) Gravel (AASHTO #8 Coarse Aggregate-CDOT Section 703)	 _____ 1" Layer ASTM C-33 Sand _____ Other: _____ _____ 9" Layer AASHTO #8 Course Agg. _____ Other: _____
4. Design Impervious Area to Porous Pavement Area Ratio (Not to Exceed 2.0)	Ratio = _____ (A_{IMP} / A_{POROUS})
5. Perimeter Wall (6" deeper than base coarse)	_____ Concrete _____ inches thick _____ Other _____
6. Contained Cells A) Type B) Slope of the base course C) Minimum distance between cutoffs (normal to flow, L_{MAX}) $L_{MAX} = 0.8 / S_O$	 _____ 15 mil (min) P.E. Liner _____ Concrete Wall S_O = _____ ft/ft L_{MAX} = _____ feet
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 subgrade is heavy or expansive clay ☐ b) Check box if subgrade is silty or clayey sands ☐ c) Check box if subgrade is well-draining soils ☐ 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 ☐	_____ Infiltration to Subgrade with Permeable Membrane: 7(c) checked **and** 7(d) = no _____ Underdrain with Impermeable Membrane: 7(a) checked **or** 7(d) = yes _____ Underdrain with Permeable Membrane: 7(b) checked **and** 7(d) = no _____ Other: _____

Notes: _____

Design Procedure Form: Porous Pavement Detention (PPD)

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Basin Storage Volume	
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$) (I_a = 100% if all paved and roofed areas)	I_a = _____ % i = _____
B) Contributing Watershed Area, Including PPD Area	Area = _____ square feet
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.8 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = _____ watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol = _____ cubic feet
E) Porous Pavement Suface Elevation	Elev. = _____ feet
2. Required Minimum MBP Surface Area: A = Vol / 0.17	A = _____ square feet
Overflow Inlet Elevation: Porous Pavement Elev. + 0.17 feet	Elev. = _____ feet
3. Modular Block Properties	Block Name: _____
Note: Blocks shall have no less than 40% open area and shall be no less than 4" thick	Manufacturer: _____
	Open Surface Area = _____ %
	Thickness (4" min.) _____ inches
4. Porous Pavement Infill (Check the type used or describe "Other")	_____ ASTM C-33 Sand _____ Other: _____
5. Base Course	
A) Sand	_____ 1" Layer ASTM C-33 Sand _____ Other: _____
B) Gravel	_____ 9" Layer AASHTO #8 Course Agg. _____ Other: _____
6. Perimeter Wall (required)	_____ Concrete _____ inches thick _____ Other: _____
7. Draining of porous pavement (Check a, **or** b, **or** c, **answer** d) Based on answers to 7a through 7d, check the appropriate method	_____ Infiltration to Subgrade with Permeable Membrane: 7(c) checked **and** 7(d) = no
a) Check box if subgrade is heavy or expansive clay ☐ b) Check box if subgrade is silty or clayey sands ☐ c) Check box if subgrade is well-draining soils ☐	_____ Underdrain with Impermeable Membrane: 7(a) checked **or** 7(d) = yes
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 ☐	_____ Underdrain with Permeable Membrane: 7(b) checked **and** 7(d) = no _____ Other: _____
8. Overflow For Larger Storms	_____ Yes / No

Notes: _____

Design Procedure Form: Porous Landscape Detention (PLD)

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Basin Storage Volume (I_a = 100% if all paved and roofed areas u/s of PLD) A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a = _____ % i = _____
B) Contributing Watershed Area Including the PLD (Area)	Area = _____ square feet
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.8 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = _____ watershed inches
D) Design Volume: Vol_{PLD} = (WQCV / 12) * Area	Vol = _____ cubic feet
2. PLD Surface Area (A_{PLD}) and Average Depth (d_{av})	A_{PLD} = _____ square feet
(d_{av}: = (Vol / A_{PLD}), Min=0.5', Max=1.0')	d_{av} = _____ feet
3. Base Course (See Figure PLD-1)	_____ 6" (Min.) Sandy Loam Turf Layer, Plus 18" (Min.) Layer of 25% Peat and 75% Sand Mix, Plus 9" (Min.) Layer of ASSHTO #8 Coarse Aggregate (CDOT Section 703 Specification). _____ Other: _____
5. Draining of porous pavement (Check a, **or** b, **or** c, **answer** d) Based on answers to 5a through 5d, check the appropriate method a) Check box if subgrade is heavy or expansive clay ☐ b) Check box if subgrade is silty or clayey sands ☐ c) Check box if subgrade is well-draining soils ☐ 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 ☐	_____ Infiltration to Subgrade with Permeable Membrane: 5(c) checked **and** 5(d) = no _____ Underdrain with Impermeable Membrane: 5(a) checked **or** 5(d) = yes _____ Underdrain with Permeable Membrane: 5(b) checked **and** 5(d) = no _____ Other: _____

Notes: _____

Design Procedure Form: Extended Detention Basin (EDB) - Sedimentation Facility

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Basin Storage Volume			
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a =	_____	%
	i =	_____	
B) Contributing Watershed Area (Area)	Area =	_____	acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 1.0 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV =	_____	watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area * 1.2	Vol =	_____	acre-feet
2. Outlet Works			
A) Outlet Type (Check One)	_____	Orifice Plate	
	_____	Perforated Riser Pipe	
	_____	Other: _____	
B) Depth at Outlet Above Lowest Perforation (H)	H =	_____	feet
C) Required Maximum Outlet Area per Row, (A_o)	A_o =	_____	square inches
D) Perforation Dimensions **(enter one only)**:			
i) Circular Perforation Diameter **OR**	D =	_____	inches, **OR**
ii) 2" Height Rectangular Perforation Width	W =	_____	inches
E) Number of Columns (nc, See Table 6a-1 For Maximum)	nc =	_____	number
F) Actual Design Outlet Area per Row (A_o)	A_o =	_____	square inches
G) Number of Rows (nr)	nr =	_____	number
H) Total Outlet Area (A_{ot})	A_{ot} =	_____	square inches
3. Trash Rack			
A) Needed Open Area: A_t = 0.5 * (Figure 7 Value) * A_{ot}	A_t =	_____	square inches
B) Type of Outlet Opening (Check One)	_____	≤ 2" Diameter **Round**	
	_____	2" High **Rectangular**	
	_____	Other: _____	
C) For 2", or Smaller, **Round Opening** (Ref.: Figure 6a):			
i) Width of Trash Rack and Concrete Opening (W_{conc}) from Table 6a-1	W_{conc} =	_____	inches
ii) Height of Trash Rack Screen (H_{TR})	H_{TR} =	_____	inches

Design Procedure Form: Extended Detention Basin (EDB) - Sedimentation Facility

Designer: _____
Company: _____
Date: _____
Project: _____
Location: _____

iii) Type of Screen (Based on Depth H), Describe if "Other"	_____ S.S. #93 VEE Wire (US Filter) _____ Other: _____
iv) Screen Opening Slot Dimension, Describe if "Other"	_____ 0.139" (US Filter) _____ Other: _____
v) Spacing of Support Rod (O.C.) Type and Size of Support Rod (Ref.: Table 6a-2)	_____ inches _____
vi) Type and Size of Holding Frame (Ref.: Table 6a-2)	_____
D) For 2" High **Rectangular Opening** (Refer to Figure 6b):	
I) Width of Rectangular Opening (W)	W = _____ inches
ii) Width of Perforated Plate Opening (W_{conc} = W + 12")	W_{conc} = _____ inches
iii) Width of Trashrack Opening ($W_{opening}$) from Table 6b-1	$W_{opening}$ = _____ inches
iv) Height of Trash Rack Screen (H_{TR})	H_{TR} = _____ inches
v) Type of Screen (based on depth H) (Describe if "Other")	_____ Klemp™ KPP Series Aluminum _____ Other: _____
vi) Cross-bar Spacing (Based on Table 6b-1, Klemp™ KPP Grating). Describe if "Other"	_____ inches _____ Other: _____
vii) Minimum Bearing Bar Size (Klemp™ Series, Table 6b-2) (Based on depth of WQCV surcharge)	_____
4. Detention Basin length to width ratio	_____ (L/W)
5 Pre-sedimentation Forebay Basin - Enter design values	
A) Volume (5 to 10% of the Design Volume in 1D)	_____ acre-feet
B) Surface Area	_____ acres
C) Connector Pipe Diameter (Size to drain this volume in 5-minutes under inlet control)	_____ inches
D) Paved/Hard Bottom and Sides	_____ yes/no

Design Procedure Form: Extended Detention Basin (EDB) - Sedimentation Facility

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

6. Two-Stage Design	
A) Top Stage (D_{WQ} = 2' Minimum)	D_{WQ} = _____ feet Storage= _____ acre-feet
B) Bottom Stage (D_{BS} = D_{WQ} + 1.5' Minimum, D_{WQ} + 3.0' Maximum, Storage = 5% to 15% of Total WQCV)	D_{BS} = _____ feet Storage= _____ acre-feet Surf. Area= _____ acres
C) Micro Pool (Minimum Depth = the Larger of 0.5 * Top Stage Depth or 2.5 Feet)	Depth= _____ feet Storage= _____ acre-feet Surf. Area= _____ acres
D) Total Volume: Vol_{tot} = Storage from 5A + 6A + 6B Must be ≥ Design Volume in 1D	Vol_{tot} = _____ acre-feet
7. Basin Side Slopes (Z, horizontal distance per unit vertical) Minimum Z = 3, Flatter Preferred	Z = _____ (horizontal/vertical)
8. Dam Embankment Side Slopes (Z, horizontal distance) per unit vertical) Minimum Z = 3, Flatter Preferred	Z = _____ (horizontal/vertical)
9. Vegetation (Check the method or describe "Other")	_____ Native Grass _____ Irrigated Turf Grass _____ Other: _____

Notes: _____

Design Procedure Form: Sand Filter Basin (SFB)

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Basin Storage Volume	
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a = _____ % i = _____
B) Contributing Watershed Area (Area)	Area = _____ acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 1.0 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = _____ watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol = _____ acre-feet
2. Minimum Filter Surface Area: A_s = (Vol / 3) * 43,560	A_s = _____ square feet
Filter Surface Elevation	_____ feet
Average Side Slope of the Filter Basin (3:1 or flatter)	Z = _____
3. Estimate of Basin Depth (D), based on filter area A_s	D = _____ feet
4. Outlet Works	
A) Sand (ASTM C-33) Layer Thickness (18" min.)	_____ inches
Gravel (AASHTO No. 8; CDOT Section 703) Layer Thickness (9" min.)	_____ inches
B) Overflow Elevation At Top of Design Volume (Filter Surface Elev. + Estimate of Basin Depth (D))	_____ feet
5. Draining of porous pavement (Check a, **or** b, **or** c, **answer** d) Based on answers to 5a through 5d, check the appropriate method	_____ Infiltration to Subgrade with Permeable Membrane: 5(c) checked **and** 5(d) = no
a) Check box if subgrade is heavy or expansive clay ☐ b) Check box if subgrade is silty or clayey sands ☐ c) Check box if subgrade is well-draining soils ☐	_____ Underdrain with Impermeable Membrane: 5(a) checked **or** 5(d) = yes
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 ☐	_____ Underdrain with Permeable Membrane: 5(b) checked **and** 5(d) = no _____ Other: _____
6 Describe Provisions for Maintenance _____	

Notes: _____

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

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Basin Storage Volume	
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a = _____ % i = _____
B) Contributing Watershed Area (Area)	Area = _____ acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.9 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = _____ watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol = _____ acre-feet
2. Wetland Pond Volume, Depth, and Water Surface Area	
A) Minimum Permanent Pool: $Vol_{Pool} \geq 0.75 * Vol$	Calculated Required Minimums: $Vol_{Pool} \geq$ _____ acre-feet WS Area = _____ acres, estimated Enter the Actual Design Values: $Vol_{Pool} \geq$ _____ acre-feet, final design WS Area = _____ acres, final design
B) Forebay (Volume $\geq$ 0.05 * Vol in 1D) Depth minimum = 2.5', maximum = 4.0'	Volume= _____ acre-feet Depth= _____ feet Area= _____ acres, % = _____ %
C) Outlet Pool (Area > 0.06 * Design WS Area) Depth minimum = 2.5', maximum = 4.0'	Depth= _____ feet Area= _____ acres, % = _____ %
D) Wetland Zones with Emergent Vegetation (6" to 12" deep) (Area = 50% to 70% of Design WS Area)	Depth= _____ feet Area= _____ acres, % = _____ %
E) Free Water Surface Areas (2' to 4' deep) (Area = 30% to 50% of Design WS Area)	Depth= _____ feet Area= _____ acres, % = _____ % %
3 Average Side Slope Above Water Surface (3:1 or flatter)	Z = _____
A) Depth of WQCV Surcharge (above permanent pool, 2' max.)	_____ feet
4. Outlet Works	
A) Outlet Type (Check One)	_____ Orifice Plate _____ Perforated Riser Pipe _____ Other: _____
B) Depth at Outlet Above Lowest Perforation (H, 2' max.)	H = _____ feet
C) Required Maximum Outlet Area per Row, (A_o)	A_o = _____ square inches
D) Perforation Dimensions (Refer to Figure 5 in W.Q. Str. Det.): **(Enter one only)**: i) Circular Perforation Diameter **OR** ii) 2" Height Rectangular Perforation Width	 D = _____ inches, **OR** W = _____ inches

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

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

E) Number of Columns (nc)	nc =	_____ Number
F) Actual Design Outlet Area per Row (A_o)	A_o =	_____ square inches
G) Number of Rows (nr)	nr =	_____ Number
H) Total Outlet Area (A_{ot})	A_{ot} =	_____ square inches
5. Trash Rack		
A) Needed Open Area: A_t = 0.5 * (UDFCD Vol. 3 Figure 7 Value) * A_{ot}	A_t =	_____ square inches
B) Type of Outlet Opening (Check One)		_____ ≤ 2" Diameter **Round** _____ 2" High **Rectangular** _____ Other: _____
C) For 2", or Smaller, **Round Opening** (Ref.: Figure 6a):		
i) Width of Trash Rack and Concrete Opening (W_{conc}) from UDFCD Vol. 3, Table 6a-1	W_{conc} =	_____ inches
ii) Height of Trash Rack Screen (H_{TR})	H_{TR} =	_____ inches
iii) Type of Screen (Based on Depth H), Describe if "Other"		_____ S.S. #93 VEE Wire (US Filter) _____ Other: _____
iv) Screen Opening Slot Dimension, Describe if "Other"		_____ 0.139" (US Filter) _____ Other: _____
v) Spacing of Support Rod (O.C.) Type and Size of Support Rod (Ref.: UDFCD Vol. 3 Table 6a-2)		_____ inches _____
vi) Type and Size of Holding Frame (Ref.: UDFCD Vol. 3 Table 6a-2)		_____
D) For 2" High **Rectangular Opening** (Refer to UDFCD Vol. 3 Figure 6b):		
I) Width of Rectangular Opening (W)	W =	_____ inches
ii) Width of Perforated Plate Opening (W_{conc} = W + 12")	W_{conc} =	_____ inches
iii) Width of Trashrack Opening ($W_{opening}$) from Table 6b-1	$W_{opening}$ =	_____ inches
iv) Height of Trash Rack Screen (H_{TR})	H_{TR} =	_____ inches
v) Type of Screen (based on depth H) (Describe if "Other")		_____ Klemp™ KPP Series Aluminum _____ Other: _____
vi) Cross-bar Spacing (Based on Table 6b-1, Klemp™ KPP Grating). Describe if "Other"		_____ inches _____ Other: _____

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

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

vii) Minimum Bearing Bar Size (Klemp™ Series, Table 6a-2) (Based on depth of WQCV surcharge)	_____
6. Basin Use for Quantity Controls (Check one or describe if "Other")	_____ Detention within the facility _____ Detention upstream of the facility _____ Other: _____
7. Basin length to width ratio	_____ (L/W)
8. Basin Side Slopes (Z, horizontal distance per unit vertical)	_____ (horizontal/vertical)
9 Annual/Seasonal Water Balance (Q_{net} has to be positive)	Q_{inflow} _____ acre-feet/year Q_{evap} _____ acre-feet/year $Q_{seepage}$ _____ acre-feet/year $Q_{E.T.}$ _____ acre-feet/year Q_{net} _____ acre-feet/year
10 Vegetation (Check the method being applied or describe)	_____ Native Grass _____ Irrigated Turf Grass Side Slopes _____ Wetland Species in Pool* _____ Other: _____ *Describe Species Density and Mixl. _____ _____ _____ _____ _____

Notes: _____

Design Procedure Form: Retention Pond (RP) - Sedimentation Facility (Sheet 1 of 3)

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Basin Storage Volume	
A) Tributary Area's Imperviousness Ratio ($i = I_a / 100$)	I_a = _____ % i = _____
B) Contributing Watershed Area (Area)	Area = _____ acres
C) Water Quality Capture Volume (WQCV) ($WQCV = 0.8 * (0.91 * I^3 - 1.19 * I^2 + 0.78 * I)$)	WQCV = _____ watershed inches
D) Design Volume: Vol = (WQCV / 12) * Area	Vol = _____ acre-feet
2. Permanent Pool	
A) Volume: Vol_{Pool} = (1.0 to 1.5) * Vol	_____ acre-feet
B) Average Depth Zone 1 = Littoral Zone - 6 to 12 inches deep	_____ feet
Zone 2 = Deeper Zone - 4 feet to 8 feet deep	Zone 2 _____ feet
C) Maximum Zone 2 Pool Depth (not to exceed 12 feet)	Depth = _____ feet
D) Permanent Pool Water Surface Area (Estimated Minimum)	
(Zone 1 - Littoral Zone = 25% to 40% of the total surface area)	% = _____ acres = _____
(Zone 2 - Deeper Zone = 60% to 75% of the total surface area)	% = _____ acres = _____
Total Estimated Minimum Surface Area (A_{Total})	% = _____ acres = _____
3. Annual/Seasonal Water Balance (Q_{net} has to be positive)	Q_{inflow} _____ acre-feet/year Q_{evap} _____ acre-feet/year $Q_{seepage}$ _____ acre-feet/year $Q_{E.T.}$ _____ acre-feet/year Q_{net} _____ acre-feet/year
4. Outlet Works	
A) Outlet Type (Check One)	_____ Orifice Plate _____ Perforated Riser Pipe _____ Other: _____
B) Depth at Outlet Above Lowest Perforation (H)	H = _____ feet
C) Required Maximum Outlet Area per Row, (A_o)	A_o = _____ square inches
D) Perforation Dimensions **(enter one only)**:	
i) Circular Perforation Diameter **OR**	D = _____ inches, **OR**
ii) 2" Height Rectangular Perforation Width	W = _____ inches
E) Number of Columns (nc)	nc = _____ Number

Design Procedure Form: Retention Pond (RP) - Sedimentation Facility (Sheet 2 of 3)

Designer: _____
Company: _____
Date: _____
Project: _____
Location: _____

F) Actual Design Outlet Area per Row (A_o)	A_o = _____ square inches
G) Number of Rows (nr)	nr = _____ Number
H) Total Outlet Area (A_{ot})	A_{ot} = _____ square inches
5. Trash Rack	
A) Needed Open Area: A_t = 0.5 * (Figure 7 Value) * A_{ot}	A_t = _____ square inches
B) Type of Outlet Opening (Check One)	_____ ≤ 2" Diameter **Round** _____ 2" High **Rectangular** _____ Other: _____
C) For 2", or Smaller, **Round Opening** (Ref.: Figure 6a):	
I) Width of Trash Rack and Concrete Opening (W_{conc}) from Table 6a-1	W_{conc} = _____ inches
ii) Height of Trash Rack Screen (H_{TR})	H_{TR} = _____ inches
iii) Type of Screen (Based on Depth H), Describe if "Other"	_____ S.S. #93 VEE Wire (US Filter) _____ Other: _____
iv) Screen Opening Slot Dimension, Describe if "Other"	_____ 0.139" (US Filter) _____ Other: _____
v) Spacing of Support Rod (O.C.) Type and Size of Support Rod (Ref.: Table 6a-2)	_____ inches _____
vi) Type and Size of Holding Frame (Ref.: Table 6a-2)	_____
D) For 2" High **Rectangular Opening** (Refer to Figure 6b):	
I) Width of Rectangular Opening form 4.D.ii. (W)	W = _____ inches
ii) Width of Perforated Plate Opening (W_{conc} = W + 12")	W_{conc} = _____ inches
iii) Width of Trash Rack Opening ($W_{opening}$) from Table 6b-1	$W_{opening}$ = _____ inches
iv) Height of Trash Rack Screen (H_{TR})	H_{TR} = _____ inches
v) Type of Screen (based on depth H) (Describe if "Other")	_____ Klemp™ KPP Series Aluminum _____ Other: _____
vi) Cross-bar Spacing (Based on Table 6b-1, Klemp™ KPP Grating). Describe if "Other"	_____ inches _____ Other: _____

Design Procedure Form: Retention Pond (RP) - Sedimentation Facility (Sheet 3 of 3)

Designer: _____
Company: _____
Date: _____
Project: _____
Location: _____

vii) Minimum Bearing Bar Size (Klemp™ Series, Table 6a-2) (Base on depth of WQCV surcharge)	_____
6. Basin length to width ratio	_____ (L/W)
7. Basin Side Slopes (Z:1) A) Above the Permanent Pool: Z= B) Below the Permanent Pool Z= Z=	 _____ (horizontal/vertical) Zone 1= _____ (horizontal/vertical) Zone 2= _____ (horizontal/vertical)
8. Dam Embankment Side Slopes Z=	_____ (horizontal/vertical)
9. Vegetation (Check the type used or describe if "Other")	_____ Native Grass _____ Irrigated Turf Grass _____ Emergent Aquatic Species* _____ Other: _____ *Specify types and densities:
10. Forebay Storage (5% to 10% of Design Volume in 1D)	Storage= _____ acre-feet
11. Underdrains	_____ yes/no

Notes: _____

Design Procedure Form: Constructed Wetlands Channel (CWC) - Sedimentation Facility

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

1. Design Discharge (total)	Q_2 = _____ cfs Q_{100} = _____ cfs
2. Channel Geometry (New Channel - No Wetland Veg. in Bottom)	
A) Channel Side Slopes (Z:1, i.e., H/V) ($Z \geq 2.5$)	Z = _____ (horizontal/vertical)
B) 2-Year Design Flow Depth (D_2) Maximum D_2 = 4', Minimum D_2 = 2'	D_2 = _____ feet
C) Bottom width of the channel (B_2) - 8-foot minimum	B_2 = _____ feet
D) Top width of the 2-Year Design Water Surface (W_2)	W_2 = _____ feet
3. Longitudinal Slope (Based on a Manning's n = 0.03 for the 2-year Channel, velocity set to 2 fps)	S = _____ feet/feet
4. Final Channel Goemetry - Wetland Vegetation in Bottom) (Based on a Manning's n = 0.08)	
A) Calculated channel geometry required to maintain design discharge during a 2-year event with mature vegetation	Z = _____ feet D_2 = _____ feet B_2 = _____ feet W_2 = _____ feet
B) Calculated discharge and velocity during a 2-year event with mature vegetation	Q_2 = _____ cfs V_2 = _____ fps
C) Geometry and velocity to use for the 100-year discharge if composite channel section is used.	D_{100} = _____ feet B_{100} = _____ feet W_{100} = _____ feet V_{100} = _____ fps
5. Number of grade control structures required	_____ number
6. Vegetation (Check the type or describe "Other")	_____ Native Grass _____ Irrigated Turf Grass _____ Wetland Species _____ Other: _____

Notes: _____

Appendix B Material Specifications

TABLE MT-1
Gradation Requirements for Riprap

Pay Item	Type	Stone Size d50 (inches)	Percent of Material Smaller Than Typical Stone	Typical Stone Dimensions (inches)	Typical Stone Weight (Pounds)
			70-100	12	85
Riprap	VL	6	50-70	9	35
			35-50	6	10
			2-10	2	0.4
Riprap			70-100	15	160
	L	9	50-70	12	85
			35-50	9	35
			2-10	3	1.3
Riprap			70-100	21	440
	M	12	50-70	18	275
			35-50	12	85
			2-10	4	3
Riprap			100	30	1,280
	H	18	50-70	24	650
			35-50	18	275
			2-10	6	10
Riprap			100	42	3,500
	VH	24	50-70	33	1,700
			35-50	24	650
			2-10	9	35

Table taken from CDOT's Standard Specifications for Road and Bridge Construction, 1999 and City of Colorado Springs/El Paso County Drainage Criteria Manual.

TABLE MT-2
Physical Requirements for Temporary Silt Fence Geotextiles

Property	Wire Fence Supported Requirements	Self Supported Requirements	Test Method
Tensile Strength, N (lbs)	400 (900) minimum	400 (900) minimum	ASTM D 4632
Elongation at 50% minimum tensile strength	N/A	50 maximum	ASTM D 4632
Permitivity1 s-1	0.01 minimum	0.01 minimum	ASTM D 4491
Apparent Opening Size (AOS), mm[1]	0.84 maximum	0.84 maximum	ASTM D 4751
Ultraviolet Degradation at 500 hours	Minimum 70% Strength Retained	Minimum 70% Strength Retained	ASTM D 4355

[1] Permitivity and AOS do not relate directly to filtration performance of silt fence fabrics. Values presented reflect minimum criteria of products currently used.

Table taken from CDOT's Standard Specifications for Road and Bridge Construction, 1999.

TABLE MT-3
Physical Requirements for Drainage Geotextiles

Property	Class A[1]	Test Method
Grab Strength, N (lbs)	800 (180)	ASTM D 4632
Seam Strength, N (lbs)[2]	710 (160)	ASTM D 4632
Puncture Strength, N (lbs)	360 (80)	ASTM D 4833
Trapezoid Tear, N (lbs)	225 (50)	ASTM D 4533
Apparent Opening Size (AOS) US Std Sieve	AOS less than 0.297 mm (greater than No. 50 sieve)	ASTM D 4651
Permeability[3], cm/s	k fabric >k soil	ASTM D 4491
Ultraviolet Degradation at 500 hours	50% strength retained	ASTM D 4355

[1] Class A drainage geotextiles are used where installation stresses are severe, i.e. very coarse sharp angular aggregate is used, a heavy degree of compaction is specified or depth of trench is greater than 3 meters (10 feet).

[2] Values apply to both field and manufactured seas, if required.

[3] A nominal coefficient of permeability may be determined by multiplying permitivity value by nominal thickness. The k value of the fabric should be greater than the k value of the soil.

Table taken from CDOT's Standard Specifications for Road and Bridge Construction, 1999.

Appendix C Inspection Checklist – Grading Erosion, and Stormwater Quality Controls

CITY OF COLORADO SPRINGS

DATE/TIME:
INSPECTOR:
TYPE OF INSPECTION: Self-Monitoring_____ Initial _____ Compliance_____ Follow-Up_____ Reconnaissance_____ Complaint_____ Final____

SITE:	DATE OF PERMIT:
ADDRESS:	
CONTRACTOR: CONTACT: PHONE:	OWNER/OWNER'S REPRESENTATIVE: CONTACT: PHONE:
STAGE OF CONSTRUCTION: Initial BMP Installation/Prior to Construction_____ Clearing & Grubbing_____ Rough Grading_____ Finish Grading_____ Utility Construction_____ Building Construction_____ Final Stabilization_____	

OVERALL SITE INSPECTION	YES/NO/N.A.	REMARKS/ACTIONS
Is there any evidence of sediment leaving the construction site? If so, note areas.		
Have any adverse impacts such as flooding, structural damage, erosion, spillage, or accumulation of sediment, debris or litter occurred on or within public or private property, wetlands or surface waters –to include intermittent drainageways and the City's stormwater system (storm sewers, gutters, ditches, etc.)?		
Are the BMPs properly installed and maintained?		
Have the BMPs been placed as shown on approved plans?		
Are the BMPs functioning as intended?		
Is work being done according to approved plans and any phased construction schedule?		
Is the construction schedule on track?		
Are drainage channels and outlets adequately stabilized?		
Is there any evidence of discharges or spills of fuels, lubricants, chemicals, etc.?		

BMP MAINTENANCE CHECKLIST	YES/NO/N.A.	REMARKS/ACTIONS NECESSARY
CHECK DAM Has accumulated sediment and debris been removed per maintenance requirements?		
EROSION CONTROL BLANKET Is fabric damaged, loose or in need of repairs?		
INLET PROTECTION Is the inlet protection damaged, ineffective or in need of repairs? Has sediment been removed per maintenance requirements?		
MULCHING Distributed uniformly on all disturbed areas? Is the application rate adequate? Any evidence of mulch being blown or washed away? Has the mulched area been seeded, if necessary?		
SEDIMENT BASIN Is the sediment basin properly constructed and operational? Has sediment and debris been cleaned out of the basin?		
SILT FENCE Is the fence damaged, collapsed, unentrenched or ineffective? Has sediment been removed per maintenance requirements? Is the silt fence properly located?		
SLOPE DRAIN Is water bypassing or undercutting the inlet or pipe? Is erosion occurring at the outlet of the pipe?		
STRAW BALE BARRIER Are the straw bales damaged, ineffective or unentrenched? Has sediment been removed per maintenance requirements? Are the bales installed and positioned correctly?		

BMP MAINTENANCE CHECKLIST	YES/NO/N.A.	REMARKS/ACTIONS NECESSARY
SURFACE ROUGHENING Is the roughening consistent/uniform on slopes?? Any evidence of erosion?		
TEMPORARY SEEDING Are the seedbeds protected by mulch? Has any erosion occurred in the seeded area? Any evidence of vehicle tracking on seeded areas?		
TEMPORARY SWALES Has any sediment or debris been deposited within the swales? Have the slopes of the swale eroded or has damage occurred to the lining? Are the swales properly located?		
VEHICLE TRACKING Is gravel surface clogged with mud or sediment? Is the gravel surface sinking into the ground? Has sediment been tracked onto any roads and has it been cleaned up? Is inlet protection placed around curb inlets near construction entrance?		
OTHER		

FINAL INSPECTION CHECKLIST	YES/NO/N.A.	REMARKS/ACTIONS NECESSARY
Has all grading been completed in compliance with the approved Plan, and all stabilization completed, including vegetation, retaining walls or other approved measures?		
Has final stabilization been achieved – uniform vegetative cover with a density of at least 70 percent of pre-disturbance levels, and cover capable of adequately controlling soil erosion; or permanent, physical erosion methods?		
Have all temporary measures been removed?		
Have all stockpiles, construction materials and construction equipment been removed?		
Are all paved surfaces clean (on-site and off-site)?		
Has sediment and debris been removed from drainage facilities (on-site and off-site) and other off-site property, including proper restoration of any damaged property?		
Have all permanent stormwater quality BMPs been installed and completed?		

ADDITIONAL COMMENTS:

The items noted as needing action must be remedied no later than _____. The contractor shall notify the inspector when all the items noted above have been addressed.

By signing this inspection form, the owner/owner's representative and the contractor acknowledge that they have received a copy of the inspection report and are aware it is their responsibility to take corrective actions by the date noted above. Failure to sign does not relieve the contractor and owner/owner's representative of their responsibility to take the necessary corrective action and of their liability for any damages that have occurred or may occur.

INSPECTOR'S SIGNATURE:	DATE:
OWNER/OWNER'S REPRESENTATIVE SIGNATURE:	DATE:
CONTRACTOR'S SIGNATURE:	DATE: