Truckee Meadows Structural Controls Design and Low Impact Development Manual

Truckee Meadows Regional Stormwater Quality Management Program

April 2015 Update

Prepared by:

NCE

Collaboration. Commitment. Confidence.℠

Truckee Meadows Structural Controls Design and Low Impact Development Manual

City of Reno, City of Sparks, and Washoe County, Nevada

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List of Acronyms

BMP	Best Management Practice
CASQA	California Stormwater Quality Association
CFR	Code of Federal Regulations
cfs	Cubic Feet per Second
CWA	Clean Water Act
ECS	Evaporative Control Systems, Inc.
EPA	U.S. Environmental Protection Agency
LID	Low Impact Development
MDE	Maryland Department of the Environment
MEP	Maximum Extent Practicable
MIT	Minimum Inter-event Time
MS4	Municipal Separate Storm Sewer System
NDEP	Nevada Division of Environmental Protection
NDF	Nevada Division of Forestry
NDOT	Nevada Department of Transportation
NEMO	Nonpoint Education for Municipal Officials
NPDES	National Pollutant Discharge Elimination System
NRS	Nevada Revised Statute
NURP	Nationwide Urban Runoff Program
PAHs	Polycyclic aromatic hydrocarbons
PCBs	Polychlorinated biphenyls
PMF	Probable Maximum Flood
RSWQMP	Regional Stormwater Quality Management Program
RWPC	Regional Water Planning Commission
SPF	Standard Project Flood
SSPWC	Standard Specifications for Public Works Construction
SUSMP	Standard Urban Stormwater Mitigation Plan
SWMP	Stormwater Management Program
SWPPP	Storm Water Pollution Prevention Plan
TMDL	Total Maximum Daily Load
TMWA	Truckee Meadows Water Authority
TMWRF	Truckee Meadows Water Reclamation Facility

TDS	Total Dissolved Solids
TN	Total Nitrogen
TP	Total Phosphorus
TPH	Total Petroleum Hydrocarbons
TSS	Total Suspended Solids
UDFCD	Urban Drainage and Flood Control District
UIC	Underground Injection Control
WQ_F	Water Quality Flow
WQ_V	Water Quality Volume
WSCD	Washoe Storey Conservation District

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This manual was developed to assist engineers, developers, contractors, City, and County staff in the planning, design, construction, operation and maintenance of source and treatment controls for storm water quality improvement. Structural controls for water quality improvement are required at private and public development and redevelopment under the NPDES Municipal Stormwater Permit NVS000001. The Nevada Division of Environmental Protection (NDEP) issued this permit and the staff members responsible overseeing its implementation are:

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Comments and Questions

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Disclaimer

This Manual should be used as a general guidance document to aid with the siting, design, operation and long-term maintenance of source controls, Low Impact Development (LID) practices, and structural treatment controls for stormwater quality enhancement. The stormwater quality controls described herein are intended to serve as Best Management Practices (BMPs) implemented to meet the standard required by the Nevada Division of Environmental Protection (NDEP) and U.S. Environmental Protection Agency (EPA). BMPs should be designed based on the water quality design criteria presented in the Manual and implemented at areas of new development and redevelopment based on the policies and procedures of the appropriate jurisdiction.

1.0 INTRODUCTION

Low Impact Development (LID) is a growing practice in stormwater management. LID principles are modeled after nature to manage urban runoff at the source using local and smaller scale controls than traditional centralized stormwater treatment. The goal of LID is to mimic the predevelopment hydrology of a site by using design practices and techniques that effectively capture, filter, store, evaporate, detain and infiltrate runoff close to its source. This section discusses the purpose and organization of the Truckee Meadows Structural Controls Design and Low Impact Development Manual (hereafter referred to as "The Manual"), as well as regulatory requirements and legal authority.

1.1 Purpose and Organization of the Manual

The primary purpose of the Manual is to provide guidance on the selection and implementation of source control and structural treatment control Best Management Practices (BMPs) in order to reduce pollutants in stormwater from new and redevelopment sites. This Manual is intended to guide siting, design, operation and long-term maintenance of LID practices and structural controls in order to improve stormwater quality and meet National Pollutant Discharge Elimination System (NPDES) permit requirements. The Manual also contains the local policies and procedures that have been developed to meet NPDES stormwater permit requirements in the Truckee Meadows. Implementation of the source control and structural treatment control BMPs in this Manual will reduce pollutant loads in stormwater runoff, reduce erosion and sedimentation resulting from hydromodification in creeks and streams, and improve the overall water quality of receiving waters. These BMPs can have the benefits of increased groundwater recharge, water conservation, and reduced flooding, also.

The source controls and structural treatment controls in the Manual were selected to provide a variety of measures that are appropriate for the soils and climate of the Truckee Meadows. The Manual was developed for use by planners, developers, design engineers, contractors, subcontractors, construction staff, and City of Reno, City of Sparks and Washoe County staff involved in public and private site development and redevelopment projects. The Design Guidance Worksheets included with the Manual are intended to expedite the plan review process, and to achieve consistent design of structural treatment controls and LID practices in the Truckee Meadows.

This Manual is organized as follows:

- **Section 1** provides a general overview of the purpose of the Manual and the federal and state regulations that provided the driving force behind its development.
- **Section 2** describes the local policies and procedures relevant to the design and development of new development and redevelopment projects in the Truckee Meadows.
- **Section 3** provides background information on urban stormwater runoff and hydrology in the Truckee Meadows, and the effects of urbanization on receiving waters.

- **Section 4** describes the principles of LID and how they can be applied to projects in the Truckee Meadows.
- **Section 5** includes a number of source control techniques that can be applied to reduce the potential for pollution to enter the storm drainage system.
- **Section 6** provides design guidance for stormwater treatment controls that remove pollutants from stormwater runoff generated on a given site.

1.2 NPDES Stormwater Permits and Regulations

Section 402 of the Federal Clean Water Act (CWA) established the NPDES program, which requires a permit to discharge pollutants to waters of the United States, including the discharge from a Municipal Separate Storm Sewer System (MS4). The Nevada Division of Environmental Protection (NDEP) is authorized by U.S. EPA to administer the NPDES program in Nevada. In 1990, a Phase 1 MS4 permit (No. NVS000001) was issued by NDEP jointly to the Cities of Reno and Sparks and Washoe County (collectively referred to as "the Permittees"). To protect water quality in the Truckee Meadows, and to satisfy CWA requirements, the Permittees are required to implement and enforce a Stormwater Management Program (SWMP) designed to reduce the discharge of pollutants from the MS4 to the maximum extent practicable (MEP). The Permittees are also required to develop policies and procedures to implement and enforce the operation and maintenance of source controls and structural treatment controls at new development and significant redevelopment sites.

The permitted area includes the limits of the urbanized area within the Truckee Meadows and the waters of the United States receiving stormwater discharges from the Cities of Reno and Sparks and parts of Washoe County located within the Truckee Meadows. Per the NPDES permit issued jointly to the three Permittees, the receiving waters subject to municipal stormwater discharges in the Truckee Meadows include the Truckee River, Silver Lake Playa, Swan Lake Playa, Whites Lake Playa and the tributaries that drain to these water bodies.

Implementation of source and structural control BMPs to reduce pollutants in runoff is required under the state and federal NPDES stormwater program [Chapter 445A of the Nevada Revised Statutes (NRS), provisions of the federal CWA, and Section 122.26 of the Code of Federal Regulations (40 CFR)]. Structural controls are engineered devices that remove pollutants from urban runoff before or after it enters the MS4. They must be designed and engineered based on-site conditions, and can be constructed in place or pre-manufactured units can be specified. LID is an approach to land development or redevelopment that works to manage stormwater close to its source. LID employs design principles, such as site layout, grading, and compaction that minimize disturbance and maintain imperviousness to preserve natural drainages, vegetation and buffer zones, and utilize on-site stormwater treatment techniques. LID practices can use both source controls and structural controls designed to reduce runoff quantity to pre-construction levels and remove pollutants by filtration and biological processing before runoff enters the MS4.

The Permittees began implementing their SWMP in 2001, the most recent updated occurred in December 2011. In accordance with the Truckee Meadows MS4 permit, the Permittees developed the Structural Controls Design Manual in 2004 (updated in 2007) and an LID

Handbook in 2007, along with procedures to implement and maintain these practices. The 2014 update combines them into a single document: The Truckee Meadows Structural Controls Design and Low Impact Development Manual. Areas subject to the MS4 Permit and the guidance provided in this Manual include new development and redevelopment in the Cities of Reno and Sparks, and the adjacent urbanized areas in Washoe County. This Manual includes the following, as prescribed by the MS4 permit:

- Structural and source control measures expected to be implemented for the life of the permit to reduce pollutants from commercial and residential runoff to the MS4, the rationale for the expected pollutant load reduction, and a proposed schedule for implementing controls;
- Maintenance activities and a maintenance schedule for pollutant load reductions from the MS4s;
- Development practices and land use planning techniques to reduce the discharge of pollutants from areas of new development and significant redevelopment ('NDSR') to MS4s;
- In addition the General Permit for Stormwater Associated with Construction Activity (NVR100000; Part III.A. 7.b, issued September 14, 2007) or "Construction General Permit" (CGP) requires that a Stormwater Pollution Prevention Plan (SWPPP) be developed by owners and/or operators of a construction site. The SWPPP must include a description of the appropriate structural control measures implemented to minimize impacts from construction related stormwater, and must include a description of post-construction stormwater management controls that are designed to be consistent with local or state stormwater management requirements. The Truckee Meadows Construction Site Best Management Practices Handbook provides guidance on stormwater management at active construction sites. This Manual is intended to provide guidance on structural controls and post-construction stormwater management controls as required by the CGP.

1.3 Legal Authority

In 2003, the Cities of Reno and Sparks and Washoe County adopted new municipal codes and ordinances for stormwater quality management, permitting, and enforcement. The Truckee Meadows Low Impact Development Manual and Structural Controls Design Manual are adopted by reference into the Reno and Sparks Municipal codes, as well as Washoe County Development Code. These codes and ordinances include requirements for the use of stormwater BMPs, spill notification, and good housekeeping practices at commercial and industrial sites. The codes and ordinances prohibit discharges of pollutants to the storm drain system, depositing waste or materials that might become a pollutant onto streets, parking areas or any public or private lands, and provide surface cleaning regulations. They also require that private stormwater facilities are maintained and a secure right of entry onto private property is provided for City and County inspections. Enforcement actions described in code include termination of activities and civil and criminal penalties.

The Cities and County also have existing ordinances that require permits for construction activities and a regulatory process for reviewing plans, approving permits, and inspecting

sites for compliance (**Section 2.0** of the Manual). The municipal codes and ordinances relevant to the MS4 Permittees in the Truckee Meadows area are contained in

- City of Reno Municipal Code Chapter 12.16. Article IV, and Section 18.12.405
- City of Sparks Municipal Code Chapters 13.55 through 13.75
- Washoe County Code Ordinance No. 1223

At the time of the writing of this manual, Washoe County is in process of revising development code to add a new article, Article 421, Construction Stormwater Management that will incorporate Ordinance 1223 as well as new items addressing post construction structural controls

1.4 Relationship to other Manuals

A designer should cross-reference the appropriate jurisdiction's drainage design manual or development codes to ensure that structural treatment controls are designed to be consistent with technical approaches and related policies and procedures. Practitioners should refer to the most current version of these drainage design manuals:

- The City of Reno Public Works Design Manual (2009 or the most current edition) describes the standards for the design and construction of public infrastructure within the City of Reno, including streets, storm drainage, sewers, erosion control, street lighting, and post construction stormwater quality. Chapter II provides guidance on the calculation of peak flow events and design of storm drainage infrastructure. Chapter X provides instruction on required submittals for larger projects, including the Post Construction Stormwater Quality Management Plan.
- The “Orange Book” Standard Specifications for Public Works Construction (SSPWC) (2012 or the most current edition) provides general provisions, material specifications, and construction methods for typical public works installations, including storm drainage infrastructure and landscaping.
- Washoe County Development Code Chapter 110, Division Four – Development Standards provides information on landscaping requirements, stream buffer zones, storm drainage standards, and other pertinent guidance.
- The Truckee Meadows Regional Drainage Manual (TMRDM) (2009 or the most current edition) describes the policies and design criteria for flood control, drainage design, and hydrology for the Cities of Reno, Sparks, and Washoe County. It provides guidance on the design of conveyance and detention facilities for large runoff events. The structural controls addressed in this Manual are intended for treatment of smaller storm flows, but bypass and overflow of larger storm events should always be considered.
- During the construction phase of new development and redevelopment projects that disturb one or more acres of land, or less than one acre within one quarter mile of an impaired waterway [TMDL or 303(d) listed water] or other sensitive site as determined by NDEP, the Truckee Meadows Construction Site Best Management Practices Handbook should be used for guidance with permitting requirements and the proper use of erosion, sediment and waste controls. The inspection and maintenance of

construction site BMPs can be a critical component in the successful performance of LID practices.

1.5 Regional Plans in the Truckee Meadows

The implementation of this manual is relevant to specific goals within the Truckee Meadows Regional Plan and the 2004-2025 Washoe County Comprehensive Regional Water Management Plan. These plans promote a watershed-based approach to stormwater management, practices that sustain our water resources, improve water quality, and promote infiltration. The Truckee Meadows Regional Plan is a comprehensive plan for development and growth that is required by state law (NRS 278.026). Its most recent version promotes a regional approach to watershed and stormwater management, and implementation of practices that support sustainable water use (e.g., LID practices). The 2004-2025 Washoe County Comprehensive Regional Water Management Plan specifically calls for implementation of LID practices that would enhance groundwater recharge, reduce non-point source pollution, preserve flood plain storage, and protect the Truckee River watershed. Implementing structural controls and LID practices described in this Manual should help the Permittees contribute to and achieve these regional goals.

1.6 Updates and Revisions

The science and technology of stormwater quality improvement is evolving, and new and/or innovative structural controls and LID practices continue to develop, thus, the Permittees will periodically review and update the Manual to include structural controls that are expected to meet the MEP standard. New approved source and structural treatment controls may be periodically added to the regional program website at www.TMstormwater.com.

In addition, the SWMP recommends Permittees to review and update the Manual every five years, to coincide with the five year NPDES permit cycle. The review process should consist of a technical review of the new structural controls used locally, by other communities and recommended by the EPA, as well as a procedural review of how well the Manual is being implemented in the Truckee Meadows. Developers, planners, design engineers and contractors, as well as agency review and inspection staff, should be consulted to determine potential deficiencies and to suggest improvements.

1.7 References

City of Reno Municipal Code: https://library.municode.com/index.aspx?clientId=14160

City of Sparks Municipal Code: https://library.municode.com/index.aspx?clientID=15068&stateID=28&statename=Nevada

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Stantec Consulting Services Inc. 2011. Truckee Meadows Regional Stormwater Quality Management Program, SWMP, prepared for the Truckee Meadows Stormwater Permit Coordinating Committee. December 2011, Reno, Nevada. http://www.reno.gov/home/showdocument?id=33578

Washoe County Public Works Department. 2009. Truckee Meadows Regional Drainage Manual (TMRDM). Reno, Nevada. http://www.washoecounty.us/repository/files/7/tmrdm_final_043009.pdf

Washoe County Development Code: http://www.washoecounty.us/comdev/publications_maps_products/comdevcode/comdevcode_index.htm

2.0 REGIONAL POLICIES AND PROCEDURES

As described in **Section 1**, the Cities of Reno and Sparks and Washoe County (the Permittees) are required under federal and state regulations (U.S. EPA and NDEP) to reduce pollutant loadings in their municipal storm drain systems to the MEP standard. **Section 2** describes the policies and planning procedures that were developed by the Permittees so they can implement and enforce the use of structural controls and LID practices to meet their obligations under the CWA, and protect water resources in the Truckee Meadows.

2.1 Regional Policies and Procedures

The policies and procedures regulating development in the Truckee Meadows region were developed with help from regional practitioners, local industry and agency stakeholders, and municipal governments. The history and development of the Truckee Meadows Stormwater Program is described in detail in **Appendix A**.

The Cities of Reno and Sparks and Washoe County promote the implementation of structural treatment controls and LID practices that are easily inspected and require minimal maintenance, such as vegetated swales, buffer strips, bioretention systems, and porous pavements. These LID practices are desirable because they are above ground, readily inspected and mostly require typical landscaping maintenance.

Structural control and LID practices should be implemented in a way that is consistent with regulations, codes and ordinances, and policies. To help this occur, the Cities of Reno and Sparks and Washoe County review the structural controls and LID practices that are proposed in various plans and permit applications for new and redevelopment. The plans that are reviewed include tentative, final, parcel and subdivision maps, site plans, drainage plans, and erosion and sediment control plans.

The Permittees also review and approve permits for construction activities including grading, site development, building, and encroachment permits. Structural treatment controls and LID practices proposed in project plans, and related drainage reports should match what is presented in the SWPPP or the construction site. A SWPPP must be prepared by owners and/or operators of construction sites of one or more acres or ¼ mile from an impaired water and the SWPPP must describe permanent erosion control measures and structural treatment controls that will be installed to control pollutants in stormwater discharges (General Construction Permit, NDEP Permit No. NVR100000).

The permitting and plan review processes differ between the three Permittee's jurisdictions, due in part to different organizational structures, ordinances, and procedures. However, similar policies and procedures have been developed for installation, operation and long-term maintenance of post-construction BMPs for specific categories of development to meet NPDES permit requirements.

For projects in the City of Sparks, visit the Community Services Department webpage: http://cityofsparks.us/departments/community-services/permits-info

Call 775-353-5555 to request a pre-application meeting to discuss your project, or stop by Permit Services at City Hall: 431 Prater Way, Sparks, NV.

For projects in the City of Reno, visit the Community Development Department webpage: http://www.reno.gov/government/departments/community-development-department/applications-and-documents/building-permit-applications
Call 775-334-2063, or stop by the permit counter on the second floor of City Hall at One East First Street, Reno, NV.

For Projects in Washoe County, browse the Building and Safety webpage: http://www.washoecounty.us/building/index.php
Call 775-328-2020, or visit the Washoe County Offices at 1001 E Ninth Street, Reno, NV.

2.2 Site Suitability

Site suitability is one of the first things to consider when planning to install structural controls and/or implement LID. Existing storm drainage, hydrology, infiltration capacity, and geotechnical factors help determine site suitability. Soil maps can identify areas suitable for infiltration type BMPs. The NRCS has extensive and detailed soil mapping information available on their website (http://websoilsurvey.sc.egov.usda.gov/App/HomePage.htm). Areas having a Hydrologic Soil Group A or B soil classifications may be suitable for infiltration of stormwater and underdrain systems may not be necessary in LID practices such as vegetated swales, bioretention basins and porous pavements. However, additional testing may be required to verify soil infiltration rates at a site where LID practices or structural controls, such as infiltration basins, are proposed. Detailed design guidance for structural treatment controls are provided in **Section 6**.

The design of projects should also attempt to preserve natural drainage ways and groundwater recharge zones where possible. Natural drainage ways can be defined as historic drainage channels. Whether currently active or inactive, historic drainage channels often serve as groundwater recharge zones that should be preserved within site designs whenever possible. Areas defined as significant hydrologic resources in Article 418 of the Washoe County Development Code should also be protected.

Potential groundwater recharge areas may be initially identified on the maps presented in **Appendix F**. Areas identified on these maps as having high or moderate groundwater recharge potential may be suitable for infiltration of runoff and should be discussed in the storm drainage, hydrology, and geotechnical reports developed for proposed projects.

The Cities of Reno and Sparks and Washoe County developed Excel-based Design Guidance Worksheets for the public domain treatment controls. The worksheets have been revised for the 2015 update to this Manual, and are included in **Appendix D**. These standard design forms assist designers and reviewers and ensure that the design criteria established in the Manual are correctly applied. Designers enter site-specific data into an established number of non-write protected cells (e.g., contributing drainage area and percent imperviousness) and the worksheet calculates design parameters, such as required water quality volume (WQ_V) for a bioretention system. The worksheets are available for download from www.tmstormwater.com.

2.3 Development Categories

The development projects that must include structural controls and LID practices are categorized into the following four tiers:

1. Projects that will disturb one or more acres of land.
2. Projects that will include constructed open channels and local or regional detention basins for flood management.
3. Projects that will include industrial, commercial or civic facilities.
4. Projects that will be located within or directly adjacent to environmentally sensitive areas.

These development categories are described below, including examples of applicable structural treatment controls. The structural treatment controls are referenced by an alphanumeric value and are described in detail in **Section 6** of this Manual.

Tier 1 - Projects that will disturb one (1) acre or more of land (see exemption below) will be required to reduce runoff peaks and volumes to pre-developed levels and incorporate design features and practices that will address water quality. BMPs that minimize directly-connected impervious surfaces and reduce effective imperviousness include directing roof runoff to landscaped areas, grading impervious surfaces to drain to landscaped areas and other pervious surfaces, incorporation of curb cuts, reduced pavement area, and the use of vegetated swales (TC-10), buffer strips (TC-11), bioretention systems (TC-30), and porous pavement (TC-62). Pavement area can be reduced by the use of smaller roadway cross sections for roadways and driveways. Porous pavement (asphalt and concrete) can be used in low-traffic areas such as parking areas and walkways. Vegetated buffers and swales can be used to convey runoff from impervious areas prior to discharge to additional structural controls or the conventional storm drainage system. Bioretention systems can be used to capture and filter runoff prior to infiltration or drainage to the conventional storm drainage system, depending upon the infiltration capacity of underlying site soils. Bioretention systems can be implemented at the perimeter of parking lots, within parking lot islands, roundabout islands, and roadway medians and anywhere landscaped areas are located adjacent to and down gradient of impervious surfaces. In addition to reduced pollutant loads, implementation of these practices will reduce rate and volume of runoff and potentially the extent and size of downstream storm drain infrastructure and detention basins.

Exemption: Unless determined otherwise by the applicable jurisdiction, individually owned and constructed single-family homes that are not part of a larger plan of development will be exempt from requirements to implement structural treatment controls and/or LID practices. This includes individual parcel map lots. However, individual lots that are part of a larger subdivision are not exempt.

As the size and complexity of proposed projects increase, structural treatment controls and LID practices such as infiltration systems (TC-20 and 21), extended detention basins (TC-40 and 41) and media filtration systems (TC-60, 61 and 62) should be considered. Stormwater ponds and wetlands (TC-50 and 51) may also be considered at areas that have a perennial water source.

Tier 2 - Projects that include constructed open channels will be required to incorporate the permanent erosion control BMPs noted in the Truckee Meadows Construction Site Best Management Practices Handbook (2015). Developers should either protect existing drainage ways to reduce erosion, or alter drainage alignments and design channel features to reduce erosion and improve water quality (e.g., vegetated swales). Permanent erosion control BMPs such as Riprap (EC-7) and Revegetation (EC-8) should be used to stabilize all open channels located within or directly adjacent to a proposed project. If natural topography and site constraints require additional structures to prevent erosion, these structures must follow the design standards of the City of Reno Public Works Design Manual (2009) and the Truckee Meadows Regional Drainage Manual (TMRDM) (2009 or the most current edition)

Projects that will include local or regional detention basins will be required to incorporate water quality outlet structures such as those noted in the current version of the Structural Controls Design Manual – TC-40 Sedimentation Basins.

Tier 3 - Projects that will include outdoor storage of equipment or materials, or will conduct activities that could produce stormwater pollution will be required to incorporate the applicable source control measures presented in **Section 5** of this Manual. These include Outdoor Material Storage (SC-20), Outdoor Material Loading/Unloading (SC-21), Fueling Areas (SC-22), Outdoor Work, Maintenance and Wash Areas (SC-23), Spill Prevention, Containment and Cleanup (SC-24), and Waste Handling and Disposal (SC-25). This tier applies to industrial facilities that have been assigned Federal SIC codes as well as properties defined as industrial by business licenses or zoning codes.

If a project will include outdoor storage of equipment or materials or fueling areas that could produce significant spills and stormwater pollution within the drainage area of the BMP, infiltration systems should ***not*** be used. Wherever there is a concern that infiltration of stormwater may impact groundwater quality, impermeable liners should be incorporated into practices such as bioretention systems (TC-30), extended detention basins (TC-40 and 41) or media filtration systems (TC-60, 61 and 62), if they are used.

Tier 4 - Projects that will disturb less than 1 acre of land that will also be located within or directly adjacent to environmentally sensitive areas such as areas of significant hydrologic resources, the Truckee River or stream buffer zones as defined by local ordinances such as Article 418 of the Washoe County Development Code, may be required by the local jurisdiction to incorporate the same BMPs as required under Tiers 1 through 3.

2.4 Construction Inspection

The Cities of Reno and Sparks and Washoe County are considering development of inspection programs for the construction of BMPs, including structural treatment controls and LID practices to ensure these facilities are constructed according to design specifications, and to assess their effectiveness. GPS coordinates of completed structural controls and LID practices may be required by the appropriate jurisdiction to assist with tracking and maintenance for these BMPs. Construction site inspections are used to demonstrate compliance with CGP and MS4 permit requirements, and local codes and ordinances. Improperly constructed facilities may become a nuisance, a public safety hazard or an additional source of stormwater pollution.

2.5 Tracking and Maintenance Notification

The Cities of Reno and Sparks and Washoe County are required to provide a description of the structural and source control measures expected to reduce pollutants in runoff from commercial and residential areas, a description and schedule for maintenance activities, and an estimation of the expected reduction of pollutant loads. A Geographical Information System (GIS) and permit database system may be used to track the type, location and ownership of structural treatment controls and LID practices implemented throughout the Truckee Meadows. The tracking system may be used by the Cities of Reno and Sparks and Washoe County for scheduling maintenance and enforcement procedures, and documenting compliance with NPDES permits.

The Cities of Reno and Sparks and Washoe County are considering the implementation of automated systems that may be used to notify annually owners of required maintenance for their stormwater treatment controls. Local jurisdiction may also conduct periodic spot inspections to verify that treatment controls have been maintained and are operating properly. Notifications may also advise BMP owners of upcoming BMP maintenance training sessions. Training sessions may also be advertised on the regional program website www.TMstormwater.com.

2.6 Operation and Maintenance

Every stormwater system, whether for drainage or treatment, needs to be properly maintained to function as designed. Regular maintenance reduces or eliminates costly repairs, flooding and ponding, and the likelihood that accumulated sediment and debris, particularly at industrial sites, will require disposal as hazardous waste. The Cities of Reno and Sparks and Washoe County are required to maintain and operate municipal facilities that are installed or used by the Permittees in order to comply with the MS4 permit and to effectively reduce the pollutants in stormwater runoff.

At private developments where stormwater treatment controls are required, development and implementation of an operation and maintenance (O&M) plan and good recordkeeping is required to assist BMP owners and operators with facility maintenance. An O&M plan must be

prepared at the time new stormwater drainage and treatment systems are designed and should follow the inspection and maintenance procedures outlined in **Section 6** of this Manual. At a minimum, the O&M plan will include a site map showing the storm drainage system, structural treatment controls and LID practices, a listing of the source controls, maintenance procedures and inspection frequencies, safety information and responsible personnel.

The long-term O&M of structural treatment controls and LID practices will be the responsibility of the owners of industrial, commercial and civic/municipal properties. The owner can contract this responsibility to a qualified operator. Operators are considered qualified if they have attended local BMP maintenance training seminars and received a certificate of completion, or have obtained equivalent training (See **Section 2.8** Training and Education for more detail). The operation and maintenance of structural treatment controls and LID practices should not become the responsibility of private residential landowners or Home Owners Associations (HOAs) without a funding mechanism to ensure maintenance is accomplished.

Some developments may be required to execute an access and maintenance agreement allowing the local jurisdiction to access the site for inspections to ensure that treatment controls are properly maintained. **Appendix E** provides an example Stormwater Treatment Device Access and Maintenance Agreement.

2.7 Inspection and Enforcement

Existing legal mechanisms and agency inspection and enforcement procedures will be applied to ensure that structural treatment controls and LID practices are maintained properly and continue to function as designed. The frequency of agency inspections will be based on land uses within the contributing drainage area, the size of the drainage area, the type of BMPs utilized, and whether public complaints are received. At industrial and commercial sites, the stormwater discharge permit classifications presented in the updated Reno, Sparks and Washoe County ordinances will be applied to determine frequency and level of inspections by Environmental Control staff. At residential developments, inspection of structural treatment controls and LID practices will be required if public complaints are received (e.g., spills, odors, ponding, mosquitoes, etc.).

Stormwater treatment controls at commercial establishments in the Cities of Reno and Sparks and Washoe County are permitted and inspected as a condition of the business license. If a complaint is received and/or visual observations indicate a BMP needs to be maintained, the agency inspector will work with the property owner and/or operator to discuss maintenance requirements, provide references for more information, and given an implementation timeline to meet prior to a re-inspection by the agency. If upon re-inspection the facility has not been maintained, a Notice of Violation will be issued to the owner and/or operator and an inspection fee may apply, and if non-compliance continues, it may result in additional fines and/or sanctions.

2.8 Training and Education

Training may be provided for designers and planners of new residential, commercial and industrial developments as well as the owners and operators of these developments. The Cities and County may consider the development of two annual training sessions. One training session will focus specifically on the proper design and construction of structural treatment controls and LID practices for engineers, planners, landscape architects and agency plan review staff. The other sessions will be geared toward the proper operation and long-term maintenance of these BMPs for property owners, operators and agency inspection and maintenance staff. City and county planning, engineering and maintenance staff should attend both training sessions so that all departments have consistent plan review procedures, design standards, and information about required long-term O&M. Inspectors and maintenance staff responsible for the maintenance of publicly owned BMPs should provide feedback to engineers and planners about field observations that can help in the development of improved design standards. It is recommended that attendees of locally developed training sessions receive a certificate of completion that can be attached to SWPPPs, drainage hydrology reports and other development submittals. Training sessions may also be provided by private professional organizations.

2.9 Public Reporting

Currently, the Cities' Environmental Control teams and the County's Community Services Department, receive and respond to complaints regarding illegal dumping and improper storage of chemicals and other materials. A centralized phone hotline was developed for public reporting of all water quality concerns and complaints by City of Reno, named “Reno Direct,” at (775) 334-INFO. The illegal dumping of unknown substances and discharges of non-stormwater substances to the storm drain system in the Truckee Meadows should immediately be reported to the Washoe County District Health Department, Environmental Health Services Division at (775) 328-2434, Sparks Environmental Control at (775) 691-9227, or to Reno Direct at any hours for central dispatch to the proper agencies.

2.10 Additional Resources

This Manual is considered the most up-to-date guidance documentation for the Truckee Meadows region; however, the following agencies can complement what is provided herein.

The NRCS is a division of the United States Department of Agriculture and its primary function in Nevada is to provide assistance to agricultural projects. However, the NRCS also provides local soil survey information to contractors and design engineers working on public and private construction projects.

Natural Resource Conservation Service
1365 Corporate Blvd.
Reno, NV 89502-7102
Phone: (775) 857-8500 Fax: (855) 816-0893

Current Contact: Vinh Hoang, State Conservation Engineer
vinh.hoang@nv.usda.gov
Website: http://www.nrcs.usda.gov/

The NDEP, Bureau of Water Pollution Control is the state agency responsible for issuing the Municipal Stormwater Permit (NVS000001) to the Cities and the County as well as the General Permits for Stormwater Associated with Construction Activity and Industrial Activity (NVR100000 and NVR050000, respectively). As such, NDEP can provide guidance to contractors and design engineers with permit requirements, preparing SWPPPs and appropriate BMP selection. The NDEP website also provides a significant amount of information about the state and EPA stormwater programs.

Nevada Division of Environmental Protection
Bureau of Water Pollution Control
901 S. Stewart Street, Suite 4001
Carson City, NV 89701
Phone: (775) 687-9440 Fax: (775) 687-4684
Current Contact: Mr. Chris Gravenstein, Technical Services, Compliance and Enforcement
Email: cgravenstein@ndep.nv.gov
Website: http://ndep.nv.gov/bwpc/bwpc01.htm

The Nevada Division of Forestry (NDF) is a state agency and its primary function is to protect, manage and enhance the state's forests, rangelands, and watersheds. BMP guidance is also provided under NRS 528 for construction sites proposing to convert forestlands to non-forest uses. NDF manages the Urban Forestry Program and provides guidance on planting and protecting trees. The agency also manages the Nevada Seed Bank and the Nevada Tree Nursery, which can supply locally adapted seed or plant material. NDF has also worked on revegetation projects in the Truckee Meadows with the Nature Conservancy, USFWS, and Washoe County Parks. NDF is familiar, and can provide assistance with local soils, native vegetation, and effective methods of controlling erosion and sediment transport at construction sites in the Truckee Meadows.

Nevada Division of Forestry
State Headquarters
2478 Fairview Dr.
Carson City, NV 89701
Phone: (775) 684-2500 Fax: (775) 687-2570
Current Contact: John Christopherson, Resource Program Manager
Website: http://www.forestry.nv.gov/

The Truckee Meadows Water Authority (TMWA) provides local landscape information that can be used to guide contractors, landscape architects and landowners with revegetation and final site stabilization efforts. TMWA's Landscape Information Package includes an "Irrigation and Design Guide", a "Plant Guide" and a "Maintenance and Planting Guide" with recommended hardy water-efficient plants and tips to design and maintain a robust landscape in the arid climate of the Truckee Meadows.

Truckee Meadows Water Authority
1155 Corporate Blvd.
Reno, NV 89502
Phone: (775) 834-8000 Fax: (775) 834-8003
Website: http://www.tmh2o.com

Wilbur D. May Arboretum and Botanical Gardens/Washoe Regional Parks and Open Space, conducts educational classes on erosion and sediment control, landscaping techniques, home irrigation design, turf alternatives and xeriscape gardening. The Botanic and Demonstration Gardens at the May Arboretum also provide numerous examples of local plants and other species that grow successfully in the Truckee Meadows.

Wilbur D. May Arboretum
Located at Rancho San Rafael Park
1595 N. Sierra Street
Reno, NV 89503
Phone: (775) 785-4153 Fax: (775) 785-4707
Current Contact: Bill Carlos, Horticulturist Email: Bcarlos@washoecounty.us

2.11 References

City of Reno Municipal Code: https://library.municode.com/index.aspx?clientId=14160

City of Sparks Municipal Code:
https://library.municode.com/index.aspx?clientID=15068&stateID=28&statename=Nevada

NDEP. 2010. Permit No. NVS000001 Permit for Authorization to Discharge from Municipal Separate Storm Sewer Systems to Waters of the United States under the National Pollutant Discharge Elimination System. Carson City, Nevada. http://ndep.nv.gov/bwpc/tmms4perm.pdf

NDEP. 2007. Stormwater General Permit NVR100000 (Construction). Carson City, Nevada. http://ndep.nv.gov/bwpc/conperm02.pdf

Stantec Consulting Services Inc. 2011. Truckee Meadows Regional Stormwater Quality Management Program, SWMP, prepared for the Truckee Meadows Stormwater Permit Coordinating Committee. December 2011, Reno, Nevada. http://www.reno.gov/home/showdocument?id=33578

Washoe County Department of Water Resources, University of Nevada Cooperative Extension, Washoe Storey Conservation District, 2003. Watershed Management and Protection Plan for Tributaries to the Truckee River.

Washoe County Development Code:
http://www.washoecounty.us/comdev/publications_maps_products/comdevcode/comdevcode_index.htm

3.0 STORM WATER QUALITY MANAGEMENT

This section describes the common effects of urbanization on natural waterways and specifically how the water quality of the Truckee River is impacted by urban runoff in the Truckee Meadows. Local climate data is analyzed and the concept of Low Impact Development is introduced.

3.1 Environmental Impacts of Untreated Urban Storm Water Runoff

Urbanization and industrial activities have significantly altered the natural landscape of our nation's watersheds, which can have negative physical, chemical, and biological impacts to water resources. Urbanization reduces pervious land surfaces that would otherwise infiltrate and treat runoff, increases land surface susceptibility to erosion and sediment transport, and increases pollutant loading in urban runoff. **Figure 3-1** compares typical hydrographic responses to a storm event occurring in urbanized (post-development) and un-urbanized (pre-development) areas. Runoff and peak flow rates tend to increase as areas are urbanized because runoff is not infiltrated by impervious surfaces such as roofs, parking lots and roadways. Conventional storm drain systems were designed to efficiently drain urbanized areas and rapidly transport stormwater, which results in increased peak flow rates and more frequent, flashier flows after development. The reduction of natural land surfaces that previously infiltrated a portion of the annual rainfall into pervious soils and recharged groundwater aquifers which slowly discharged to streams and rivers has resulted in decreased baseflows and changes to stream channel morphology.

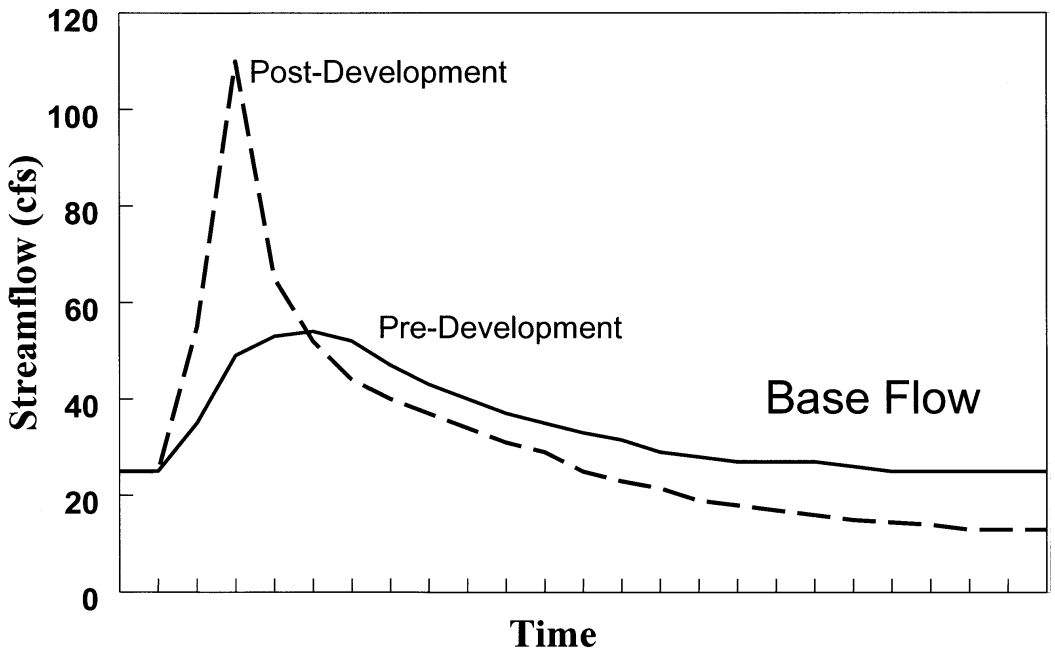

Figure 3-1. The hydrographic response of urbanization within a hypothetical watershed. Source: The Center for Watershed Protection

Urbanization also affects the water quality of receiving waters in an urbanized watershed. Increased pollutants in stormwater adversely affect both the quantity and the quality of stormwater runoff and can degrade the chemical, physical, and biological health of receiving waters. In the Truckee Meadows Region, these are important assets to the community and the economy. The Nationwide Urban Runoff Program (NURP) study (U.S. EPA, 1983) and Center for Watershed Protection (2003) have demonstrated that that stormwater from urbanized areas contain elevated levels of heavy metals, synthetic organics, pesticides and fertilizers, oil/grease, sediments, and bacteria. These pollutants are deposited on developed impervious surfaces by a variety of mechanisms (e.g., deposition, spills, leaks, etc.) and become incorporated into stormwater runoff. During a storm, water accumulates and collects these pollutants as runoff flows over impervious surfaces, until the polluted stormwater runoff is ultimately discharged into receiving waters. **Table 3-1** lists pollutants commonly found in urban stormwater, the major sources and their potential environmental impacts.

Table 3-1. Common Pollutants in Urban Runoff

Pollutant	Major Sources	Potential Effects
Nutrients • **Nitrogen** • **Phosphorus**	• Fertilizers • Animal Waste • Detergents • Atmospheric deposition • Leaking sewage pipes	• Lowers oxygen levels • Destroys habitat • Promotes algal blooms • Limits recreation • Interferes with navigation
Pathogens • **Bacteria** • **Viruses**	• Animal waste • Illicit connections between storm sewers and sewage lines • Leaking sewage pipes	• Poses human health risks • Closes beaches • Closes shellfish harvesting areas
Hydrocarbons • **Oil** • **Grease** • **Petroleum-based products** • **Polycyclic aromatic hydrocarbons (PAHs)**	• Parking Lots • Roads • Automobile emissions • Improper disposal of used motor oil • Illicit connections to drain systems	• Lowers levels of dissolved oxygen • Causes toxic impacts • Damages habitat
Toxic Organics • **Pesticides** • **Polychlorinated biphenyls (PCBs)**	• Lawn care • Agricultural lands • Industrial uses • Illicit connections to storm drain systems	• Causes toxic impacts • Leads to human and animal reproductive abnormalities • Increases animal mortality rates
Sediments	• Construction sites • Agricultural lands • Logged forest lands • Eroded stream banks	• Increases water turbidity (cloudiness) • Alters water flows • Destroys benthic habitat • Blocks sunlight • Attracts particulate forms of metals and nutrients

Pollutant	Major Sources	Potential Effects
Metals • **Lead** • **Copper** • **Cadmium** • **Zinc** • **Mercury** • **Chromium** • **Selenium** • **Nickel**	• Illicit storm drain connections • Automobile usage – emissions, brake pad residues • Atmospheric deposition • Industrial activities • Commercial activities	• Increases toxicity of sediment and water column • Adds toxics to food chain • Causes genetic defects, reproductive abnormalities and increased mortality rates among fish and wildlife • Increases risks of cancer, neurological disorders and birth defects among humans
Litter	• Human activities	• Aesthetic • Impairs recreational uses • Threatens aquatic life
Chlorides	• Outdoor storage and use of salts on roads, driveways and sidewalks in cold areas	• Toxic to freshwater organisms
Elevated Temperatures	• Industrial sources • Removal of trees next to streams and rivers • Impervious surfaces and conveyances	• Threat to insects, fish and other temperature sensitive aquatic species

Sources: Terrene Institute, 1996; U.S. EPA, 1995

The biological health of a waterbody is often affected by flow-alterations and increased pollutant loads associated with urban runoff from impervious surfaces. Effects to river systems include sedimentation, increased water temperature, and loss of aquatic populations. Macroinvertebrates, fish, and aquatic vegetation can all be used as indicators of aquatic ecosystem health and stream function. USGS studies such as the National Water Quality Assessment (NAWQA) program use some of the biological indicators and have observed impacts to macroinvertebrate and fish populations in urban areas in Eastern Washington (USGS, 2003). Lamphere et al. (2006) found that fish and invertebrates both exhibited a strong decline in biotic integrity because of urbanization.

3.2 Storm Water Pollution and the Truckee Meadows

The Truckee Meadows is located in a semi-arid high desert area with an average annual precipitation of approximately 7.5 inches (WRCC, 2003). The Truckee River flows through the Truckee Meadows and provides approximately 75% to 90% of the area's drinking water supply (TMWA, 2003). A majority of urban runoff in the Truckee Meadows flows into municipal storm drains and discharges to Truckee River and its tributaries untreated.

Under the Federal CWA, the NDEP is required to develop a listing of all the impaired water bodies in the state. The Truckee River and many of its tributaries throughout the Truckee Meadows appear on this list. In NDEP's 2012 Water Quality Integrated Report, the Truckee River from the Nevada-California state line through Wadsworth are assessed as not

supporting aquatic life due to elevated temperatures. The reaches from the eastern Truckee Meadows to Wadsworth have been assessed as not supporting recreation that involves contact with water due to excessive loading of nitrogen and phosphorus and total dissolved solids (TDS). A number of tributaries to the Truckee River, including Galena Creek, Steamboat Creek, Whites Creek, and Thomas Creek, have been listed on the 303(d) list for a variety of constituents ranging from E. coli and pH to metals such as Mercury and Arsenic.

Total Maximum Daily Loads (TMDLs) on the Truckee River were established in 1994 for total nitrogen (TN), total phosphorus (TP) and TDS for the reaches between the eastern edge of the Truckee Meadows and the Pyramid Lake Reservation (NDEP, 2012). Downstream of the Truckee Meadows, the river flows to Pyramid Lake, a terminal lake within the Pyramid Lake Paiute Indian Tribal Lands. The Tribe has historically relied on the Pyramid Lake fishery and remains active and engaged in water rights and water quality issues related to the river.

Nutrient concentrations in the Truckee River are collected by the Truckee Meadows Water Reclamation Facility (TMWRF) and NDEP once a month at locations upstream and downstream of the Truckee Meadows. Based on data from 2004 to 2012 shown in **Figure 3-2**, nutrient concentrations measured at Vista, downstream from Reno and Sparks, are significantly greater than upstream concentrations measured at Farad. **Figure 3-3** also shows that bacteria and TDS increase in the urban areas. There are increased concentrations of various water quality constituents as the Truckee River flows through the Reno/Sparks urban area. These general trends are associated with numerous effects of urbanization, including increased stormwater runoff.

In addition to pollutant concentrations increasing in the urban area, biological data also show that degraded conditions occur in the urban portions of the Truckee River. USGS has collected macroinvertebrate and fish species in the Truckee River upstream and downstream from the Reno/Sparks urban area since 1991 to evaluate river water quality (Bevins and Kilroy, 1991; Lawrence and Seiler, 2002). Higgins et al (2006) found a decline in biological integrity as the Truckee River travels through the Reno/Sparks urban area, with a reduction in fish species and abundance and a fish IBI score steadily decreasing from Verdi to Marble Bluff Dam (near Pyramid Lake). Low quality physical and chemical habitat downstream from the Reno/Sparks urban area has likely had negative impacts on fish populations (Higgins et al., 2006).

A number of recent projects and programs have been advanced to address the effects of urban drainage and hydromodification on the Lower Truckee River. Anecdotal evidence from the Nature Conservancy's McCarran Ranch restoration project, for example, suggests that improved habitat and water quality may be reversing some of the negative trends in biological integrity described above.

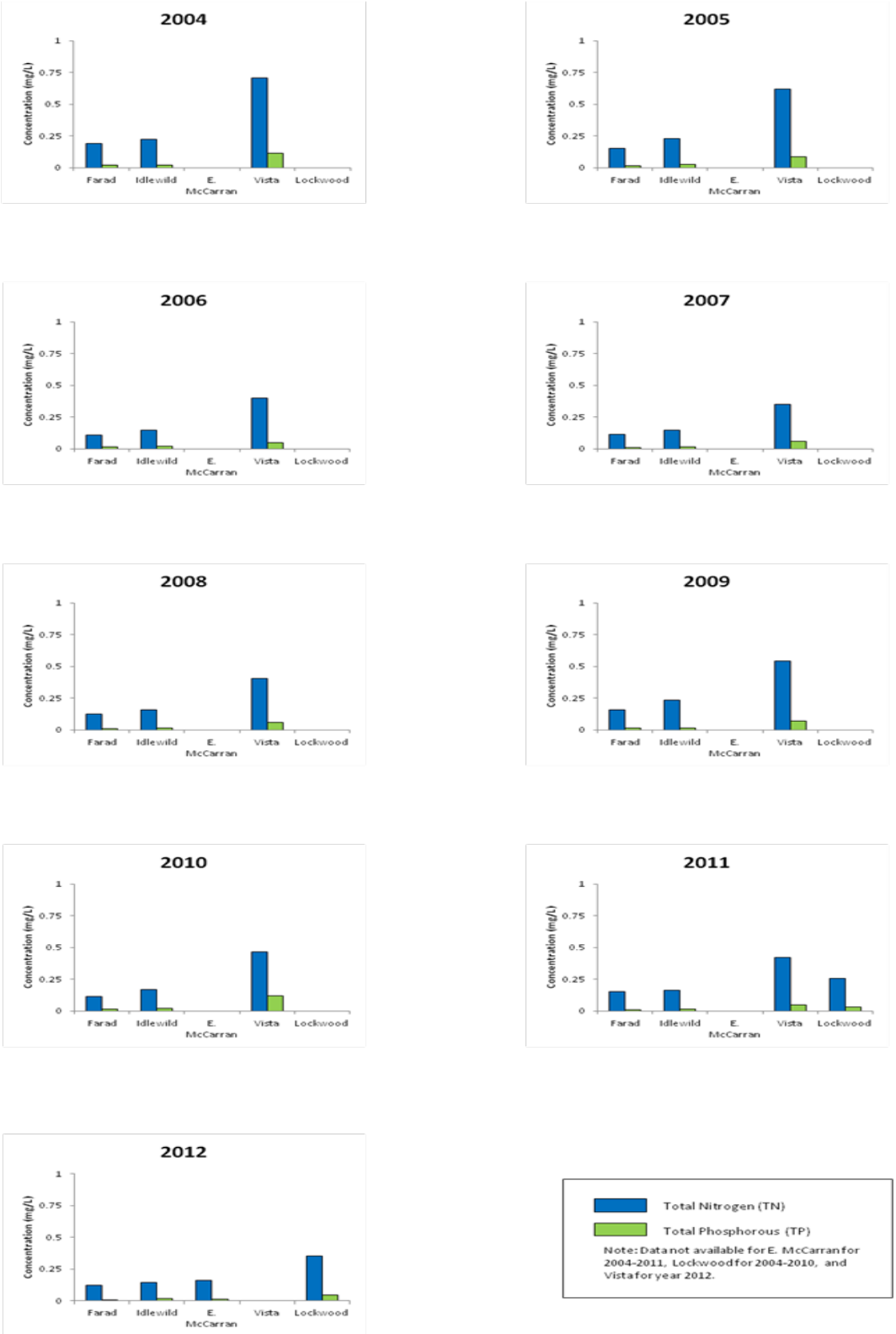

Figure 3-2. Annual average concentrations of TN and TP measured from upstream of Reno/Sparks urban area (at Farad) to downstream of the urban area (at Lockwood). Data from NDEP and (TMWRF)

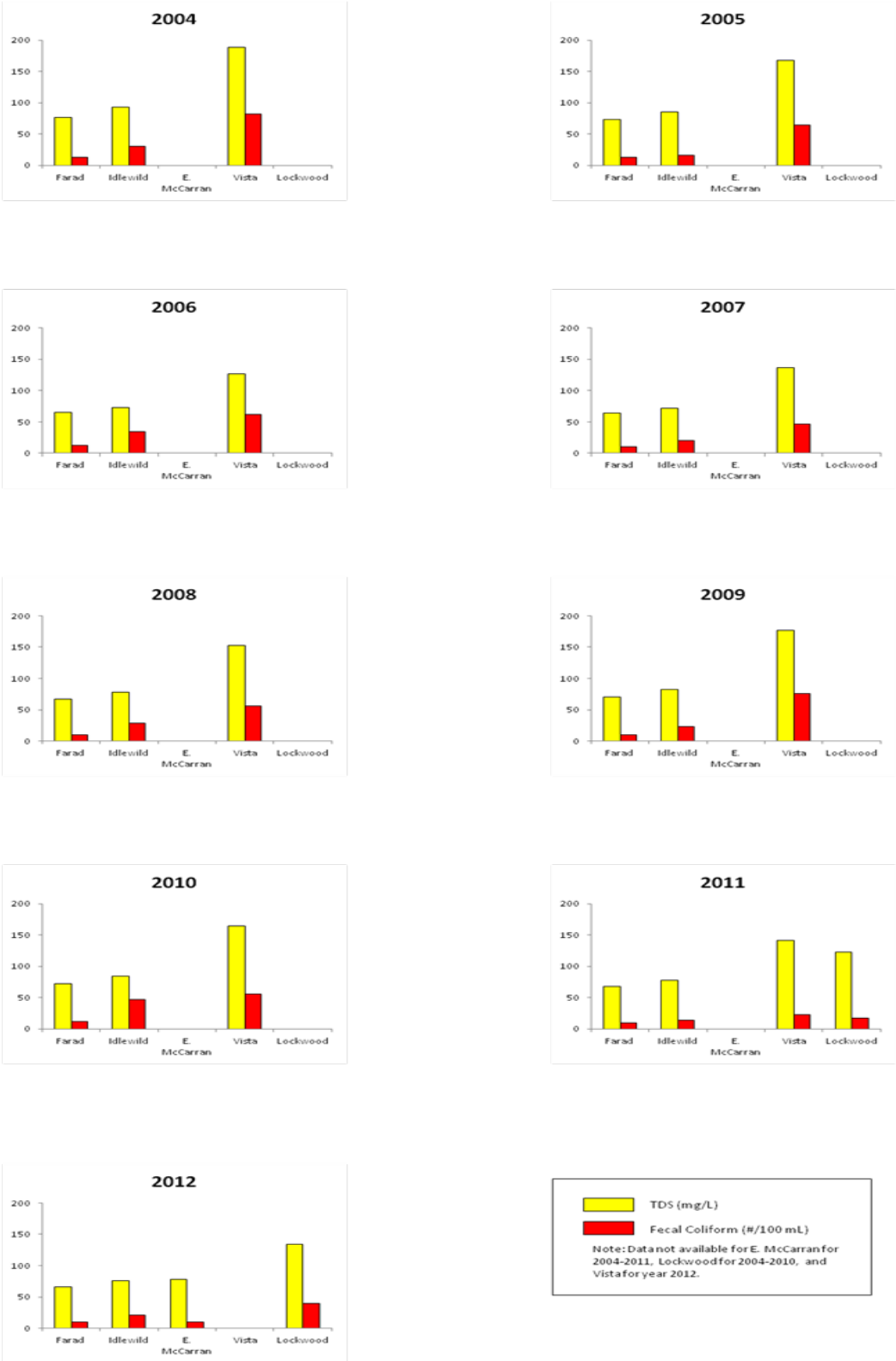

Figure 3-3. Annual average concentrations of TDS in mg/L and Fecal Coliform (in #/100 mL) measured on the Truckee River from upstream of the Reno/Sparks urban area (at Farad) to downstream of the of the Reno/Sparks urban area (at Lockwood). Data from NDEP and TMWRF.

3.3 Storm Water Quality Hydrology of the Truckee Meadows

Sections 3.1 and **3.2** describe how urbanization in the Truckee Meadows has resulted in increased runoff volumes, increased peak flows, and increased pollutant loads to receiving waters. Although individually, residential homes or businesses typically contribute relatively small amounts of additional runoff and pollutants, collectively untreated stormwater runoff from urban and suburban areas has been shown to have significant impacts on water resources.

Since pollutants tend to accumulate on urban surfaces over time, the majority of pollutants are typically transported during the "first flush", which is generally assumed to occur within the first 0.5 inches of rainfall. Higher pollutant loads also occur with the first storm that follows an extended dry period (e.g., 7 days or more). Therefore, stormwater treatment controls are most efficient and cost effective when they are sized to capture or convey and treat the most frequently occurring storm events as well as the first 0.5 inches of runoff from the majority of runoff producing storm events.

In order to develop sizing criteria to support cost effective and efficient stormwater control design, precipitation patterns in the Truckee Meadows were analyzed. Average annual precipitation in the Truckee Meadows can range from 6.5 to 12 inches per year. The Reno-Tahoe Airport precipitation gage has the longest period of record in the region and collects hourly rainfall data; based on data from this gage collected in 1937 to 2003, the region received an average of 7.3 inches per year. Continuous precipitation data recorded at the Reno-Tahoe Airport gage from 1948 to 2003 were analyzed to develop the structural control design criteria in this Manual.

Figure 3-4 presents the observed distribution of storm events at the Reno Tahoe International Airport from 1948 to 2002, assuming a 6-hour Minimum Inter-event Time (MIT). Precipitation analyses in the United States typically assume a 6-hour dry period to separate storm events and a minimum depth of 0.05 inches to produce runoff (Driscoll et. al., 1989). This analysis indicates that the majority of storm events in the Truckee Meadows produce less than 0.50 inches of total rainfall. As rainfall depth increases, the total number of storms significantly decreases. Therefore, sizing structural treatment controls for the larger storm events (e.g., storms up to 1.50 inches) may significantly increase the size and cost of structural treatment controls, while the total number of additional storms treated is insignificant. In addition, structural treatment controls designed to capture and treat runoff from the larger storm events typically release smaller runoff volumes over a shorter period of time, providing inadequate detention and treatment from the smaller storm events. This explains why structures designed to detain runoff volumes for the 5, 25 or 100-year storm events typically provide limited treatment for stormwater quality.

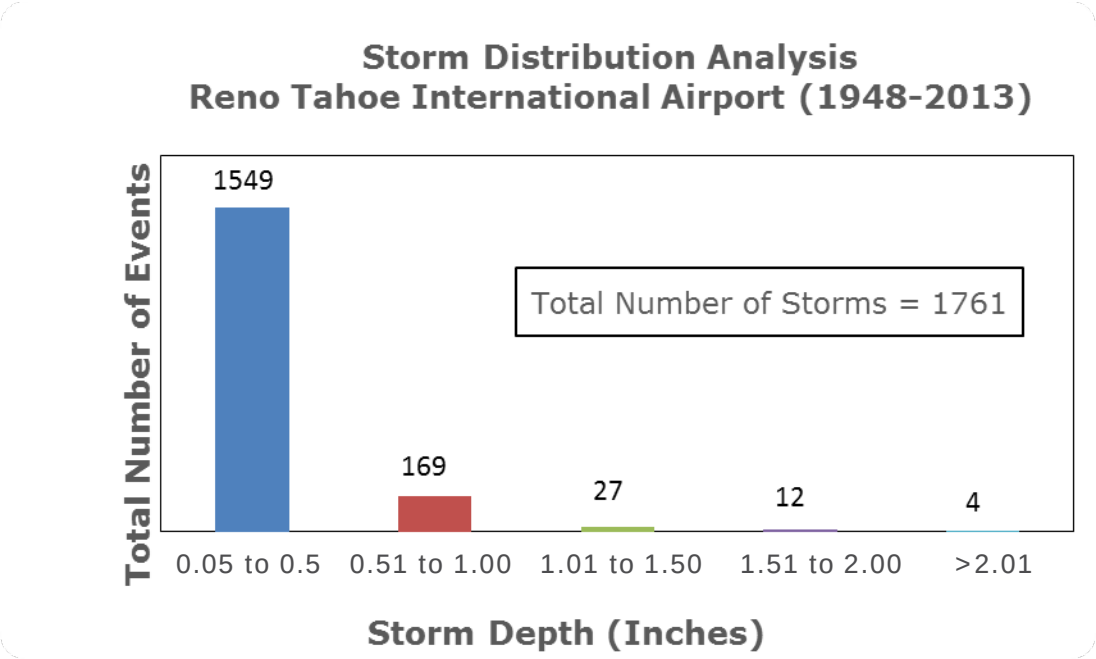

Figure 3-4. Distribution of runoff producing storm events at the Reno Tahoe International Airport (assuming a 6-hour MIT).

Figure 3-5 presents a precipitation frequency analysis from rainfall at Reno Tahoe International Airport. This analysis assumes a minimum depth of 0.05 inches of precipitation is required before runoff occurs and a minimum 6-hour dry period (MIT) is required to define a new storm event. As storms become larger in magnitude, but occur less frequently, the slope of the curve increases. This transition occurs at point of inflection or the "knee of the curve" where the magnitude of a storm event increases more rapidly than the corresponding number of events. The position of the knee of the curve varies depending on the climatic patterns and precipitation characteristics of the geographic area under analysis. For the Truckee Meadows, the 90th percentile event is approximately at the knee of the curve, corresponding to 0.6 inches of rainfall (**Figure 3-5**).

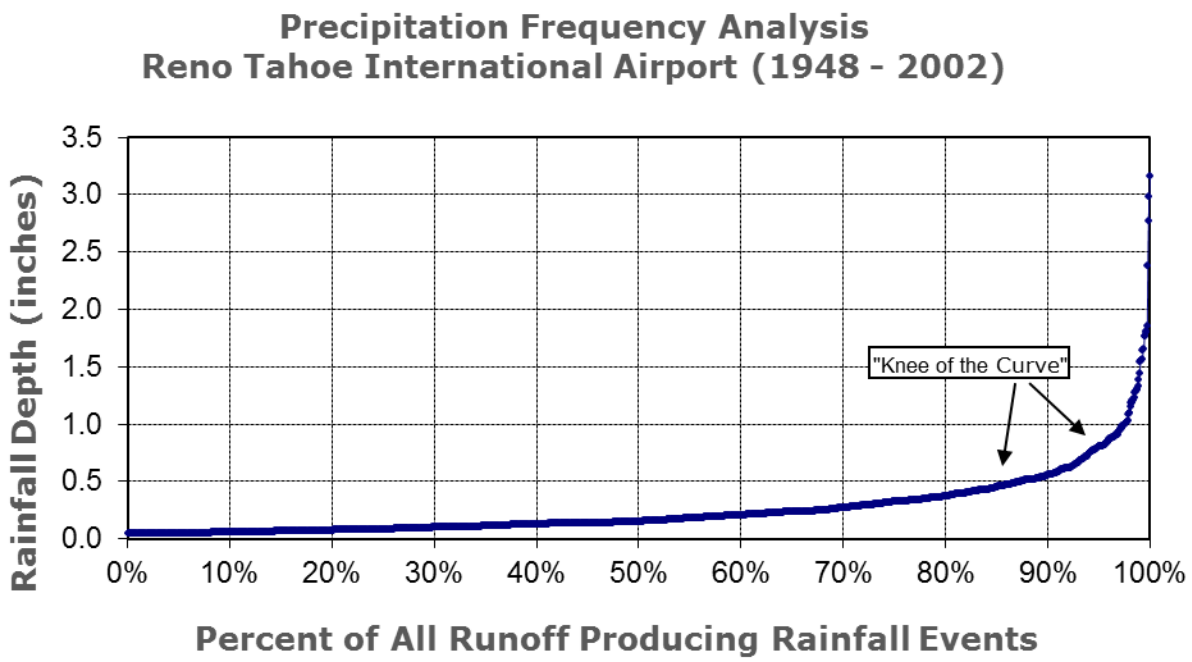

Figure 3-5. Precipitation Frequency Analysis of the runoff producing storm events at the Reno Tahoe International Airport (assuming a 6-hour MIT).

3.4 Pollutants of Concern

In addition to using precipitation analyses to design appropriate source and structural controls, the pollutants that need to be addressed are another important factor to consider when selecting candidate approaches to address stormwater. For the health of the Truckee River in and downstream of the Truckee Meadows, the pollutants of concern that should be considered in the design of stormwater treatment controls generally include phosphorous, nitrogen and sediment. Metals are also of concern in some tributaries to the Truckee River, and BMPs should take into consideration the removal of metals if a particular site has the potential for production of metals in stormwater. Therefore, at a minimum, controls used in the Truckee Meadows should be selected and/or designed to target these pollutants.

To evaluate pollutants of concern and to select appropriate source controls and/or structural treatment controls the project designer should consider the following:

- Pollutants included on CWA 303(d) lists, and pollutants for which TMDLs have been developed, if any, for your waterbody,
- Pollutants associated with the land use type of the development project,
- Changes in stormwater discharge flow rates, velocities, durations, and volumes resulting from the development project,
- Sensitivity of receiving waters to changes in stormwater discharge flow rates, velocities, durations, and volumes.

Table 3-2. Anticipated Potential Pollutants Generated by Land Use Type

Development Type	General Pollutant Catagories								
	Pathogens	Heavy Metals	Nutrients	Pesticides	Organic Compounds	Sediments	Trash & Debris	Oxygen Demanding Substances	Oil & Grease
Detached Residential Development	X		X	X		X	X	X	X
Attached Residential Development	P		X	X		X	X	P(1)	P(2)
Commercial / Industrial Development >100,000 ft^2	P(3)		P(1)	P(5)	P(2)	P(1)	X	P(5)	X
Automotive Repair Shops		X			X(4)(5)		X		X
Restaurants	X						X	X	X
Hillside Development >5,000 ft^2			X	X		X	X	X	X
Parking Lots		X	P(1)	P(2)		P(1)	X	P(5)	X
Streets, Highways & Freeways		X	P(1)		X(4)	X	X	P(5)	X

X = Anticipated

P = Potential

(1) A potential pollutant if landscaping exists onsite.

(2) A potential pollutant if the project includes uncovered parking areas.

(3) A potential pollutant if land use involves food or animal waste products.

(4) Including petroleum hydrocarbons.

(5) Including solvents.

Source: CASQA, 2003

3.5 Planning Principles

Since conventional development methods have been shown to increase runoff, contribute pollutant loads to receiving waters, and reduce groundwater recharge, planning principles for stormwater quality enhancement require different site and facility design considerations. Planning principles for stormwater quality enhancement and protection of local water resources should consist of:

1. Reducing or maintaining post-project runoff to pre-development conditions;
2. Controlling sources of pollutants; and
3. Treating polluted stormwater runoff before discharging it to the storm drain system or to receiving waters.

Planning elements 1 and 2 are considered “source controls” because they emphasize reducing or eliminating pollutants in stormwater runoff at their source by reducing runoff and potential pollutant exposure to rainfall and runoff. Planning element 3 considers the implementation of “treatment controls” that physically or biologically remove pollutants that have already affected stormwater runoff. Some land uses, such as residential developments, can effectively reduce runoff and control sources of pollutants through the implementation of source controls alone. Whereas industrial and commercial land uses may require a combination of source and treatment controls.

Source controls act to prevent stormwater pollution by ensuring that potential pollutant sources are maintained in a manner that reduces exposure. Source controls should be applied in storage areas, fueling areas, and maintenance and work areas, wash areas, waste-handling

areas, and should include the labeling of storm drains. To reduce the volume of stormwater run-on to these areas, berming, grading, and roofing techniques can be applied.

Structural treatment controls are engineered facilities designed for the treatment of stormwater runoff. They use infiltration, retention/detention and biofiltering techniques to remove pollutants. Vegetated swales and buffer strips, infiltration systems, bioretention systems, extended detention basins, ponds and constructed wetlands, media filtration systems, and oil/water separators are examples of structural treatment controls for stormwater quality. They reduce the concentration of suspended solids, particulates, nutrients, metals, organics, and/or bacteria through filtration, absorption, mineralization, and microbial decomposition of pollutants.

3.6 LID, Smart Growth and Sustainable Development

Low Impact Development (LID) is a growing practice in stormwater management. LID principles are modeled after nature to manage urban runoff at the source using local and smaller scale controls than traditional centralized stormwater treatment. The goal of LID is to mimic the predevelopment hydrology of a site by using design practices and techniques that effectively capture, filter, store, evaporate, detain and infiltrate runoff close to its source. Site design features can accomplish these goals by directing runoff to vegetated areas, protecting native vegetation and open space, and reducing the amount of hard surfaces and soil compaction. LID addresses stormwater through small, cost-effective landscape features at the lot level. Urban spaces provide multiple areas to implement LID, including open space, rooftops, streetscapes, parking lots, sidewalks, and medians. LID is a versatile approach that can include both source controls and structural treatment controls and be applied equally well to new development, urban retrofits, redevelopment, and revitalization projects. LID and Green Infrastructure (GI) principles and techniques are discussed in detail in **Section 4** of this Manual.

3.7 References and Additional Information

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Additional Information

Organizations and Resources:	Website:
California Stormwater BMP Handbooks	https://www.casqa.org/resources/bmp-handbooks
City of Sparks Municipal Code	https://www.municode.com/library/nv/sparks
City of Reno Municipal Code	https://www.municode.com/library/nv/reno
Washoe County Development Code	http://www.washoecounty.us/comdev/publications_maps_products/comdevcode/comdevcode_index.htm
Low Impact Development Center	http://www.lowimpactdevelopment.org
Sacramento Stormwater Quality Program	http://www.sacstormwater.org/
Nevada Department of Environmental Protection	http://ndep.nv.gov/bwpc/storm01.htm
Stormwater Manager's Resource Center	http://www.stormwatercenter.net/
US EPA Smart Growth	http://www.epa.gov/smartgrowth/
Truckee Meadows Stormwater Quality Management	http://reno.gov/government/departments/public-works/regional-stormwater-quality-management-program

4.0 LID PLANNING PRINCIPLES AND SITE DESIGN

This section introduces Low Impact Development (LID) and Green Infrastructure (GI) practices that can be integrated with traditional source and structural treatment controls to improve stormwater quality. Planning and design strategies can be used to reduce impervious area in parking lots, streets and roads, and other project elements. A variety of LID treatment techniques can also be incorporated in a site to treat and infiltrate stormwater before it leaves a site.

4.1 LID Site Design Strategies

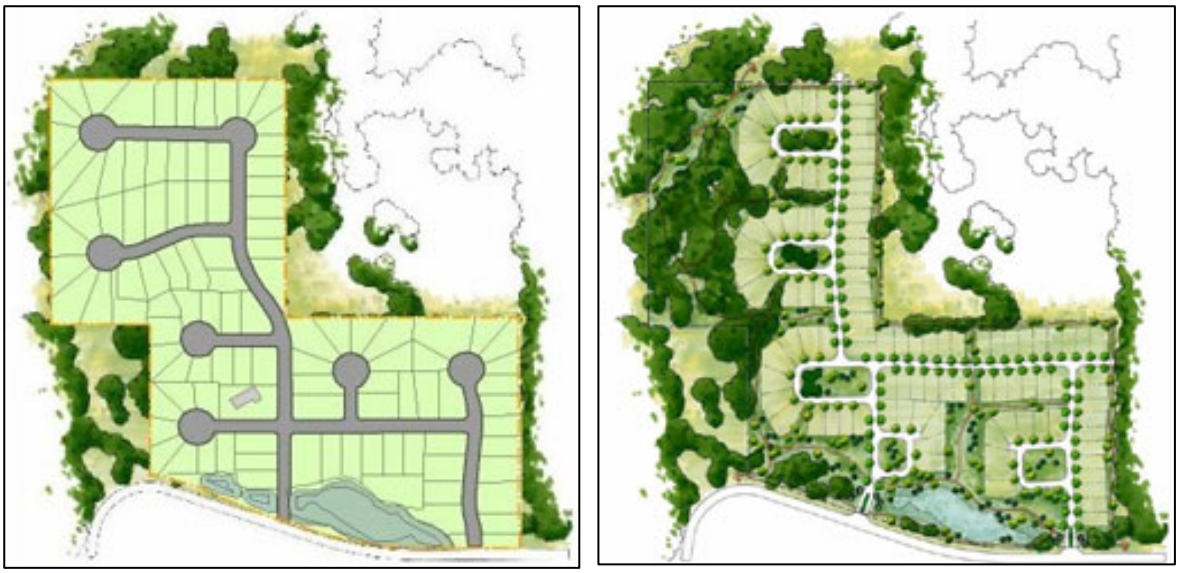
Low Impact Development (LID) is a term that describes site design and source controls that are implemented to maintain pre-development hydrologic functions at a site (e.g., retention, infiltration, evaporation, etc.). The term "Green Infrastructure" (GI) refers to practices that use or mimic natural processes to infiltrate, evapotranspirate, or reuse stormwater runoff on-site. If sited and implemented correctly, LID and GI can minimize post-construction stormwater runoff at new and redevelopment sites. This helps achieve NPDES permit requirements, improve aesthetics, and may reduce the need to build larger centralized stormwater controls.

Case studies have linked urbanization and increased impervious surfaces to hydrologic impacts on streams, reduced water quality, and loss of fish populations (US EPA 1997). Effective impervious areas (EIA) are impervious surfaces that are directly connected to the storm drain system. As EIA increases, so do runoff volumes and peak flows. Where Low Impact Development and Green Infrastructure (GI) are implemented, they can reduce the area of EIA, providing some on-site treatment of stormwater, and reducing stormwater volumes leaving a site. Thus, the use of LID and GI practices has been increasing with the goal to reduce impacts from development and to help achieve stormwater management requirements. These practices are designed to disconnect impervious areas from storm drains, maximize on-site infiltration and conveyance through vegetated features, and maximize open space.

Whether LID practices are suitable at any given site depends on soil type, slope, land uses, water table depth, and maintenance requirements. Existing codes and local ordinances can also dictate the selection and design of LID and GI practices. Regardless of site conditions, these practices where possible, should be designed to protect and preserve natural features and processes that the hydrology of a site, such as riparian areas, vegetated areas, steep slopes, and highly erosive or permeable soils.

LID practices can be implemented at various scales, from large and site-wide to small and at the corner of a lot. Cluster and open space development are examples of implementing LID on a larger scale through a site design. **Figure 4-1** illustrates how the LID site plan positions development to specific area of a site and leaves portions of the development in open space. LID design strategies include smaller lot sizes, minimized setbacks and frontages, alternative

street layouts to reduce road networks. In comparison to a LID site design, LID and GI implemented at the small scale could be an individual rain garden, or vegetated swale, for example. Often these individual LID and GI practices can be combined to form a treatment train to provide more stormwater management benefits. The major types of LID and GI practices include bioretention, vegetative treatments (e.g., vegetated swale, rain garden), rainwater harvesting (e.g., Rain barrels), green roofs, and permeable pavements. The mechanisms that provide stormwater management benefits from these practices include retention, infiltration, evapotranspiration, and flow attenuation. The subsequent sections of this Manual contain planning level information about these common LID and GI practices to understand how they function and to help identify which practices may be suitable for a given site. **Sections 5.0** and **6.0** of the Manual contain design and siting criteria, and maintenance considerations for LID and GI practices, as well as more traditional stormwater controls.



Conventional Site Plan **LID Site Plan Utilizing Open Space and Cluster Development**

Figure 4-1. Comparison of a LID site plan to a conventional site plan on the same site. Source: Puget Sound Action Team.

For LID and GI practices involving infiltration, underlying soil type and water table depths may control the rate and volume of water that can be treated. The NRCS identifies Hydrologic Soil Groups, based on soil textures and their range of infiltration rates (**Table 4-1**). Note that these infiltration rates are approximate and can decrease in areas with a high water table. In general, sites with medium-high infiltration rates (>0.15 in/hr) that are not in an area with a seasonally high water table are good candidate sites for implementing infiltration type practices (See **Section 6.0** for specific details).

Table 4-1. Hydrologic Soil Groups (HSG) and infiltration rates

HSG	Soil Texture	Infiltration Rate
A	Sand, Loamy sand, or sandy loam	> 0.30 in/hr
B	Silt loam or loam	0.15 - 0.30 in/hr
C	Sandy clay loam	0.05 - 0.15 in/hr
D	Clay loam, silty clay loam, sandy clay, silty clay, or clay	0.00 - 0.05 in/hr

4.1.1 LID Parking Lot Design

Parking lots contribute a sizeable area of impervious coverage to a community, and are significant sources of stormwater runoff and the discharge of associated pollutants to the storm drain system and local surface waters. Several strategies can be implemented to mitigate this impact. Impervious surfaces can be reduced by using permeable paving alternatives in overflow parking areas, and landscaped detention (bioretention) basins can be installed in parking lot islands and perimeter landscaping.

Figure 4-2. Parking lot bioretention.

Figure 4-3. Parking grove made of a permeable paving surface. (photo from ToolBase Services)

Reducing impervious area is the most direct method of reducing urban runoff. Research has shown that zoning regulations typically require more parking spaces than are needed. Parking lot size is usually based on peak demand rather than average usage, and creative design can reduce number of parking spaces. Other strategies that can also be implemented to reduce the total parking area include compact parking spaces, a reduction in stall dimensions, and determining the most space-efficient design for parking spaces (e.g., angled or perpendicular). Consideration should be given to design options such as underground parking or multi-storied garages. As noted above, vegetation and landscaping can be designed to intercept rainfall and capture stormwater. Including trees in parking lot landscaping should

also be considered. Trees provide many benefits in parking lots, including stormwater treatment, reducing impervious cover, and reducing the heat island effect.

Design Considerations

- Work with local municipal codes and design standards to find flexibility in parking ratio requirements and reduce impervious parking area. Consider shared parking for businesses with different hours of peak demand. Bus and shuttle services can be provided between commercial centers that only experience peak demands during holidays and parking areas such as government facilities and schools that are typically vacant over holidays.
- Porous surfaces can be installed in down gradient parking stalls and in overflow parking areas. Permeable materials that can be utilized include permeable pavers, porous asphalt, and porous concrete (see **Section 4.4** and TC-62).
- Utilize minimum stall dimensions and compact parking spaces. In larger commercial lots, include compact parking spaces as allowed by local code. Care should be taken to determine the most space-efficient design for parking spaces (e.g., angled or perpendicular).
- Utilize vegetation and landscaping for capture and infiltration of rainfall and stormwater runoff, for impervious surface reduction, and for shading.
- Landscaped detention areas (TC-30, **Figure 4-2**) can be installed within and/or at the perimeter of parking lots to capture and infiltrate runoff. Permeable landscaped areas designed several inches below the impervious parking surface can be delineated by flush concrete curbs, shrubs, trees and bollards (**Figure 4-3**).
- Landscaped detention areas in parking lots can also reduce the icing problems typically associated with conventional mounded parking lot islands. Melting snow stockpiled on landscaped detention areas will tend to infiltrate into the basin, instead of draining onto the adjacent paved surface and refreezing at night.

Examples

- Based on construction cost estimates provided by the City of Reno, storm drainage systems for parking lots with landscape detention basins installed in well-draining soils (see **Section 4.2** 'Bioretention', and TC-30 Landscape Detention) would be expected to cost approximately 50% less than conventional storm drainage systems. Landscape detention basins installed in well-draining soils typically do not include underdrain systems and only a limited amount of conventional storm drain infrastructure. Conventional storm drain infrastructure, such as catch basins and underground concrete pipe, are often one of the most expensive items in conventional parking lot construction. When landscape detention basins are installed in poorly draining soils, such as soils with a high silt or clay content, LID parking lot storm drainage system costs can be higher due to required underdrains and liners.
- The Morton Arboretum in DuPage County, Illinois is a 1700+ acre outdoor museum of woody plants adjacent to Meadow Lake and the East Branch of the DuPage River. When a new visitor center was proposed for the facility, a "green" parking lot was constructed to accommodate the anticipated increase in visitation. A concrete paver

system was utilized for the parking lot, and biofiltration swales were designed along 9-foot parking lot medians to capture and infiltrate runoff. Perforated underdrains were utilized along the length of each biofiltration swale so that run-off entering the drainage system could have a chance to infiltrate back into the ground. A control structure was installed at the downstream end of the system to restrict flows and allow more time for water to infiltrate into the ground, which is removable in case the sub-base becomes over-saturated. Also utilized were grassy filter strips, created wetlands, vegetated channels, and vortex-type oil traps. After a year of use, the paving system continued functioning properly. (Kelsey and Sikich, 2005)

4.1.2 LID Street and Road Design

Streets and roads constitute a significant portion of the impervious coverage in most communities and are one of the largest contributors of runoff and pollutant loads. LID strategies can be applied to street and road design to limit this impact by reducing impervious coverage and maximizing stormwater infiltration and pollutant uptake.

Elements of LID Street and Road Design:

- Consider alternative layouts that reduce impervious coverage by reducing the overall length of the road network. This could be achieved by clustering homes and narrowing lot frontages. Another approach is to lengthen street blocks and reduce cross streets, providing mid-block pedestrian and bicycle paths to increase access.
- Cul-de-sacs create large areas of impervious coverage in neighborhoods. Alternatives to the traditional cul-de-sac can reduce impervious coverage and include landscaped center islands with bioretention (shown in **Figure 4-4**).
- Reducing cul-de-sac radius can save impervious area, if allowed by local fire code. A T-shaped hammerhead design or a loop road network may also be considered.

Figure 4-4. Landscaped cul-de-sac.

- Permeable materials such as porous concrete and pavers can be used in alleys and on-street parking.

- Traffic calming features – traffic circles, chicanes, chokers, speed tables, center islands, and speed humps offer the opportunity for stormwater management using bioretention areas or infiltration within these areas while providing pedestrian safety.
- Preserve natural drainage patterns and avoid locating streets in low areas or highly permeable soils where runoff would naturally flow and infiltrate.
- Uncurbed roads – where allowed by local code, build roads without curbs, using vegetated swales as an alternative (**Figure 4-5**). Alternatively, if curbs are required, use curb cuts to divert runoff to a surface swale, instead of entering a catch basin to the storm drain system.
- Concave medians can be designed as depressed areas between adjacent travel lanes, receiving runoff by curb inlets or sheet flow. Concave medians can function as landscaped swales or bioretention facilities.

Figure 4-5. An uncurbed road utilizing a vegetated swale.

Benefits of LID Street Designs:

- Narrower streets slow traffic and increase safety for pedestrians, bicycles and drivers, while reducing paving costs.
- Less runoff generated from decreased impervious surfaces creates a reduction in stormwater runoff, which may reduce expensive stormwater conveyance and treatment infrastructure.

Example of LID Street Design

In Seattle, WA, a pilot project, Street Edge Alternatives Project (SEA Streets), attempts to mimic pre-developmental hydrologic conditions by reducing impervious surfaces 11 percent less than a traditional street, incorporating LID principles such as reducing on-street parking, narrowing street widths, reducing sidewalks, eliminating curbs and gutters by providing surface detention in swales, and adding 100 evergreen trees and 1100 shrubs. One of the most prominent features of the project is the 14-foot wide curvilinear streets, which is wide enough for two standard size cars to pass each other slowly. The edge of the roadway has no curb and has a two-foot grass shoulder capable of bearing traffic loading to accommodate emergency vehicle passage. Parking stalls are grouped between swales and driveways with the number of spaces determined by homeowner needs. The sidewalk also follows a curvilinear design and is only located on one side of the

street. Swales are located in the right of way adjacent to the street to capture runoff from the street, sidewalk and adjacent property. After two years of monitoring, the project has reduced the total volume of stormwater leaving the street by 98 percent for a two-year storm event. (Seattle Public Utilities District, 2003)

Figure 4-6. Images of SEA Project streets (images courtesy of Seattle Public Utilities District)

4.1.3 LID Driveway Design

Driveways add a significant amount of impervious coverage to a community and are an element of a site's design that can be altered to minimize total impervious coverage. Driveways often slope directly to the street and storm drain system and contribute significantly to stormwater pollution. There are several strategies that can be implemented to reduce this impact, including:

- Utilize shared driveways to provide access to several homes.
- Reduce driveway length by reducing front yard setbacks – check municipal development code for minimum setbacks.
- Reduce driveway width by allowing tandem parking (one car in front of the other).
- Install a narrowed driveway with a flared entrance for multi-car garage access.
- If allowed by local code, consider ribbon driveways, which consist of two strips of pavement with grass or some other permeable surface in between the strips. Wheel tracks should be wide enough to accommodate variability in driving and vehicle widths. For soils with low infiltration rates, a perforated drain line buried between the wheel tracks may be appropriate to collect and direct runoff.
- Utilize porous surfaces such as porous concrete or asphalt, or permeable pavers (see **Section 4.4** 'Porous Pavements', and TC - 62).
- Create a temporary parking area where parking or access is infrequent. These areas can be paved with permeable surfaces.

Figure 4-7. This driveway is designed with multiple LID strategies including permeable pavers and a slotted drain built in to catch sediment and runoff, which is funneled into a landscaped area. (Photo courtesy of NEMO Nevada)

Disconnect the driveway from the storm drain system by directing surface flow from the driveway to a permeable landscaped area (see **Section 4.2** 'Bioretention', and TC-30 'Landscape Detention'). The driveway can be graded so that drainage can sheet flow off the edge of the driveway, which should be set approximately 3 inches above adjacent grade so that the vegetation does not impede flow from the driveway.

Alternatively, a slotted channel drain can be installed at or below the surface of the driveway roughly perpendicular to the flow path to capture flow from driveway and direct it to an infiltration system or vegetated area. Slotted channel drains should have removable grates to allow access for cleaning. (**See Figure 4-7**)

4.1.4 LID Sidewalk and Bike Path Design

Sidewalks and bike paths are another source of impervious coverage that can adversely affect water quality by the runoff generated from their surface. Several management opportunities and strategies are available to reduce this impact, including:

- Reduce sidewalk width when possible, or limit sidewalks to one side of the street.
- Utilize pervious materials to infiltrate stormwater and reduce runoff (See **Section 4.4** 'Porous Pavements')
- In some cases, sidewalks and bike paths can be placed between rows of homes instead of alleys or cross streets to provide access and decrease overall impervious area.
- Disconnect sidewalks and bike paths from streets. These narrow surfaces can be graded toward adjacent vegetation to capture, infiltrate, and treat runoff. Bioretention areas and vegetated swales can often be installed between the street and sidewalks or bike paths (see **Section 4.2** 'Bioretention' and **Section 4.3** 'Vegetative Treatments' for more information). Furthermore, a landscaped buffer separating sidewalks and bike paths from roadways will reduce and traffic hazards and improve safety. Select

landscaping in narrow buffer areas to avoid excessive water use and sprinkler "overspray" onto impervious surfaces.

- Install grated infiltration systems in sidewalks and bike paths to receive runoff as sheet flow. These can be installed to protect trees or can provide off-line stormwater management. Grated infiltration systems should include removable grates to allow for maintenance, and must be capable of bearing the weight of pedestrians. For further information on infiltration trenches, see TC-20 'Infiltration Trenches'.

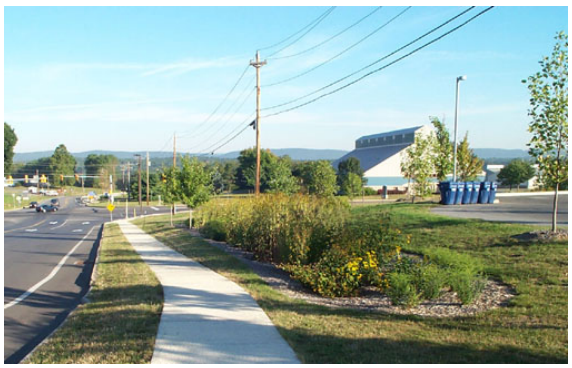


Figure 4-8. This sidewalk at Pennsylvania State University is made of porous concrete. (Photo courtesy of Cahill Associates)

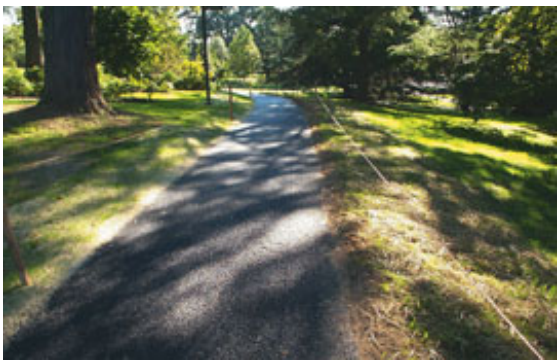


Figure 4-9. This walkway is made of porous asphalt. (Photo courtesy of Stormwater Journal)

4.2 Bioretention

Bioretention systems, also known as landscape detention or rain gardens, capture stormwater and use engineered soils and plants to remove pollutants from runoff through a variety of physical, biological and chemical treatment processes. Bioretention must be engineered using porous soils mixed with organic matter (peat or leaf compost), and typically include a gravel sub-base and a permeable filter fabric liner. To conserve water, bioretention systems should be planted with drought tolerant shrubs and grasses. When the infiltration rates of native soils are slow, landscape detention areas and rain gardens typically require underdrain systems to drain properly.

The upper surface of a bioretention system is located below the grade of the surrounding impervious drainage area and temporary shallow ponding occurs as water is conveyed through the system. Stormwater and urban runoff are filtered through engineered soils and plant root structure, removing the majority of pollutants before infiltrating into native soils, draining to an underdrain system, or evaporating. In a semiarid environment such as the Truckee Meadows, the majority of water captured by bioretention systems would likely be held in the pore spaces of the engineered soil matrix and lost to evapotranspiration. Therefore, these LID practices can effectively reduce both the volume and rate of runoff from developed areas, and can provide significant project cost savings by reducing the required size and quantity of conventional storm drain infrastructure. They can also reduce the need for downstream storm drain system improvements and assist with water conservation efforts

by reducing landscaping irrigation needs. **Figure 4-10** demonstrates a bioretention basin in the landscaped area of a multifamily development.

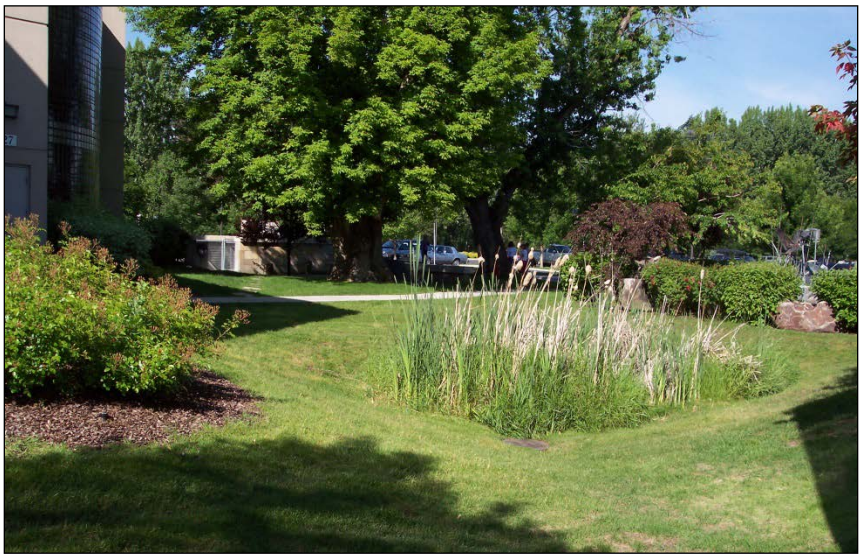


Figure 4-10. Bioretention system in a multifamily development

Bioretention systems can be integrated into a site's overall landscaping and typically require the same routine maintenance as any landscaped area. They are suitable for residential, commercial, industrial, and municipal development and redevelopment and can be applied in various settings including:

- Landscaped areas in apartment complexes and multifamily housing (**Figure 4-10**)
- Parking lot islands (**Figure 4-11**)
- Parking lot perimeters – curbless or curbed with curb cuts
- Tree wells and tree box filters – boxed bioretention cells placed at the curb typically just upstream of storm drain inlets (**Figure 4-12**)

Figure 4-11. Parking lot island bioretention.

Figure 4-12. Tree box filter installed in downtown Reno.

- Within right-of-ways along roads (**Figure 4-13**)
- Street median strips
- Driveway perimeters
- Cul-de-sacs
- Landscaped areas in commercial, industrial, and municipal developments
- Residential on-lot bioretention – landscape detention or rain gardens (**Figure 4-14**)

Figure 4-13. Street-side bioretention.

Figure 4-14. Residential on-lot bioretention.

Figure 4-15. Rain Garden installed to collect and treat runoff from impervious surfaces at McKinley Arts Center. (Source: City of Reno)

Bioretention Examples:

Somerset development in Prince George's County, Maryland, incorporated rain gardens into each of the nearly 200 lots of this 60-acre development. Combined with grassy swales that replaced curbs and gutters and disconnection of impervious areas through rain barrels and other LID strategies, this development had considerably lower runoff volumes and peak flow rates when compared to a neighboring conventional development (Cheng, 2003). The cost of installing LID stormwater facilities when compared to conventional storm drainage facilities brought about a savings of approximately $300,000. Additionally, utilization of LID techniques in the development yielded six additional lots, where stormwater ponds would traditionally have been housed if conventional stormwater strategies had been applied (Guillette, 2005).

A residential neighborhood in Maplewood, Minnesota installed small rain gardens in a two-block area as a demonstration project. The neighborhood had experienced periodic flooding and was slated for repaving, curbs and gutters, and a conventional underground storm drain system. However, the rain gardens effectively controlled runoff by slowing and infiltrating stormwater, negating the need for curbs and gutters and costly underground storm drain infrastructure. The success of this project prompted the City of Maplewood to incorporate rain gardens into other neighborhoods (Hager, 2003).

In 2008, the City of Reno constructed the McKinley Arts Low Impact Development Project, with assistance from the Truckee River Fund and NDEP. The project included the installation of a bioretention system and porous paving designed to treat runoff from impervious surfaces including the rooftop and sidewalks, and alleviate drainage problems around the historic McKinley arts building. The bioretention system was designed using guidance provided in this manual for TC-30. Site soils were over excavated and replaced with drain rock and amended top soil, and planted with vegetation requiring little supplemental irrigation. A description of a rain garden installation and steps taken are on www.tmstormwater.com in the LID section.

Refer to the Truckee Meadows Structural Controls Design Manual fact sheet TC-30 for more information on the design, construction and maintenance of Landscape Detention and Bioretention Basins.

4.3 Vegetative Treatments

Swales and buffer strips are stormwater treatment systems that rely upon vegetation and the subsoil matrix to filter pollutants from runoff. They can also provide infiltration and groundwater recharge. These systems reduce the velocity of urban runoff, can serve as part of the conveyance system, and provide pretreatment for other structural controls and LID practices. Swales and buffer strips can be accessible to runoff via curb cuts and flush curbs, or in some cases, they can be used in place of curbs, gutters, and subsurface storm drainpipe systems. By designing impervious surfaces such as driveways and sidewalks to slope towards vegetated areas instead of gutters and inlets, stormwater can be conveyed through vegetated surfaces and receives treatment prior to entering the storm drain.

Swales are shallow open channels. Also known as vegetated swales, biofiltration swales or grassy swales, they are commonly vegetated with grasses (**Figure 4-16**). Rock-lined low flow channels and underdrain systems can be added where native soils have poor infiltration characteristics, grades are flat, or when infiltration near a building's foundation is a concern (**Figure 4-17**). Low flow channels and underdrain systems can also reduce the potential of extended ponding and mosquito breeding. Xeriscaped swales (**Figure 4-18**) are planted with native vegetation interspersed among rock with little to no watering requirements once established. Stormwater runoff is conveyed along the length of the low slope channel, which decreases the velocity, traps sediments, and reduces erosion. In Biofiltration swales, stormwater runoff is treated by filtering sediments and associated pollutants through the engineered subsoil and vegetation and by infiltration into the underlying soils. Pollutant removal and treatment efficiency improves as contact time and the amount of infiltration increases, or, in the case of a rock lined swale, if flows from the swale discharge to another GI or LID practice.

Figure 4-16. Grassy swale.

Figure 4-17. Swale with rock lined low flow channel.

Grassy and xeriscape swales are simple to design and install. They can serve as part of the storm conveyance system in place of curbs and gutters. These practices can also be used with other structural treatment controls and LID practices as part of a treatment train. They can be used to convey and treat runoff from parking lots, buildings, and roadways and can be applied in residential, commercial, industrial, and municipal land uses. Xeriscape swales are recommended wherever possible to assist with water conservation strategies. Grassy swales are appropriate in parks or private landscaped areas that are irrigated. Specific guidance for the design, construction and maintenance is provided in **Section 6** under TC-10 - Vegetative Swales.

Figure 4-18. Xeriscape swale.

Buffer strips are also known as vegetated buffer strips and filter strips. They are gently sloping and uniformly graded vegetated strips that provide stormwater treatment to relatively small drainage areas. Buffer strips slow the velocity of runoff to promote filtration of sediments and pollutants and infiltration into underlying soils. They require sheet flow to function properly and often require a flow spreader to distribute evenly runoff across the width of the buffer. Grassed or vegetated buffers consist of uniformly graded, densely vegetated turf surfaces that can be interspersed with shrubs and trees to improve aesthetics and provide shade. In the Truckee Meadows, irrigation is typically required for grassy buffer strips to maintain a vegetative cover capable of withstanding the erosive forces of runoff from adjacent impervious areas.

Buffer Strip and Bioswale Example

The Morton Arboretum in DuPage County, Illinois is a 1,700+ acre property adjacent to the DuPage River. When a new visitor center was proposed for the facility a “green” parking lot was constructed to accommodate the increased use. The parking lot utilized biofiltration swales as parking lot medians to drain the parking lot.

The biofiltration swales were designed along 9-foot wide median with a surrounding barrier that had 3-foot curb cuts to receive runoff. Curb structures were specially graded with the gutter being pitched from the middle to slope at approximately 0.5 percent to the curb cut.

The swales were constructed to pond to a depth of 0.5 ft prior to overflowing to the conventional storm drain system. Side slopes were graded at a 3H:1V slope, being approximately 1-foot below the edge of the pavement, and having a 3-foot bottom width. The soil consisted of a sandy loam mix with approximately 5 percent coarse organic matter.

After a year of use, the biofiltration swales were still functioning properly. Plantings and stepping stones near curb cuts were recommended as a way to prevent pedestrians from viewing the curb cut areas as access through the parking lot (Kelsey and Sikich, 2005).

Xeriscaped buffer strips use the same concept as vegetated buffer strips except they incorporate low water use plants and rock, allowing for water conservation. Buffer strips are typically located on the edge of landscaping areas and can provide pretreatment for other treatment controls. Xeriscape buffer strips (**Figure 4-19**) are ideal at the edge of landscaping features to reduce runoff and conserve water. Lawn areas adjacent to sidewalks, driveways and streets are typically hotter and drier and require more water than areas adjacent to other vegetation. By planting a xeriscape buffer between lawn and sidewalks, driveways, and streets, water needs will be reduced. Less runoff will also occur as the xeriscape buffer strip captures and infiltrates the water leaving the lawn area. See TC-10 and TC-11 "Vegetative Swales and Buffer Strips" for design and site criteria, as well as maintenance considerations.

Figure 4-19. Xeriscape buffer strips between the lawn and sidewalk, and the lawn and street.

4.4 Porous Pavements

Porous paving systems allow infiltration of stormwater while providing a stable load-bearing surface for walking and driving. These systems contain void spaces to provide infiltration of runoff into their underlying engineered porous materials and then into native soils. Porous paving systems can preserve natural drainage patterns, enhance groundwater recharge and soil moisture, and can help establish and maintain roadside vegetation. There are several different types of porous paving systems, generally classified here as 'Porous Concrete and Asphalt', and 'Permeable Pavers'.

4.4.1 Porous Concrete and Asphalt

Porous Concrete and Asphalt

Porous concrete and asphalt both make a continuous, smooth paving surface like their impervious counterparts. However, they have reduced fine material (sand and finer) in the aggregate mix, and therefore contain void spaces that allow water to pass through to a permeable subbase layer. Porous materials such as clean gravels are typically placed below the porous concrete or asphalt to detain and filter pollutants prior to infiltration into the

underlying soils. If infiltration is not desirable on a site, a porous paving system can employ an underdrain to discharge to the conventional storm drain system.

Porous concrete and asphalt are ideal for light to medium duty applications such as residential access roads, overflow parking areas, utility access, sidewalks, paths and trails, residential driveways, and stopping lanes on divided highways. Porous asphalt has, however, also been used in heavy applications such as airport runways and highways because its porosity creates a favorable driving surface in rainy weather (BASMAA, 1999). If porosity is properly maintained, porous concrete and asphalt can also reduce icing hazards during winter freeze and thaw cycles since runoff will tend to infiltrate rather than freeze onto the surface.

Figure 4-20. Demonstration project at Lake Tahoe. Underlying clean gravels being installed (left) and water rapidly infiltrating into porous concrete (right).

Porous Pavement Examples

A porous concrete parking lot installation at the Lake Mansion on Arlington and Court Streets in Reno proved to be a learning experience for future porous concrete applications in the Truckee Meadows. During installation, delays occurred between pours and the concrete set up quickly in the hot and dry summer conditions. The contractor did not cleanly separate the pours into sections, and the finished parking lot experienced raveling problems. Subsequently the surface of the porous concrete was covered with a seal coat layer to stabilize the surface, effectively producing an impervious layer over the porous concrete such that the parking lot is no longer porous.

Reno's Public Works Department secured grants to build a pervious concrete parking lot at the McKinley Arts and Culture Center, and applied lessons learned from the Lake Mansion project. Q & D Construction completed the demonstration project, using boards to separate the parking lot into several sections or bays, allowing workers to access each pour from all sides. A large roller screed was used to smooth the porous concrete, preventing detachment and raveling. After each pour was completed, the surface was covered with plastic to allow sufficient time for curing before the porous concrete became too dry. City of Reno Public Works staff has found that a vactor truck in combination with a low-pressure water jet is an effective method for removing the fines from the porous pavement and preventing clogging. A

maintenance manual from this project was created to capture lessons learned, and is available at www.tmstormwater.com.

Applications of porous pavements in Durham, New Hampshire (Briggs et al, 2005), and at the Tahoe Regional Planning Agency headquarters in Stateline, Nevada have demonstrated that properly installed porous concrete can hold up to harsh winter conditions and snow plows, while maintaining porosity and high infiltration rates.

The oldest porous asphalt pavement surface in the United States can be found at the University of Delaware Visitors' Center. It was built in 1973 and is still permeable and structurally sound (BASMAA, 1999).

4.4.2 Permeable Pavers

Permeable pavers are an alternative to conventional pavement and can create an opportunity for infiltration of stormwater runoff and groundwater recharge. For areas that are not heavily trafficked, permeable pavers are also an alternative to conventional asphalt and concrete. Permeable pavers are modular systems with pervious openings that allow water seepage. Runoff that permeates is detained in an underlying gravel bed, infiltrated into the underlying soil, or both. Types of permeable pavers include open-celled unit pavers or modular blocks made of concrete or brick with pervious openings.

Open-celled unit pavers are pre-assembled, flexible plastic grid networks that utilize soil and turf grass or gravel backfill to fill the blocks and create a flat surface. **Figure 4-21** demonstrates a type of open-celled unit paver known as a turf block paver. The grid systems have a solid support structure surrounding an open cell where the grass or gravel is placed. The plastic grids are flexible, allowing for use on uneven surfaces. These systems work well in overflow parking areas, driveways and sidewalks. Open-celled unit pavers can also be made out of concrete.

Concrete block pavers (**Figure 4-22**), and brick pavers (**Figure 4-23**), are designed to set on sand and form an interlocking pavement surface. Modular block pavers are designed to bear heavy loads and are well suited for industrial and commercial parking lots, utility access, residential access roads, driveways, and walkways.

Figure 4-21. Plastic grid pavers. (Source: ToolBase services)

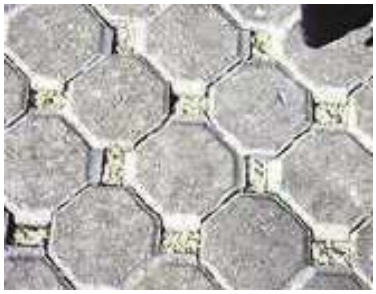


Figure 4-22. Concrete block pavers. (Source: NEMO UConn)

Figure 4-23. Brick pavers. (Source: NEMO Nevada)

Permeable Pavers Example

At the Morton Arboretum in DuPage County, Illinois, a concrete paver system was installed in the parking lot. The decision to use a concrete paver system was due to its ability to withstand heavy traffic loading. The decision was also based on initial cost, anticipated maintenance, and lifespan of the system. With an expected lifespan of 50 years, the concrete paver system was estimated to be almost half the cost of an asphalt system at $45/sq yd when compared to $80/sq yd, when considering a total 50 year cost (totals in 2002 dollars).

The subbase for the parking lot was made up of a permeable uniformly graded, washed, granular base, which provides stormwater storage and opportunity for infiltration. Perforated storm sewers were utilized along the length of each biofiltration swale so that stormwater entering the storm sewer could have a chance to infiltrate back into the ground. A control structure was installed at the downstream end of the system to restrict flows and allow more time for water to infiltrate into the ground, which is removable in case the subbase becomes overly saturated. (Kelsey and Sikich, 2005)

4.5 Rainwater Catchment and Green Roofs

Rainwater Catchment

Runoff from the roofs of buildings and homes contributes a significant volume to the amount of stormwater runoff resulting from developed properties. Rooftop runoff can also contribute pollutants to stormwater when roofs are exposed to atmospheric deposition or when the runoff is discharged directly onto an impervious surface such as a parking lot that is directly connected to the storm drain system. Capture and re-use of roof runoff reduces the volume of runoff discharged to the storm drain system, helps to reduce stormwater pollution, and assists with water conservation efforts. The water collected from roofs can be used to irrigate landscaping, or it can be slowly released into the soil. Collected water can be applied to decrease use of potable water for irrigation practices during dry period, resulting in significant water savings during peak summer months.

Rainwater catchment systems are simple structures designed to collect and store stormwater runoff from impervious surfaces such as roofs, paved terraces, and patios. Stormwater from these impervious surfaces is conveyed through gutters and downspouts, and screened to remove leaves and other debris before discharging to above or below ground storage tanks or cisterns. The water collected by these systems may be reused for non-potable water uses within a house or building, or for exterior landscape irrigation purposes. Uses can include water for toilet flushing and irrigation at exterior hose bibs.

Stormwater management benefits provided by rainwater catchment systems include flow and volume control, and pollutant load reductions. In areas where onsite infiltration is not feasible, rainwater catchment systems can provide significant flow rate and volume reduction into the conventional storm drain system. A water budget should be developed, to balance anticipated rainwater supply and potential irrigation demand. Rainwater catchment systems may be subject to plumbing and health department codes.

Rainwater catchment systems can provide a stormwater management solution where impervious surfaces are unavoidable and site constraints limit the use of other LID practices. Such situations may include highly urbanized areas (such as downtown centers), dense housing developments without adequate space for stormwater infiltration or detention, or locations where soil and groundwater conditions do not permit infiltration. Additional design information on rainwater catchment systems can be found in **Section 5** under Source Control SC-11.

Figure 4-24. A rainwater catchment system on a residential home. (Source: Kennedy/Jenks Consultants)

Figure 4-25. A typical rain barrel set-up at a residence. (Source: Low Impact Development Center)

Green Roofs

Green Roofs are vegetated roofing systems that can provide numerous environmental benefits and offer a valuable tool for integrated stormwater management. Green Roofs can help absorb rainfall, reduce urban runoff at its source, increase evapotranspiration, and reduce urban heat island effects.

Additional benefits of Green Roofs include:

- improving building insulation that reduces heating and cooling costs and energy consumption (Rozenzweig, C. et al.)
- increase life span of the roof's structural elements through protection from UV rays, wind and temperature fluctuations (Green Roofs for Healthy Cities, and Rosenzweig, C. et al.)
- improving air quality, and reducing air temperatures and urban heat island effect

Green Roofs are best utilized in highly urbanized areas where there is little pervious ground surface to infiltrate and manage stormwater, and on buildings with significant roof areas such as industrial facilities, warehouses, shopping centers, and office buildings. The arid climate of

the Truckee Meadows is amenable to succulents, grasses, and native perennials for use on Green Roofs. Supplemental irrigation may be necessary to maintain a green appearance and for fire protection during the dry season.

Figure 4-26. Green Roof at GAP Corporate Campus, San Bruno, CA. (Source: Rana Creek)

Figure 4-27. Green Roof on a commercial office building. (Source Photo: Jonathan Feldman)

Green roofs can be constructed as lightweight vegetated roofs consisting of 4-8 inches of growth media (or soil), planted with hardy, drought-tolerant species to minimize additional irrigation, maintenance, cost and weight (Rozenzweig, C. et al. and City of Portland, Bureau of Environmental Services). In the Truckee Meadows, these types of roofs will likely require supplemental irrigation to support growth during extended dry periods.

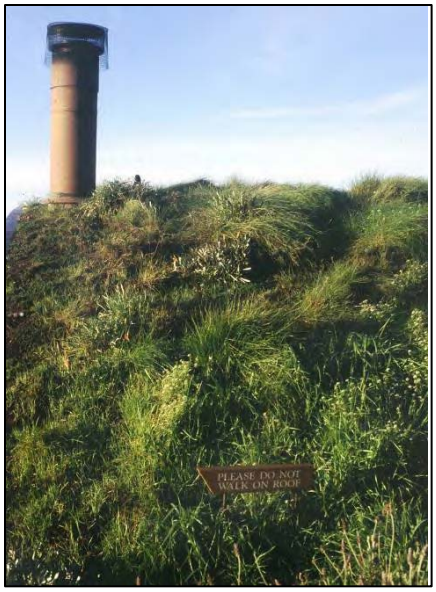


Figure 4-28. Extensive green roof at Post Ranch Inn, Big Sur, CA (Source: Rana Creek)

Alternatively, green roofs can be designed to support lawns, trees, and outdoor garden space; often referred to as roof gardens. This type of structure would require a much more extensive irrigation system. Additional design information on Green Roofs can be found in **Section 5** under Source Control SC-12.

4.6 LID Design Considerations

If not sited, designed, and maintained properly, structural treatment controls and LID practices can have undesirable consequences such as groundwater contamination, basement flooding, and creation of mosquito breeding habitat. This section discusses the basic considerations and site limitations to consider when selecting BMPs, and **Section 6** provides further guidance on design techniques, criteria, and methods that, if properly implemented, will prevent these undesirable consequences.

Groundwater contamination

Infiltration type BMPs can be every effective at treating stormwater; soils remove pollutants from urban runoff through natural processes such as physical filtering, ion exchange, mineralization, adsorption, biological processing, conversion, and uptake by plants. However, it is important to consider some limitations when siting infiltration type practices and treatment controls (i.e., infiltration BMPs). If infiltration is applied in inappropriate land uses or soil types, this could cause soil and/or groundwater contamination. Particular land uses are likely to generate pollutants that should not be treated through infiltration on-site. This includes areas where there is a high potential for spills that may be conveyed directly to a structural treatment control or a LID practice, such as at an industrial site with chemicals stored outdoors. Infiltration should not be used to treat runoff from industrial sites that could contain significant concentrations of hydrocarbons, metals or toxicants, (e.g., scrap yards and transit stations). Infiltration BMPs should not be installed within 150 feet of drinking water wells or in areas where the seasonally high groundwater table would be within 3 feet of the

bottom of a proposed system. Additional restrictions may apply if the site is in a wellhead protection zone. Contact NDEP for more information.

A nationwide map of water table depths is available from ESRI: (http://www.arcgis.com/home/item.html?id=6030e985be8b483c802376c63c956ca6). However, a thorough geotechnical investigation of the site is recommended. In these examples, runoff should be routed to a treatment control that does not infiltrate runoff.

The rate that water infiltrates into the soil is also important when siting infiltration practices. Stormwater infiltrating directly into native soils with infiltration rates greater than 2.4 in/hr generally do not provide adequate treatment prior to transport to groundwater, particularly in sandy soils with little to no organic matter. Soils with these high infiltration rates may not provide sufficient treatment because soil-water contact times are low and there may be less organic matter in the soil, which would otherwise facilitate pollutant removal. In areas where native soil infiltration rates exceed 2.4 in/hr, stormwater should be fully pretreated by some other device or soil amendments should be added to slow infiltration rates to 2.4 in/hr or less.

If a bioretention basin, swale, buffer strip or porous pavement system is proposed in a location where there is a potential for spills or highly polluted runoff to be conveyed to the LID practice, it should be relocated or an impermeable liner and underdrain system should be incorporated into the design to prevent infiltration and groundwater contamination. Other factors may also need to be considered by the jurisdictions, including the approval of the City or County Engineer.

Shallow dry wells, infiltration galleries, and subsurface drainfields that release stormwater or other fluids directly below the land surface are considered Class V injection wells and may be subject to regulation by NDEP and the U.S. EPA. By definition, a Class V injection well is any bored, drilled, or driven shaft, or dug hole that is deeper than its widest surface dimension. A pipe that conveys stormwater to an underground infiltration gallery is also considered a Class V injection well. These types of facilities are considered stormwater disposal systems, not treatment systems, and have affected groundwater quality in a number of communities across the nation. NDEP and the U.S. EPA are concerned that there may be a dramatic increase in the use of Class V injection wells as a result of NPDES stormwater permit requirements to implement BMPs. When not allowed to filter through surface soils and plant roots, stormwater contaminated with sediments, hydrocarbons, nutrients, metals, salts, fertilizers, pesticides, bacteria, or other pollutants can contaminate groundwater supplies, resulting in costly treatment alternatives and the closure of drinking water wells. However, when stormwater is allowed to temporarily pond in an open basin that is exposed to the atmosphere; is wider than it is deep; and infiltrates stormwater through engineered soils and gravel; the system is not considered a Class V injection well and typically presents little risk to groundwater quality. The treatment controls and LID practices presented in the Structural Controls Design Manual and the LID Handbook are not considered Class V injection wells and should not present a threat to groundwater quality if sited and designed correctly.

Stormwater in basements and crawl spaces

Shallow groundwater, stormwater, and water from landscape irrigation can penetrate foundations and seep into the basements and crawl spaces of homes and other structures. Since many types of building materials contain organic matter, mold can occur in the favorable environment created in these areas. Mold in crawl spaces and basements is a concern because several species can present health risks. Commonly, stormwater and water from landscape irrigation creates mold problems in basements and crawlspaces when homeowners re-grade their property for landscaping improvements, creating a drainage pattern that redirects moisture towards the foundation of the home.

Landscaping should be graded to direct moisture away from the foundation. A grade of at least six inches fall over the first ten feet from the foundation wall is recommended to keep moisture away from foundations. In addition, foundation drains can reduce the potential for water in basements and crawl spaces. Foundation drains that extend and drain to LID practices such as swales can be expected to provide better drainage than foundation drains surrounded by native soils. Additional measures include the installation of a vapor barrier (a plastic cover over the exposed dirt of crawlspaces) to prevent moisture from coming in from the ground. Crawl spaces and basements should also incorporate adequate cross ventilation so air will circulate freely.

Conformance with local building design standards and the design standards presented in the Structural Controls Design Manual is necessary to keep stormwater out of crawl spaces and basements in new development and redevelopment. Public education about the importance of maintaining proper grades, directing moisture away from foundations, and providing good ventilation for crawlspaces and basements should also help to minimize the potential mold problems in the Truckee Meadows.

Mosquito Breeding

Stagnant pools of shallow water that contain organic matter from plants and debris can provide an ideal habitat for mosquitoes to breed. Mosquitoes that spread diseases such as West Nile Virus and other diseases are present in the Truckee Meadows. Developed areas can increase breeding habitats for mosquitoes when water ponds for extended periods. To prevent mosquito breeding in structural treatment controls and LID practices, stormwater must not be allowed to pond for seven (7) days or more from May through October, the local mosquito-breeding season. BMPs that permanently retain water, such as stormwater ponds and wetlands, must be designed and maintained based on the standards presented in the current version of this Manual. These standards include rock lining and steep slopes along the edge of stormwater ponds and wetlands and periodic removal of debris and vegetation. Mosquito fish (*Gambusia* sp.) that eat mosquito larvae can also be introduced to stormwater ponds and wetlands to provide an additional method of control.

Nationally, structural treatment controls and LID practices that include landscaping and depressed areas that temporarily pond water have only been shown to breed mosquitoes when these facilities were not designed correctly, not properly planted, not maintained

adequately, or were not infiltrating properly. In bioretention basins, proper infiltration rates are attained using engineered soils with good permeability and proper plant composition. Proper design and routine maintenance will ensure that water is not ponded for long enough periods to allow for mosquito breeding. Routine maintenance is necessary to ensure proper infiltration rates and discourage invasion of species such as cattails, which can increase the chances of standing water and, therefore, mosquito breeding potential. Vegetated swales and extended detention basins that include rock lined low flow channels and underdrain systems typically prevent the development of stagnant pools of water, particularly in areas that receive persistent runoff from turf and landscaping irrigation. Low flow channels should be designed with a minimum continuous grade of 0.5 percent. Those that do not include underdrain systems may require more frequent maintenance to prevent ponding water from standing longer than seven (7) days.

In 2003, the District Board of Health Regulations Governing the Prevention of Vector-Borne Diseases were created. These regulations require that all plans for new development undergo a review process by the Washoe County District Health Department, Vector-Borne Diseases Program (VBDP). The VBDP staff is available to provide consultation for homeowners, builders, and developers in the Truckee Meadows and will consider creative ideas regarding designs that minimize potential breeding habitat for mosquitoes. VBDP staff also responds to public complaints and apply significant quantities of insecticides and larvicides in the Truckee Meadows that effectively control the production of mosquitoes

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5.0 SOURCE CONTROLS

Source Control BMPs are design, operational, and management practices that are used to prevent or reduce pollutants at the source, before entering stormwater. Implementation of adequate and appropriate source control measures at commercial, industrial and multi-family developments can reduce or eliminate the need for higher cost treatment control measures. Source controls are typically less costly to facilitate, and more effective, than downstream methods for stormwater treatment.

The source controls discussed in this section are divided into two groups. Site design and structural source controls include design strategies and installed systems that reduce or prevent pollution from being transported in urban runoff. These include:

- Roof Runoff Controls
- Rainwater Catchment Systems
- Green Roofs
- Efficient Irrigation
- Storm Drain Labeling

Operational source controls consist largely of good housekeeping practices and proper maintenance guidelines that help site managers to prevent pollution from leaving their site. These include:

- Roof Runoff Controls
- Rainwater Catchment Systems
- Green Roofs
- Efficient Irrigation
- Storm Drain Labeling

In order to select the appropriate source control measures, the outdoor activities that are conducted at a particular site must be carefully evaluated. The activities that have the potential to contribute significant pollutants to stormwater and non-stormwater discharges are commonly referred to as “activities of concern.” If not managed adequately, these activities may provide sources of pollutants that meet rain or runoff as it drains over the area where the activities of concern are conducted. The pollutants can then leave the site when runoff drains into the municipal storm drain system, resulting in polluted stormwater ultimately being discharged to tributaries and/or the Truckee River.

5.1 Site Design and Structural Source Controls

The source control BMPs discussed in this section include site design techniques and structural pollution prevention systems that can be applied at new developments or as retrofits at existing sites.

SC-10 ROOF RUNOFF CONTROLS

Description

Runoff from the rooftops contributes to the volume of stormwater runoff as well as acting as a source of pollutants. Controlling roof runoff by filtering it through vegetated swales, buffers or sand filters, storing it for irrigation, or allowing for infiltration reduces the peak flow rates and volume of stormwater runoff and associated pollutants loads. Rainwater collected in rain barrels and cisterns can be used to water gardens and landscaping.

Infiltration trenches and infiltration basins can be applied as methods to infiltrate stormwater. These methods may require gutter and downspout systems, and consideration should be given to slab or ice hazards on north facing rooftops. If these are significant, snow slide clips may also be needed. Equally effective for small roof areas, would be the placement of landscaping beneath the dripline to catch runoff and reduce irrigation needs.

Potential benefits of roof runoff controls include decreased use of potable water for irrigation practices, an increase in groundwater recharge, removal of pollutants from stormwater runoff, and capture of the first flush pollutants. Onsite retention of a portion of the runoff will also assist by reducing the peak runoff and volume, and attenuating thermal loading to receiving waters associated with stormwater runoff.

Applications

Appropriate for single-family homes and multi-family developments, commercial and industrial areas. Can be applied in areas of new development or in areas of redevelopment.

Performance Data

The expected range of pollutant removal percentages varies depending upon the combination of roof runoff control technologies used at a site.

Limitations

- An uncovered cistern can provide mosquito habitat if it contains standing water. To prevent mosquitoes from breeding in rainwater catchment systems, the storage tanks and cisterns need to remain tightly sealed and screened. Mosquitoes can fit into holes as small at 1/16”.
- Site soil conditions may limit applicability of infiltration trenches and dry wells. See the Soil Considerations Fact Sheet 09-23 included in **Appendix B**.

Siting Criteria

- Installation of vegetative landscaping under roof drip lines will provide protection against soil erosion and aid in stormwater infiltration.
- Plants installed along a building’s drip line should be sturdy enough to handle heavy sheet flows from rooftop runoff.
- Infiltration systems for roof runoff should be installed an adequate distance from building foundations. Consult local building code for minimum separations, and perform a geotechnical investigation to determine soil conditions.

- Tanks should be placed on level pads in areas not vulnerable to settling, erosion or slope failure.

Design and Construction Criteria

- Rain barrels and cisterns must be securely covered to prevent vector breeding.
- Rain barrels and cisterns must be childproof.
- Downspouts can be directed towards vegetated swales or buffers, infiltration trenches or basins.
- Splash blocks or gravel splash pads should be used to dissipate runoff energy from downspouts.
- Roof materials should be considered when designing treatment controls to address roof runoff. For example, galvanized roofing can be a significant source of zinc, and vegetative treatment systems receiving runoff from a galvanized roof may require special plant selection.

SC-11 RAINWATER CATCHMENT SYSTEMS

Description

Rainwater catchment systems can be designed to fit a wide range of site conditions. Storage tanks and cisterns should be sized according to the impervious surfaces feeding into the system utilizing the WQ_V method outlined in this Manual. Additional storage capacity can also be provided to assist with site water needs. In addition to determining the required storage tank volume, a regular use for the non-potable water needs to be planned into the system such that there is an assurance that there will be available volume to capture the WQV from subsequent storm events (e.g., toilet flushing, regular irrigation). A water budget should be developed for each proposed rainwater catchment system to determine the minimum required storage volume (e.g., the WQV), dedicated water uses, and the schedule necessary to maintain a regular use. If a rainwater catchment system is proposed for stormwater management, a water budget should be included as part of the development plans to be reviewed by City or County staff. Such calculations will help evaluate whether a rainwater catchment system is a feasible stormwater management strategy for a particular site.

Though rainwater catchment systems can be designed with various materials and configurations, components of a basic system should consist of the following:

- An impervious surface to collect runoff from (e.g., roofs or elevated paved surfaces);
- A system to collect and convey water from the impervious surfaces (e.g., gutters, and downspouts);
- A debris screening device (also known as a “First Flush” or “Foul Flush” filter);
- Tanks, rain barrels or cisterns to contain the WQ_V as outlined in the Manual plus any additional water desired for site needs (e.g., toilets and landscape irrigation);
- An overflow pipe; and
- An exit point to distribute the harvested rainwater (e.g., hose bib).

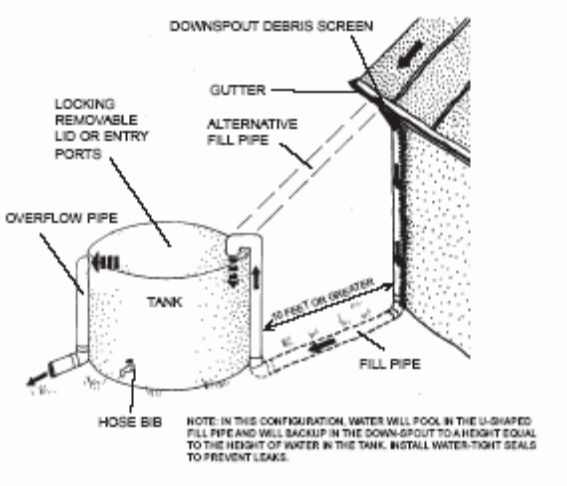


Figure 5-1. Rainwater catchment system schematic with an aboveground storage tank.

Applications

Rainwater catchment systems can be designed to fit a wide range of site conditions. Any impervious surface (e.g., rooftop) located near a potential point of use (e.g., landscaping) has potential application for a rainwater catchment system.

Limitations

- Extensive use of rain barrels and cisterns can become a water rights concern.
- Aboveground storage systems may be susceptible to freezing and cracking during winter months.

Siting Criteria

Aboveground tanks at higher elevation provide more gravity-fed pressure for water distribution from the tank. A system should also be sited so that the interior space of the tanks is accessible for maintenance. Tanks can be constructed individually or in a series with the overflow from one tank filling the adjoining tank, or connected at the bottom to maintain the same water level in all tanks. Avoid placing vegetation with intrusive roots near or on top of belowground tanks.

Design Considerations

The following parameters should be considered in the design and construction of any Rainwater Catchment System:

- Prefabricated tanks of plastic, metal, or concrete can be purchased and installed professionally.
- Tanks should be securely capped with opaque material to prevent evaporation, mosquito breeding, and algae growth. Lock all caps and entry ports for safety.
- The interior of the storage tank(s) should be accessible for periodic inspection and maintenance.

- Position outlet pipes several inches above the bottom of the tank to allow sediment to settle in the bottom.
- All tanks need an overflow pipe of equal or greater capacity than the fill pipe.
- Overflow pipes must be able to operate passively (i.e., not be dependent on a pump).

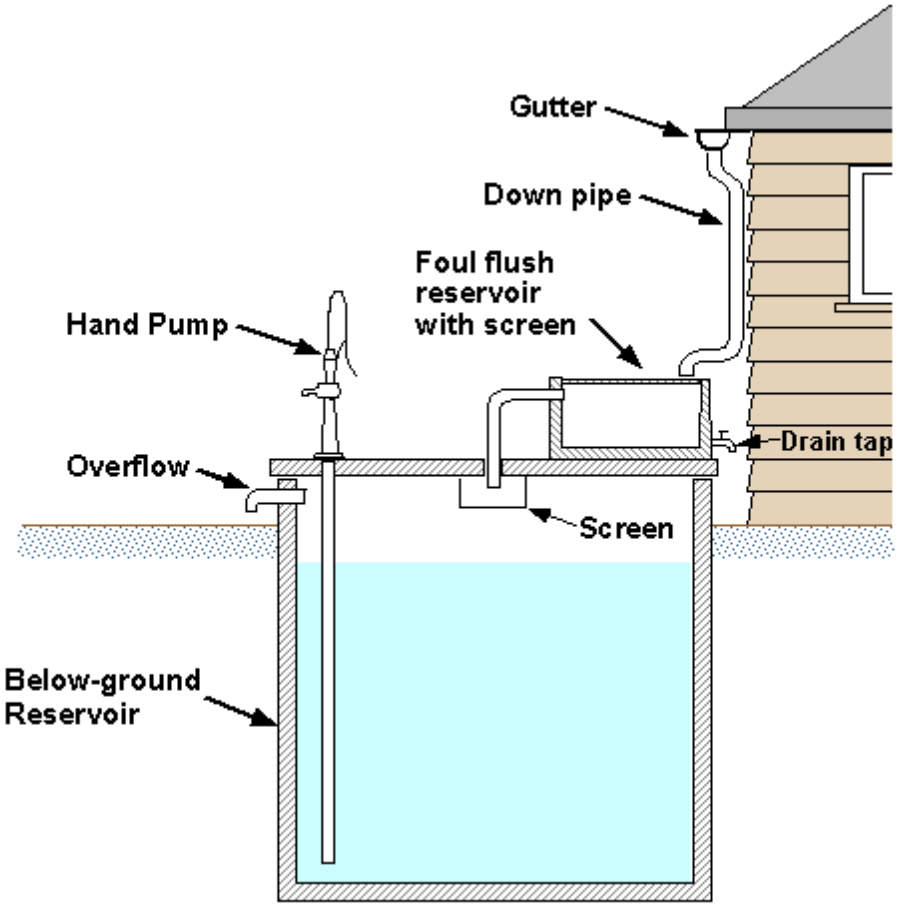


Figure 5-2. Rainwater catchment system schematic with a belowground storage tank or cistern.

- Belowground tanks can reduce footprint, but are typically more costly, and require a booster pump to supply the water to its intended uses.
- Overflow water should be routed into a bioretention basin, adjacent tank, French drain, or other useful location away from buildings.
- Water in aboveground tanks should be delivered by gravity flow alone to low-pressure uses nearby whenever possible.
- A booster pump can be added to increase water pressure. Tank water should be filtered before it enters supply pipes, particularly to keep debris from plugging the irrigation system and prior to any connection with interior plumbing for supplying water to toilets, etc.

Inspection and Maintenance Requirements

Regular maintenance is critical to any dependable Rainwater Catchment System. The following inspection and maintenance practices are recommended.

- Clean out gutters, inflow and outflow pipes of leaves and debris as needed.
- Make sure gutters and downspouts are free of debris prior to the rainy season. The "first flush", or the runoff created by the first storm event after a long dry spell, will need to be carefully monitored to ensure that the system is working properly.
- Inspect water tanks periodically and remove any debris and sediment that may interfere with the proper function of the system.
- Screen inlet and outlet pipes to keep the system closed to mosquitoes. No opening shall be greater the 1/16" on systems where water will be retained for more than 72 hours.
- Cap and lock tanks for safety. Caps should have access ports for interior inspection and maintenance.

SC-12 GREEN ROOFS

Description

Green Roofs are vegetated roofing systems that can provide a valuable tool for integrated stormwater management by absorbing rainfall, reducing impervious area, and capturing urban runoff at its source. Green Roofs can also improve building insulation and increase life span of the roof's structural elements.

Applications

Green Roofs are best utilized in highly urbanized areas where there is little pervious ground surface to infiltrate and manage stormwater, and on buildings with significant roof areas such as industrial facilities, warehouses, shopping centers, and office buildings

Limitations

- Initial costs can be prohibitive, especially for retrofitting a standard roof. However, Green Roofs can be cost-competitive on a life cycle basis. Numerous economic benefits can help to offset initial costs of Green Roofs including: reduced energy costs, extended roof life, increased property values.
- Specific maintenance, such as irrigation and cleaning out drainage features will need to be factored into the long-term building care.
- Vegetation should be selected by a landscape architect or other specialist with an understanding of plant needs and stressing conditions in a rooftop environment.

Figure 5-3. Intensive Green Roof on a parking structure at Stanford University, Palo Alto, California. (Source: Rana Creek)

Design and Construction Criteria

Green Roofs can be placed on flat or pitched roof structures at slopes up to 40 percent (or 5 in 12 pitch). Site factors to consider include the aspect of the roof, the microclimate of the site, prevailing winds and the building's functions. Generally, a building's structure must be able to support an additional 10-25 pounds per square foot of saturated weight, depending on the growth media and vegetation used. For New construction, the load requirement of the Green Roof can be addressed as part of the building's design process.

Green Roof systems are typically composed of several layers as depicted in **Figure 5-4** below, and typically require additional structural support and drainage systems.

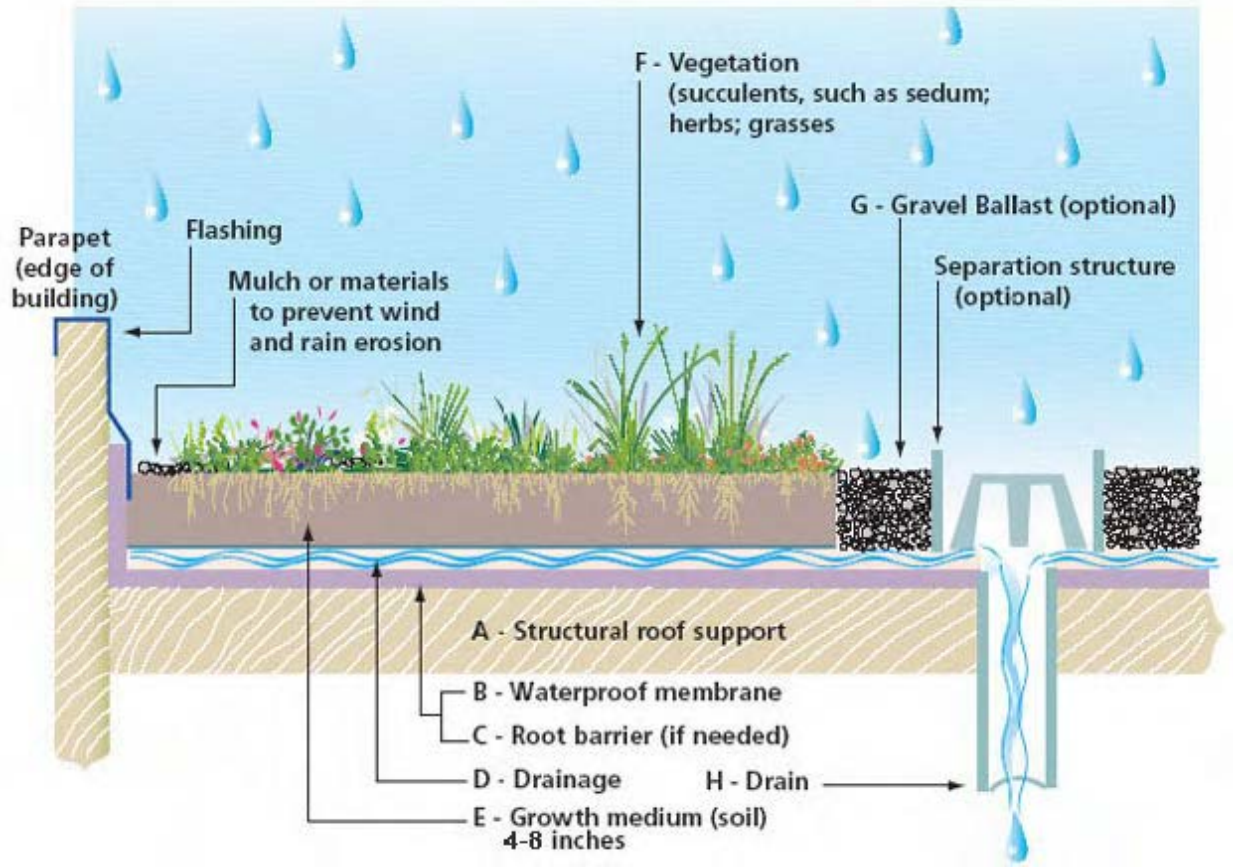


Figure 5-4. Green roof construction detail schematic.

Inspection and Maintenance Requirements:

- Upon installation, the Green Roof system should be inspected monthly for the first year and after each large storm event for erosion, plant survival, proper drainage and waterproofing.
- Inspections can be reduced to a quarterly schedule once the Green Roof system has proven to work properly and vegetation is established.
- Irrigation frequencies should be established by the designer.
- Weeding and mulching may be necessary during the establishment period, depending on the planting design.
- Replace or fill in vegetation as needed.
- Inspect soil levels semi-annually to ensure plant survival and rainfall absorption.
- If the vegetation used is flammable during the dry season, it should be mowed or watered as needed to prevent fire.

SC-13 EFFICIENT IRRIGATION

Description

The application of efficient irrigation techniques will minimize the waste of water resources and reduce the volume of dry weather flows discharging to the storm drain system. Efficient

irrigation techniques include rain and wind-triggered shutoff devices, automatic line break detection shutoff valves and soil moisture sensors. These devices automatically regulate the amount and frequency of irrigation based on climatic conditions and function to provide only the amount water required to sustain vegetation requirements.

Applications

Appropriate at any location that includes irrigated landscaping, including residential, commercial, and industrial sites that are either being developed or redeveloped.

Limitations

- Installation of rain-triggered shutoff devices and automatic shutoff valves involve an initial additional expense; however, these costs can be offset through water savings.
- May require additional inspection and maintenance to insure the irrigation system is functioning as designed.

Siting Criteria

- Applicable at any location that includes an irrigation system for landscaping.

Design and Construction Criteria

- Install rain-triggered shutoff devices to prevent automatic irrigation during and following precipitation events.
- Install flow reducers or automatic shutoff valves that will shut off the flow in case of a broken line or sprinkler head.
- Watering schedule to the saturation time of soils and actual water requirements of vegetation used. Prevent runoff by reducing times and increasing frequencies.
- Set irrigation timing and duration to minimize runoff and to comply with watering restrictions set by TMWA.
- Choose plant types that are appropriate for local climatic conditions.
- Choose plants that require little to no application of fertilizers or pesticides for healthy growth.
- Minimize runoff by covering areas of bare soil with mulch.
- Provide vegetative buffers along property lines and channel banks to filter out sediments.

Inspection and Maintenance Requirements

- Monitor and maintain the irrigation system to minimize runoff.
- Repair or replace broken pipes, nozzles, or other devices as soon as possible.
- Use alternative environmentally friendly fertilizers and an integrated pest management approach to reduce chemical runoff from pesticides.

SC-14 STORM DRAIN LABELING

Description

Illegal dumping of wastes into storm drain inlets is a significant problem in some areas. Many times this occurs because polluters are unaware that the storm drain system conveys

stormwater and wastes directly to rivers, streams and lakes without treatment. To educate the public and reduce the disposal of wastes such as used motor oil into the storm drain system; signs, stencils, markers or labels can be applied as a source control. Storm drain labels can be applied with paint and a stencil, secured with an adhesive, heat applied, and stamped into concrete or cast into iron of manufactured drop inlets. Storm drain labels stating educational messages and prohibitions should be placed above or next to storm drain inlets.

Applications

Appropriate in all areas where illegal dumping is possible including residential, commercial, and industrial sites. Reflective materials may help to decrease the occurrence of illegal nighttime dumping.

Limitations

- Storm drain stencils tend to weather and fade over time.
- If not properly attached with a secure adhesive, storm drain signs, markers or labels may become detached or be subject to vandalism.

Siting Criteria

- Storm drains inlets within new development projects should be clearly marked with storm drain signs, stencils, markers or labels.
- May be applied on either the top or face of curbs above or directly adjacent to storm drain inlets.

Design and Construction Criteria

- Image and wording on the label must be clearly stated. The following message is recommended in the Truckee Meadows: “No Dumping, Drains to River”.
- Storm drain signs, stencils, markers or labels should be permanent.
- A durable, long lasting adhesive should be used to apply all storm drain signs, markers and labels.
- When stamped into concrete or cast into iron drop inlets, the label should be a minimum of 0.25 inch deep and have a minimum letter height of 1.5 inches.
- **Figure 5-5** provides an example of the storm drain label typically used in the Truckee Meadows.
- Bilingual storm drain labels may be used in neighborhoods where English is a second language.

Inspection and Maintenance Requirements

- Inspect storm drain labels every two years and replace or reapply as necessary.

Figure 5-5. Example of storm drain label.

5.2 Operational Source Controls

Operational source controls primarily involve good housekeeping practices such as spill prevention, proper outdoor storage methods, and proper cleanup procedures. These source controls can be developed and implemented in a low cost and time effective manner at existing sites.

The source control measures presented in this manual address the more common activities of concern at commercial, industrial and multi-family developments. There may be other activities of concern at a particular site that are not covered in the fact sheets presented in the following sections that may also need to be addressed.

SC-20 OUTDOOR MATERIAL STORAGE

Materials must be stored under cover on all sides, to prevent rain, snow and wind contact from causing stormwater pollution.

Description

Improper outdoor storage of materials may provide a source of pollutants for stormwater and can have undesired impacts on receiving waters. Material types range from raw materials to finished products depending on the industry involved. Examples may include toxic compounds, oils and grease, heavy metals, nutrients, and suspended solids. Proper containment and coverage of materials stored outdoors can prevent or reduce contamination of stormwater runoff and receiving waters.

Applications

Toxic and hazardous materials must be stored in a manner to prevent exposure to rain and stormwater runoff. Significant amounts of non-toxic or non-hazardous materials may also

have a deleterious effect on receiving waters and should be considered for outdoor material storage controls.

Limitations

- Coverage of materials can potentially create additional impervious surfaces.
- Containment berms can potentially create drainage management issues.

Siting Criteria

- Materials can be contained and stored using the following: shelving, stacking, tanks, and containers.
- Materials should be covered and runoff should be captured or diverted around the material storage area.

Design and Construction Criteria

- Storage areas should be underlain with pavement and sloped toward a dead-end sump to prevent groundwater contamination.
- Runoff from adjacent areas should be directed away from storage areas.
- Roofing should extend beyond the footprint of the storage area to limit wind-blown precipitation from entering.
- A berm or other secondary containment should be installed around the material storage area to confine any spills or leaks.

Inspection and Maintenance Requirements

- If materials are covered with tarpaulins, frequent inspection and replacement may be necessary.
- Sumps and containment systems should be inspected frequently and accumulated rainwater removed and properly disposed.

Additional Information

- Spill prevention plans shall be in place where required by local, NDEP, or Federal environmental control regulations.

SC-21 OUTDOOR MATERIAL LOADING/UNLOADING

Description

The loading and unloading of materials occurring on docks, trucks, or around storage areas introduces the risk of spilling or leaking materials. The accumulation of spilled materials around the loading area may be washed away during cleaning, by precipitation, or other runoff thereby introducing contaminants into the storm drain system. Certain precautions should be taken to reduce the risk of polluting stormwater runoff from material loading/unloading areas.

Applications

- Applicable in industrial and commercial areas undergoing development or redevelopment. Can be applied on maintenance bays, docks, staging areas, and around outside storage areas.

Limitations

- Each site should be considered individually and stormwater protection measures should be taken accordingly.

Siting Criteria

- To be applied on maintenance bays, docks, staging areas, and around outside storage areas.

Design and Construction Criteria

- Loading/unloading areas should be constructed from impermeable surfaces such as concrete or asphalt.
- An overhead cover that extends at least 3 feet beyond the loading dock is recommended.
- Depressed loading docks should not drain directly into the storm drain system. An Environmental Control permit may be required prior to connecting a pretreatment system (e.g., oil and water separator) to the sanitary sewer system.
- Below-grade loading docks should drain runoff through an infiltration system where practicable. However, limitations exist where toxic, hazardous, or other deleterious materials may be present.
- Use berm to prohibit runoff from surrounding areas from draining onto loading/unloading areas, and direct downspouts away from loading/unloading areas.

Inspection and Maintenance Requirements

- Inspect loading/unloading areas regularly, clean up litter and wastes as soon as possible, and keep spill prevention, containment and cleanup supplies available at all times.

Additional Information

- Follow local codes when designing loading/unloading areas and associated drainage/pretreatment systems, including RMC Division 2, Stormwater Regulations and Requirements, Sections 12.16.900-12.16.1800.
- Properly dispose of stormwater and non-stormwater runoff in accordance with local codes and policy. Do not dispose of waters directly into the storm drain system or receiving waters, pursuant to RMC Sec 12.16.920.

SC-22 FUELING AREA BMPS

Description

The potential exists for oils, greases, solvents, car battery acids, and coolants to impact stormwater quality at fueling stations. Accidental spills during fueling or during the delivery of fuels as well as rainwater and wash waters running over fueling areas can have a significant impact on the water quality of runoff. Heavy metals and toxic substances in fuels are not easy to remove by stormwater treatment devices and thus spill prevention is of paramount importance. For this reason, stormwater infiltration BMPs are not recommended in fueling areas.

Applications

Applicable in commercial or industrial areas where fuels are dispensed, including gasoline stations and automotive repair shops.

Limitations

- Each site should be considered individually and stormwater protection measures should be taken accordingly.

Design and Construction Criteria

- Fueling areas must be designed according to local codes and regulations.
- Fueling areas should be paved with a smooth impervious surface such as Portland cement concrete. Asphalt should not be used near fuel dispensers because fuels can dissolve and/or destroy the structural integrity of asphalt.
- The concrete surface should extend a minimum of 6.5 feet from the corner of each fuel dispenser or the length of the hose plus 1 foot, whichever is less.
- An overhanging roof or canopy structure should cover the entire fueling dispensing area and it should not drain onto or toward the fueling area.
- Fueling areas should be separated from the rest of the site by grade breaks and should be on a slight slope to prevent the ponding of water. The dimensions of the overhanging roof or canopy structure should be greater than the area within the grade break.
- A dead-end sump or an oil and water separator should be used to collect wash runoff and/or spills from fueling dispensing areas and the wastewater contained in the sump or separator should be disposed of properly.
- Fueling areas are generally prohibited from being plumbed to the sanitary sewer or storm drain systems. However, an Environmental Control permit may be obtained allowing some discharge of pretreated wastewater to the sanitary sewer system.
- Storm drains and LID features should not be located directly down slope or next to fueling areas.
- Storm drain seals (drain covers, plugs, or isolation valves) should be provided in case of a spill and/or emergency to prevent pollutants from entering the storm drain system.

Inspection and Maintenance Requirements

- Inspect dead-end sumps quarterly, or at the appropriate interval to ensure they do not overflow.
- Pump and properly dispose of wastewater contained in the sump at regular intervals.
- Spill cleanup materials should be maintained on site and be readily accessible.
- Any spills should be cleaned up immediately, and absorbent material should be cleaned up as soon as practicable and disposed of properly.

SC-23 OUTDOOR WORK, MAINTENANCE AND WASH AREA BMPS

Description

In commercial and industrial areas, contaminants such as oils, grease, metals, phosphates, suspended solids, and nutrients present in work areas and resulting from equipment and automotive maintenance and washing can affect water quality if stormwater runoff is not properly conveyed to the sanitary sewer. Sources of contaminants include; cleaning of parts, equipment and vehicles, cleaning of the work area, spilled or dripped fuels, oils or other chemical agents, and the disposal of rags, filters, batteries, and other wastes. Wastes and runoff from these areas must be collected and not allowed to infiltrate. (RMC 12.16.1900)

In multi-family developments or mobile home parks, wash waters from automobiles and other outdoor surfaces commonly contain high concentrations of sediments, oils and grease, cleaning chemicals, phosphates, antifreeze and heavy metals and have a negative impact on stormwater quality if wash waters are not prevented from entering the storm drain system.

Applications

Applicable in commercial and industrial areas, including restaurants, gasoline stations, and automotive repair shops. Also applicable in multi-family developments or mobile home parks.

Limitations

- Some commercial and industrial locations may be required to pre-treat and monitor wash waters entering the sanitary sewer.

Siting Criteria

- Do not locate work, maintenance, or wash areas near storm drains. Some wash areas should have a paved access.

Design and Construction Criteria

Work and Maintenance Areas

- Underlay the work area with Portland cement concrete or use prefabricated metal drip pans
- Maintenance/work areas should be covered with a roof or canopy.
- Establish a berm or grade break around the work area to prevent run-on or runoff.
- Berm and/or cover areas where vehicle parts and fluids are stored.
- Certain regulated industrial activities may require pre-treatment with a structural control prior to discharge to the sanitary sewer.

Equipment and Vehicle Wash Areas

- Wash areas should be self-contained and paved with Portland cement concrete. Surrounded the wash area with a berm or grade break, sloped toward a drain having a pre-treatment device properly connected to the sanitary sewer system
- The entire wash area should be covered with a roof to prevent contact with rainwater.
- An Environmental Control permit may be required prior to discharging wastewater from a dead-end sump or connecting an oil and water separator to the sanitary sewer

system.

- Wash areas for vehicles should have a minimum width of 15 feet, a minimum length of 25 feet and a paved access.
- Use biodegradable and phosphate-free detergents when possible.
- Use hoses that have nozzles that turn off automatically when not in use.
- Clearly mark wash areas with posted signs stating that vehicle fluids should not be dumped in the area.

Inspection and Maintenance Requirements

- Train employees on proper cleaning and maintenance techniques as well as wastewater handling procedures.
- Pre-treatment devices will require inspection and maintenance appropriate to the device (refer to TC fact sheets).

Additional Information

- Contact the local sewer authority or Environmental Control department to determine if pre-treatment of wash waters is required prior to discharge.
- Wash waters are non-storm discharges and are not considered to be stormwater.
- Hazardous and toxic wastes must not enter the storm drain system.
- Provide drain plugs or valves to prevent spilled materials from entering the storm drain system.

SC-24 SPILL PREVENTION, CONTAINMENT AND CLEANUP BMPS

Description

Containment berms, curbing, and drip pans are methods for controlling and containing spills on commercial and industrial sites. These methods prevent spilled materials from entering the storm drain system. Berms can be either a temporary or a permanent feature at a site and can be constructed from a variety of materials including concrete, metal, synthetics, or earthen materials. Operational BMPs such as regular inspections are also very important and effective at catching leaks and resolving issues before they become a problem.

Applications

To be applied on any commercial or industrial site having the potential to spill materials that will introduce pollutants to the storm drain system.

Limitations

- Containment dikes may be too expensive for small sites.
- Drip pans are only applicable for small leaks and may be blown off-target by wind if not secured.

Siting Criteria

- Drip pans should be located where they are easy to remove, clean, and maintain.
- Do not place drip pans next to sidewalks or on uneven surfaces where they have a potential for being overturned.

- Firmly secure drip pans to prevent heavy winds from moving or damaging them.
- Operational practices such as regular leak inspection and repair are preferred to the use of drip pans.

Design and Construction Criteria

- The floor of the spill area must be impermeable. Suggested materials include asphalt or concrete.
- Containment dikes must be capable of containing a spill from the largest storage tank within the potential spill area.
- Curbs should be placed to route spill materials down gradient from the largest container within the spill area to a collection basin.
- Curbing is typically constructed from earth, concrete, metal, asphalt, or other impervious materials
- Containment dikes may be equipped with normally closed valves to assist with management of retained stormwater.

Inspection and Maintenance Requirements

- Drip pans must be inspected and cleaned frequently.
- Drip pans must be secured in bad weather conditions.
- Containment dikes and berm should be inspected after significant storm events and spills to check for leaks or overflows.
- Closely inspect the overflow system to control leaks.
- Visually inspect snowmelt and rainwater present in the spill containment area prior to release. Stormwater present in the spill containment area may need to be treated or collected and disposed of properly.

Additional Information

- Sorbents or gelling agents are effective means of controlling spilled materials.
- The type of berm selected will determine the costs of installation and maintenance.
- Local, state, and federal codes and regulations must be followed when removing spilled materials from a site. See RMC Sec. 12.16.1200.

SC-25 WASTE HANDLING AND DISPOSAL BMPS

Description

Storage areas for industrial or chemical wastes need to be properly maintained to prevent or reduce pollutants from entering the storm drain system. Wastes should be stored, treated, or disposed of in a safe and responsible manner consistent with applicable regulations. Pollutant and waste sources may include dumpsters, waste piles, storage of treatment chemicals or residuals, or process wastes. Any wastes spilled or lost from work areas may build-up in soils to be released later during precipitation events effecting stormwater quality. Thus, proper management of facilities is vital in preventing stormwater pollution.

Residential waste products can also have a negative impact on stormwater quality. Oils, anti-freeze, batteries, fuels, paints, cleaning agents, weed killers, fertilizers, as well as many other products may contaminate stormwater runoff if not properly managed.

Applications

Wastes should be properly managed and maintained on all commercial and industrial sites.

Limitations

- Each site should be considered individually and stormwater protection measures should be taken accordingly.

Siting Criteria

- Specific sites should be designated onsite for waste collection and handling.
- Waste handling areas should be elevated if practicable, and storm drains should not be located within the waste handling area.
- Follow local codes or ordinances for the design of multi-family waste handling areas.

Design and Construction Criteria

- Waste handling areas should be underlain by an impervious material such as concrete.
- A barrier (concrete pad or berm) should be constructed around the waste collection area and the area should be graded such that spills or wastes will move toward a dead-end sump.
- Provide overflow protection devices around tanks and the storage area.
- For industrial and commercial sites, the waste containment area should be covered and would be preferably located indoors.
- Waste containers must be covered to prevent rainwater exposure or materials from being blown away.
- Dumpsters should be lined and covered to reduce waste spills and leaks.
- Recyclables should be stored indoors or under an overhang, or securely covered.
- Signs should be posted on dumpsters restricting disposal of hazardous wastes.

Inspection and Maintenance Requirements

- Assure that wastes will be collected regularly, or before overflowing occurs.
- Spills should be cleaned up immediately.

Additional Information

- Provide appropriate instruction and signage regarding waste storage and management.
- Local, state, and federal regulations must be followed when disposing of accumulated wastes. See RMC Sec. 12.16.930.

5.3 References

California Stormwater Quality Association, 2003. Stormwater Best Management Practice Handbook, New Development and Redevelopment.

City and County of Sacramento, 2007. Stormwater Quality Design Manual for the Sacramento and South Placer Regions.

City of Portland, 2014. Stormwater Management Manual. Portland, Oregon

Idaho Department of Environmental Quality, 2005. Catalog of Stormwater Best Management Practices for Idaho Cities and Counties.

Los Angeles County, 2002. A Manual for the Standard Urban Stormwater Mitigation Plan (SUSMP), Los Angeles County Department of Public Works, May 2002.

Urban Drainage and Flood Control District, 2013. Urban Storm Drainage Criteria Manual Volume 3 – Best Management Practices. Denver, Colorado.

6.0 STORM WATER TREATMENT CONTROLS

Local codes and ordinance in the Truckee Meadows require stormwater treatment for new development and significant redevelopment. Large reductions in treatment BMP size and investment can be made by effectively managing stormwater quantity and quality using the following two strategies:

- Reduce runoff that needs to be captured, infiltrated, or treated by limiting the amount of effective impervious area in the project (See **Section 4** – LID Planning Principles and Site Design)
- Control sources of pollutants and prevent them from contacting runoff (See **Section 5** – Source Controls)

After these strategies have been applied to a project, structural treatment controls should be evaluated and designed. This section provides guidance for the selection, design and maintenance of public domain treatment control BMPs and for selected manufactured or proprietary treatment controls that are commercially available.

6.1 Identifying Candidate BMPs

The selection of structural controls should be based on pollutants of concern and is a function of site constraints, expected BMP performance, and watershed specific requirements such as TMDLs. Cost can become an important differentiator in BMP selection. **Appendix C** provides a Structural Control Design and Selection Matrix to assist site designers with the proper selection of the public domain treatment controls. Matrix 1 indicates what types of treatment controls are applicable for a given type of land use. Matrix 2 provides a list of the physical design constraints that must be considered when siting public domain treatment controls. Matrix 3 indicates the potential stormwater management capabilities of the treatment controls in addition to stormwater quality enhancement. Matrix 4 provides a comparison of the community and environmental factors, such as ease of maintenance, safety considerations, and the potential for habitat creation, that are associated with public domain structural treatment controls. Matrix 5 provides a general summary of the expected pollutant removal effectiveness of the treatment controls presented. More detailed information on pollutant removal effectiveness is provided on the individual BMP fact sheets presented later in this section.

6.2 Using the Design Guidance Worksheets

The Truckee Meadows Standard Design Guidance Worksheets have been developed as part of a toolkit to assist designers incorporating Low Impact Development (LID) into projects. Sufficient engineering analysis must show that the proposed stormwater quality management measures are capable of capturing runoff and potential pollutants from the site in compliance with the appropriate jurisdiction's Structural Controls Ordinance. Proposed measures must also meet specifications as described in this Manual. The engineering analysis must illustrate the drainage subareas and demonstrate the proposed mitigation measures, which must be designed to meet or exceed the minimum treatment standard required. The Design Guidance

Worksheets have been created to provide a consistent submittal format, and when properly completed, demonstrate sufficient engineering analysis.

A worksheet has been created to assist designers with the calculations required for each of the treatment controls included in this Manual. An additional worksheet is included for "self-treating areas" which may exist within the project area, but do not require treatment controls because no runoff is expected to result from a 90th percentile storm event. The designer should complete the TC-STA worksheet to justify their reasoning for designating an area as "self-treating". Examples of self-treating areas include large landscaped areas, preserved natural areas, and ponds which may occur within the overall project area. In general, a self-treating sub-basin should have no more than 20% impervious area and native infiltration rates of at least 0.5 in/hr.

To use the Design Guidance Worksheets, begin by downloading the latest version from www.TMstormwater.com, and follow these steps:

1. Fill out the Project Summary Worksheet
2. Enter pre- and post-development impervious areas and runoff coefficients for each sub-basin in the Project Pass/Fail Checklist.
3. Complete a design guidance worksheet for each Treatment Control in the project. If the project includes more than one installation of the same type of Treatment Control, simply copy the applicable worksheet.
4. Enter actual WQ_V and WQ_F values for each sub-basin into the Pass/Fail Checklist and see if sufficient treatment has been applied
5. Repeat steps 3 and 4 until a passing score is achieved
6. Print Project Summary, Pass/Fail Checklist, and all other Design Guidance Sheets used
7. Submit appropriate number of copies to reviewing agency

6.3 Water Quality Design Criteria

To adequately treat runoff and enhance water quality, design criteria are required for both flow and volume-based structural treatment controls. A set of general design criteria that should be consulted when sizing all structural treatment controls in the Truckee Meadows are provided in the following sub-sections. These design criteria apply to water quality flow (WQ_F) or volume sizing criteria that is based on the analysis of the local precipitation data presented in **Section 3**. Flows in excess of the water quality flow or volume must be diverted around or through structural treatment controls in a manner that does not allow the scour or re-suspension of collected sediments or increase the discharge of pollutants into the storm drain system. Therefore, general design criteria for diversion structures are also provided. Design criteria that are specific to individual structural treatment controls (e.g., perforation diameter sizing for the principal outlet structure of an extended detention basin) are provided on the BMP fact sheets later in this section.

The water quality design criteria developed and implemented by the following communities were reviewed and used as models during the development of regional sizing criteria for flow and volume-based treatment controls and diversion structures in the Truckee Meadows:

- The City and County of Sacramento, California
- The City of Livermore, California
- The City of Boise, Idaho
- The City of Denver, Colorado
- The City of Austin, Texas

In addition, the California Stormwater Best Management Practices Handbook for New Development and Redevelopment developed in 2003 by the California Storm Water Quality Association was reviewed and referenced.

6.3.1 Sizing Criteria for Flow-Based Stormwater Treatment Controls

Flow-based design standards apply to those structural treatment controls where the primary method of pollutant removal is based on the flow and filtration of runoff through the BMP. A specified WQ_F rate is conveyed through the BMP and pollutants are removed by filtration through vegetation, sand filters and other types of media capable of trapping sediments and associated pollutants typically transported in urban runoff. The WQ_F rate represents the flow rate produced by the most frequently occurring rainfall/runoff events. Infiltration into underlying soils typically enhances the performance of flow-based BMPs. The general categories of flow-based stormwater treatment controls include vegetated treatment systems, some media filtration systems and many manufactured (proprietary) treatment controls.

The WQ_F for flow-based stormwater treatment controls installed in the Truckee Meadows should be determined by using the Rational Method to estimate the peak discharge produced by the 2-year storm event for the drainage area of the BMP. The Rational Method is based on the formula:

$$Q = CIA \qquad \text{Equation 6-1}$$

Where: Q = peak flow rate (cfs)

C = the runoff coefficient of the contributing drainage area

I = rainfall intensity (in/hr) for a duration equal to the time of concentration

A = the contributing drainage area (acres)

The Rational Method should be used to determine peak flow rates for drainage areas of 100 acres or less, and 25 acres or less where the composite runoff coefficient is 0.50 or less. It should be used with caution when estimating peak flows for relatively large undeveloped areas (25 acres or more), particularly where runoff coefficients are highly variable with storm intensity and antecedent soil moisture conditions. Where these conditions exist, the Rational Method will likely overestimate peak flow rates.

When 'I' equals the rainfall intensity for the 2-year storm event, $Q_2 = WQ_F$. The Truckee Meadows Regional Drainage Manual provides detailed explanations and examples of the Rational Formula, including rainfall intensities and runoff coefficients. An example of the "C" values provided in the Truckee Meadows Regional Drainage Manual (2009) is provided on **Table 6-1**. Rainfall intensities for sites within the City of Sparks should be determined using the intensity-depth-duration curves provided in the Truckee Meadows Regional Drainage

Manual, while sites within Reno and Washoe County should apply rainfall intensities from the NOAA Atlas 14. An example of the intensity-depth-duration curve developed for Region 1 in the City of Sparks is provided on **Figure 6-1**.

For drainage areas greater than 100 acres, peak flow rates should be estimated using the NRCS TR-55 Method or HEC-1. Design of flow-based stormwater treatment controls and use of the Rational Method, NRCS TR-55 Method and HEC-1 for determining flow rates should be consistent with the policies and procedures described in the Truckee Meadows Regional Drainage Manual.
To ensure that flooding of critical areas and structures will not occur during larger storm events, upstream diversion structures that limit flows through flow-based BMPs to the 2-year peak flow rate may be required. If upstream diversion structures are required because a flow-based stormwater treatment control only has the capacity to convey the peak discharge produced by the 2-year storm event, all excess flows must be diverted.

6.3.2 Sizing Criteria for Volume-Based Stormwater Treatment Controls

Volume-based BMP design standards apply to those stormwater treatment controls whose primary method of pollutant removal is based on the facilities ability to capture and detain, retain and/or infiltrate a specific WQ_V. The WQ_V represents the runoff volume produced by the most frequently occurring rainfall/runoff events. The primary pollutant removal mechanism is the extended detention of the WQ_V so that suspended sediments and associated pollutants are allowed sufficient time to settle and collect in the basin or in the voids of permeable materials in the BMP. As with flow-based treatment controls, infiltration into underlying soils typically enhances the performance of volume-based BMPs. The general categories of volume-based stormwater treatment controls include infiltration systems, bioretention systems, extended detention basins, and ponds and constructed wetlands.

Volume-based stormwater treatment controls in the Truckee Meadows should be designed to capture and detain the WQ_V determined using the following formulas:

$$WQ_V = (P*RV*A)/12 \qquad \text{equation 6-2}$$

$$RV = 0.05 + 0.009I \qquad \text{equation 6-3}$$

Where:
WQ_V = water quality volume (ft^3)
P = 90th percentile precipitation depth (0.60 inches)
R_V = watershed runoff coefficient
I = percent of watershed impervious area (not rainfall intensity as in eq. 6-1)
A = the contributing drainage area (ft^2)
12 = unit conversion constant

The watershed runoff coefficient (R_V) in the WQ_V method is based on a regression equation developed from precipitation data for a number of relatively small urban drainages distributed throughout the U.S. The 90th percentile precipitation depth (P) of 0.60 inches is based on an analysis of local long-term hourly precipitation data for the Reno Tahoe International Airport. Refer to **Section 3** for additional discussion of the stormwater hydrology of the Truckee Meadows.

Table 6-1. Runoff coefficients for the Rational Method from the Truckee Meadows Regional Drainage Manual (2009).

RATIONAL FORMULA METHOD
RUNOFF COEFFICIENTS

Land Use or Surface Characteristics	Aver. % Impervious Area	Runoff Coefficients 5-Year (C_5)	Runoff Coefficients 100-Year (C_{100})
Business/Commercial:			
Downtown Areas	85	.82	.85
Neighborhood Areas	70	.65	.80
Residential:			
(Average Lot Size)			
⅛ Acre or Less (Multi-Unit)	65	.60	.78
¼ Acre	38	.50	.65
⅓ Acre	30	.45	.60
½ Acre	25	.40	.55
1 Acre	20	.35	.50
Industrial:	72	.68	.82
Open Space:			
(Lawns, Parks, Golf Courses)	5	.05	.30
Undeveloped Areas:			
Range	0	.20	.50
Forest	0	.05	.30
Streets/Roads:			
Paved	100	.88	.93
Gravel	20	.25	.50
Drives/Walks:	95	.87	.90
Roof:	90	.85	.87

Notes:

1. Composite runoff coefficients shown for Residential, Industrial, and Business/Commercial Areas assume irrigated grass landscaping for all pervious areas. For development with landscaping other than irrigated grass, the designer must develop project specific composite runoff coefficients from the surface characteristics presented in this table.

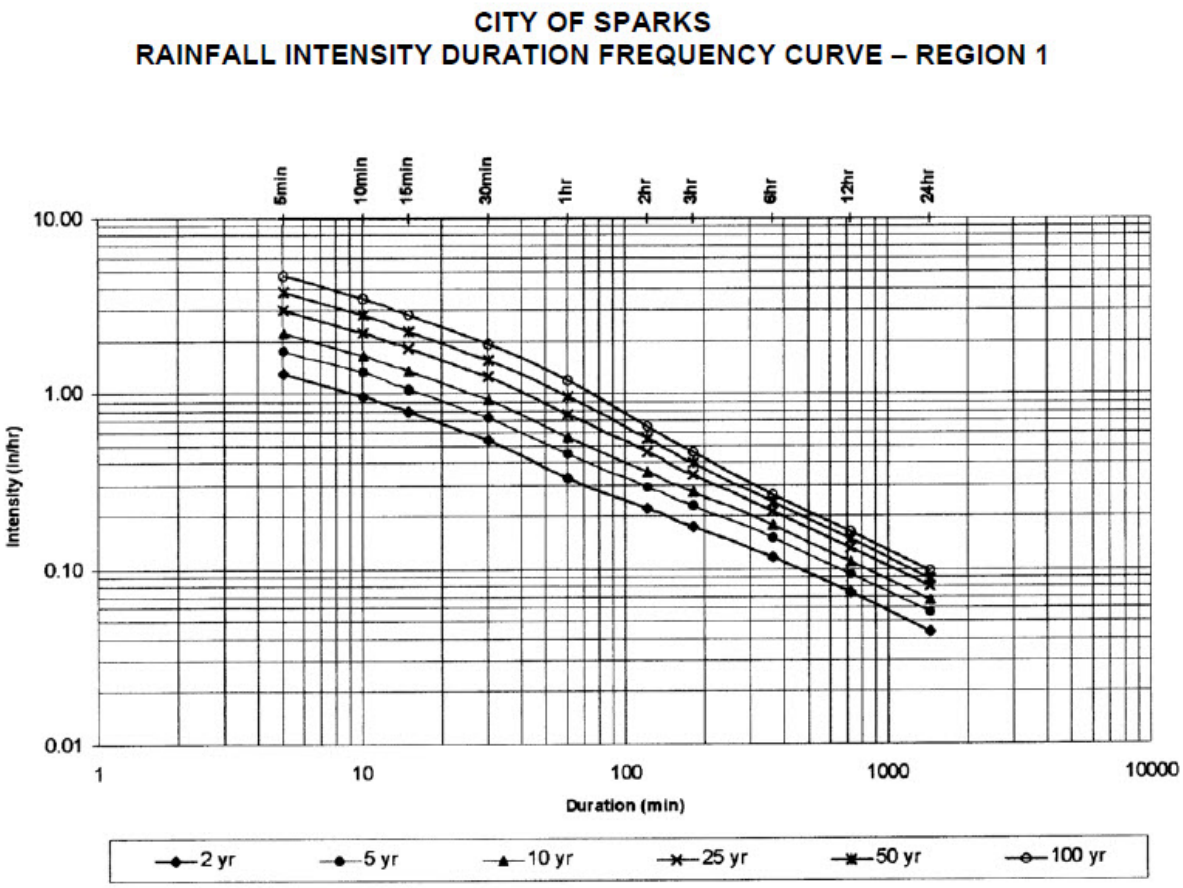


Figure 6-1. Example intensity-depth-duration curve for Region 1 of Sparks from the Truckee Meadows Regional Drainage Manual (2009).

6.3.3 Combining Volume and Flow Based-BMPs

Flow and volume-based BMPs do not necessarily treat the same type of stormwater runoff produced by different types of storm events. For example, a flow-based BMP might be overwhelmed by a short but intense storm event if the storm intensity results in runoff rates that exceed the flow-based BMP design flow rate (WQ_F). However, an in-line volume-based BMP such as an extended detention basin may be able to treat the design runoff volume (WQ_V) from the same storm event and is essentially unaffected by runoff entering the basin at a high rate but for a short duration. By contrast, a flow-based BMP such as a swale can treat the design flow rate of runoff and is essentially unaffected by the duration of a storm event such as a long, low intensity storm. However, a volume-based detention basin subjected to the same type of storm event may fill over time and overflow or go into a diversion structure, providing less treatment than the flow-based BMP.

Therefore, there may be some situations where a designer might need to consider application of both flow and volume-based BMPs. An example of where both types of design criteria might apply is an off-line detention basin. For an off-line detention basin, the capacity of the diversion structure could be designed to comply with the flow-based BMP design criteria while

the detention basin itself could be designed to comply with the volume-based criteria. When both volume-based and flow based criteria apply, the designer should determine which of the criteria apply to each element of the BMP system, and then size the elements accordingly.

6.4 Infiltration Testing

If infiltration BMPs are being considered for a project, infiltration testing should be performed as part of the geotechnical study. For infiltration of stormwater and urban runoff, a minimum infiltration rate of 0.5 in/hr (120 min/inch) is required in the native soils underlying infiltration systems. If native soils have infiltration rates less than 0.5 in/hr (120 min/inch), structural treatment controls and LID practices must incorporate underdrain systems to prevent extended ponding. In areas where native soil infiltration rates exceed 2.4 in/hr (25 min/inch) pretreatment of stormwater prior to infiltration may be required to prevent potential groundwater contamination. Addition of soil amendments to slow infiltration and allow adequate treatment and processing of stormwater may also be considered by the jurisdictions (see **Section 4.6** for more information).

The minimum infiltration testing method acceptable for regional use is the Percolation Test as defined in the current version of the District Health Department Regulations Governing Sewage, Wastewater, and Sanitation (Sections 090 in the May 23, 2013 approved revision). This is the minimum infiltration testing method required by Reno, Sparks and Washoe County whenever practices that will infiltrate stormwater are proposed. As an alternate to conducting percolation testing in the benched test trenches required in the District Health Department Regulations, a boring or test pit is acceptable provided it is installed to a minimum depth of 5 ft. below the bottom of the proposed infiltration system. The boring or test pit may be used to identify seasonally high groundwater (e.g., staining) and potential shallow confining layers (e.g., bedrock or clay). In some instances, more rigorous testing methods such as the "Flooding Basin Test" may be required by one of more of the agencies.

6.5 Diversion Structures

Some treatment control facilities are designed to be "on-line", meaning that they are part of the normal storm drainage system and peak flow events are conveyed through the treatment control. Vegetated swales and extended detention basins are often designed in this way, providing treatment to smaller water quality storm events and conveyance or detention for larger peak events. When designing on-line facilities, the engineer must consider hydraulic performance under both low-flow and high-flow conditions, and make sure that sediments and pollutants that may have settled out under low flow conditions are not re-suspended during high flow events.

For "off-line" treatment controls, a diversion structure is used to divert smaller storm events to the treatment structure, while allowing larger events to bypass to the conventional storm drain system. In this way, the treatment control is not subjected to the potentially damaging velocities that may occur during a high-flow event. Furthermore, off-line treatment facilities are usually smaller and less expensive than on-line facilities because they do not need to have additional capacity for large storm events.

Since conventional storm drainage systems are typically constructed to convey flows from the larger storm events (the 5-year up to the 100-year peak flow) without regard for treatment, the design engineer must ensure there is sufficient capacity in the diversion structure to accommodate overflows. Therefore, the engineer must establish the design capacity of the storm drain system when designing diversion structures and structural treatment controls for stormwater quality enhancement.

Implementing one or both of the following techniques typically accomplishes capture or isolation of the WQ_F or WQ_V:

- Use of diversion structures, such as weirs, orifices or pipes, to divert the WQ_F or WQ_V into an off-line structural treatment control. The diversion structure is typically located at or upstream of the inlet to the BMP (**Figures 6-2 and 6-3**).
- Bypassing flows in excess of the WQ_F or WQ_V using weirs, orifices or pipes within in-line structural treatment controls and routing these flows to the conventional storm drain system or another treatment control BMP (**Figures 6-4 and 6-5**).

The following figures provide examples of diversion structures and the following discussion provides the recommended procedures for sizing various diversion structures for flow and volume-based treatment control BMPs.

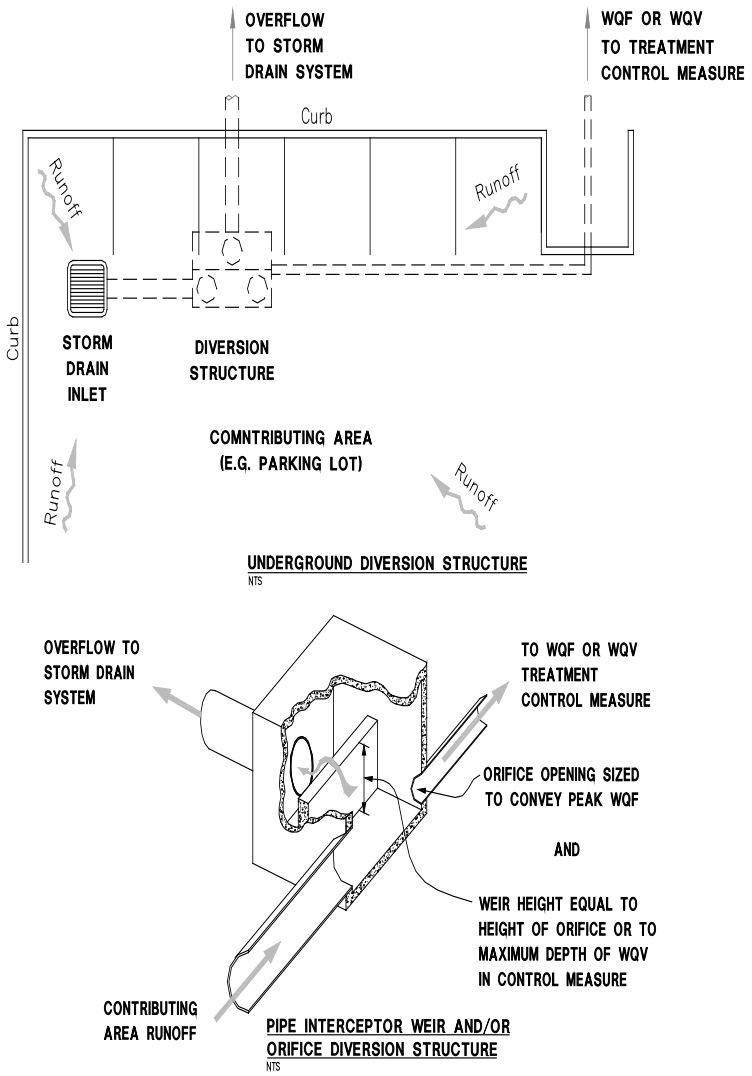
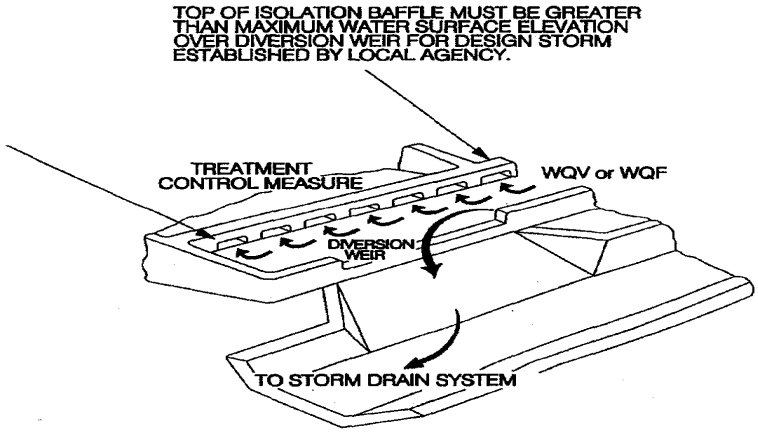
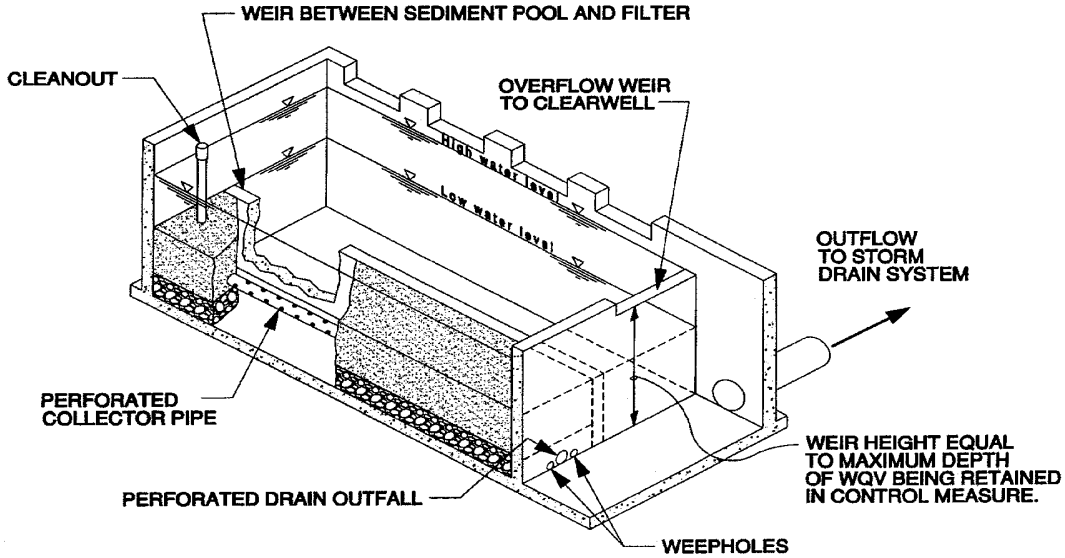


Figure 6-2. Example of an underground pipe interceptor weir and/or orifice diversion structure for WQ_F or WQ_V treatment control measures



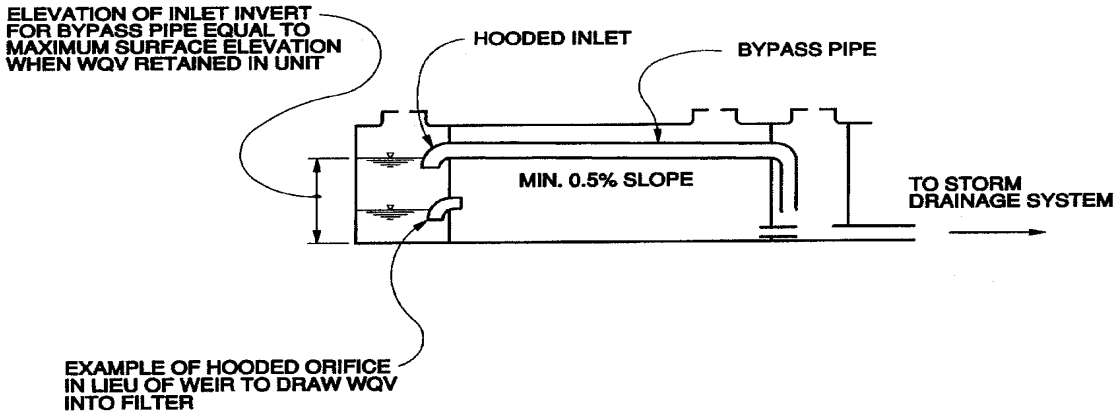
SURFACE CHANNEL DIVERSION STRUCTURE

Figure 6-3. Example of a surface channel diversion structure for flow or volume based treatment controls (modified from City of Austin, 2003).



Delaware Filter In-Line By-Pass

Figure 6-4. Example of an in-line underground sand filter with an overflow weir (City of Sacramento, 2000)



D.C. Filter In-line By-Pass

Figure 6-5. Example of an in-line treatment control measure with a bypass pipe (City of Sacramento, 2000).

Designing Weirs for Flow-Based Treatment Controls

1) Establish the design capacity of the storm drain system at the point of diversion.
2) Determine the WQ_F for the proposed structural treatment control using equation 6-1.
3) Determine the depth of flow in the storm drain system at the WQ_F using the Manning's equation, solving for depth.

$$WQ_F = (1.49/n)AR^{2/3}S^{1/2} \qquad \text{equation 6-4}$$

Where: WQ_F = water quality peak flow rate (cfs)

1.49 = conversion factor for English units

n = Manning roughness coefficient (dimensionless)

A = cross sectional area of the storm drain pipe or channel (ft^2)

R = hydraulic radius of the storm drain pipe or channel (ft.)

S = slope of the pipe or channel (ft./ft.)

Since depth of flow enters into both the cross sectional area (A), and the hydraulic radius (R), solving for depth is typically an iterative process, depending on the channel geometry. For this reason, nomographs or computer programs are often used to determine the depth of flow.

4) Set the weir height (H) at the flow depth determined in step 3.

5) Use the equation for a rectangular broad-crested weir to determine weir length (L) for the peak flow to bypass treatment:

$$Q_{SD} = CLh^{1.5} \qquad \text{equation 6-5}$$

Where: Q_{SD} = the peak flow rate for the storm drain system (cfs)

C = weir coefficient (typically 3.0)

L = the effective horizontal length of the weir (ft.)

h = the depth of flow above the crest of the weir (ft.)

6) Ensure sufficient head is available in the design of the weir structure to accommodate overflow from the larger storm events.

The weir or discharge coefficient "C" for a broad-crested weir accounts for factors such as the flow approach velocity. It has been determined experimentally to range between 2.67 and 3.05. A value of C = 3.0 is typically used for the design for the design of detention overflow structures, spillways and diversion structures (Stahre and Urbonas, 1990). **Table 6-2** provides a list of Manning roughness coefficients (n) for various channel-lining materials as provided in the Truckee Meadows Regional Drainage Manual (2009).

Designing Weirs for Volume-Based Treatment Controls

1) Establish the design capacity of the storm drain system at the point of diversion.
2) Determine the WQ_V for the proposed structural treatment control using equations 6-2 and 6-3.
3) Using the design and construction criteria provided in the BMP fact sheets; determine the water level height in the treatment control measure when the entire WQ_V is retained within the structure.
4) Set the weir height (H) at the water level height determined in step 3.
5) Use equation 6-5 to determine weir length (L).
6) Design weir with low-flow capabilities so that no ponding occurs behind the weir.

Ensure sufficient head is available in the design of the weir structure to accommodate overflow from the larger storm events.

Designing Orifices for Volume-Based Treatment Controls

1) Establish the design capacity of the storm drain system at the point of diversion.
2) Determine the WQ_V for the proposed structural treatment control using equations 6-2 and 6-3.
3) Using the design and construction criteria provided in the BMP fact sheets; determine the water level height in the treatment control measure when the entire WQ_V is retained within the structure.
4) Set the invert elevation of the orifice at the water level height determined in step 3.

5) Establish the size of the orifice opening using the following equation:

$$Q_{SD} = C_d A(2gh_d)^{1/2} \qquad \text{equation 6-6}$$

Where: Q_{SD} = capacity of the storm drain system from step 1 (cfs)

C_d = orifice coefficient = 0.65 (dimensionless)

A = orifice area (ft^2)

g = acceleration of gravity (32.2 ft./sec^2)

h_d = height of water above mid-point of orifice (ft.)

6) Ensure sufficient head is available in the treatment control BMP to accommodate flows from larger storm events through the orifice.

In addition to providing a bypass for water that exceeds the WQ_V, orifices can be used within volume based treatment controls in place of weirs or pipes to prevent floatables from entering the conventional storm drain system.

<u>Designing Bypass Pipes for Volume-Based Treatment Controls</u>

1) Repeat steps 1 through 3 under Designing Orifice Diversions for Volume-Based Treatment Controls.
2) Size the bypass pipe to the design capacity of the storm drain system (Q_{SD}). Assuming the bypass pipe flows full at Q_{SD}, use the following version of the Manning's equation:

$$D = \left(\frac{2.15 Q_{SD} n}{S^{\frac{1}{2}}}\right)^{\frac{3}{8}} \qquad \text{equation 6-7}$$

Where: D = diameter of the bypass pipe (ft.)

Q_{SD} = capacity of the storm drain system (cfs)

n = Manning's roughness coefficient (dimensionless)

S = slope of the pipe or channel (ft./ft.)

Ensure sufficient head is available in the treatment control BMP to accommodate flows from larger storm events through the bypass pipe.

Table 6- 2. Manning's Roughness Coefficients for Open Channels (From TRMDM and Chow, V.T., Open Channel Hydraulics, 1959).

TYPICAL ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
EXCAVATED OR DREDGED			
a. Earth, straight and uniform			
1. Clean, recently completed	0.016	0.018	0.020
2. Clean, after weathering	0.018	0.022	0.025
3. Gravel, uniform section, clean	0.022	0.025	0.030
4. With short grass, few weeds	0.022	0.027	0.033
b. Earth, winding and sluggish			
1. No vegetation	0.023	0.025	0.030
2. Grass, some weeds	0.025	0.030	0.033
3. Dense weeds or aquatic plants in deep channels	0.030	0.035	0.040
4. Earth bottom and rubble sides	0.028	0.030	0.035
5. Stony bottom and weedy banks	0.025	0035	0.040
6. Cobble bottom and clean sides	0.030	0.040	0.050
c. Dragline-excavated or dredged			
1. No vegetation	0.025	0.028	0.033
2. Light brush on banks	0.035	0.050	0.060
d. Rock cuts			
1. Smooth and uniform	0.025	0.035	0.040
2. Jagged and irregular	0.035	0.040	0.050
e. Channels not maintained, weeds and brush			
1. Dense weeds, high as flow depth	0.050	0.080	0.120
2. Clean bottom, brush on sides	0.040	0.050	0.080
3. Same as above, but highest stage of flow	0.045	0.070	0.110
4. Dense brush, high stage	0.080	0.100	0.140
NATURAL STREAMS			
Minor Streams (top width at flood stage < 100 ft)			
a. Streams on plain			
1. Clean, straight, full stage, no rifts or deep pools	0.025	0.030	0.033
2. Same as above, but more stones and weeds	0.030	0.035	0.040
3. Clean, winding, some pools and shoals	0.033	0.040	0.045
4. Same as above, but some weeds and stones	0.035	0.045	0.050
5. Same as above, but lower stages, and more ineffective slopes and sections	0.040	0.048	0.055

VERSION: April 30, 2009	REFERENCE: Chow, V.T., 1959, Open-Channel Hydraulics	TABLE 802 1 of 3
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Table 6- 2. Continued

TYPICAL ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
6. Same as 4, but more stones	0.045	0.050	0.060
7. Sluggish reaches, weedy, deep pools	0.050	0.070	0.080
8. Very weedy reaches, deep pools, or floodways with heavy stand of timber and underbrush	0.075	0.100	0.150
b. Mountain streams, no vegetation in channel, banks usually steep, trees and brush along banks submerged at high stages			
1. Bottom: gravel, cobbles, and few boulders	0.030	0.040	0.050
2. Bottom: cobbles with large boulders	0.040	0.050	0.070
Flood plains			
a. Pasture, no brush			
1. Short grass	0.025	0.030	0.035
2. High grass	0.030	0.035	0.050
b. Cultivated areas			
1. No crop	0.020	0.030	0.040
2. Mature row crops	0.025	0.035	0.045
3. Mature field crops	0.030	0.040	0.050
c. Brush			
1. Scattered brush, heavy weeds	0.035	0.050	0.070
2. Light brush and trees, in winter	0.035	0.050	0.060
3. Light brush and trees, in summer	0.040	0.060	0.080
4. Medium to dense brush, in winter	0.045	0.070	0.110
5. Medium to dense brush, in summer	0.070	0.100	0.160
d. Trees			
1. Dense willows, summer, straight	0.110	0.105	0.200
2. Cleared land with tree stumps, no sprouts	0.030	0.040	0.050
3. Same as above, but with heavy growth of sprouts	0.050	0.060	0.080
4. Heavy stand of timber, a few down trees, little undergrowth, flood stage below branches	0.080	0.100	0.1200
5. Same as above, but with flood stage reaching branches	0.100	0.120	0.160
Major Streams (top width at flood stage > 100 ft). The *n* value is less than that for minor streams of similar description, because banks offer less effective resistance			
a. Regular section with no boulders or brush	0.025	---	0.060
b. Irregular and rough section	0.035	---	0.100

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Table 6- 2. Continued

TYPICAL ROUGHNESS COEFFICIENTS FOR OPEN CHANNELS

TYPE OF CHANNEL AND DESCRIPTION	MINIMUM	NORMAL	MAXIMUM
LINED OR BUILT-UP CHANNELS			
a. Corrugated Metal	0.021	0.025	0.030
b. Concrete			
1. Trowel finish	0.011	0.013	0.015
2. Float finish	0.013	0.015	0.016
3. Finished, with gravel on bottom	0.015	0.017	0.020
4. Unfinished	0.014	0.017	0.020
5. Gunite, good section	0.016	0.019	0.023
6. Gunite, wavy section	0.018	0.022	0.025
7. On good excavated rock	0.017	0.020	---
8. On irregular excavated rock	0.022	0.027	---
c. Concrete bottom float finished with sides of:			
1. Dressed stone in mortar	0.015	0.017	0.020
2. Random stone in mortar	0.017	0.020	0.024
3. Cement rubble masonry, plastered	0.016	0.020	0.024
4. Cement rubble masonry	0.020	0.025	0.030
5. Dry rubble or riprap	0.020	0.030	0.035
d. Gravel bottom with sides of :			
1. Formed concrete	0.017	0.020	0.025
2. Random stone in mortar	0.020	0..023	0.026
3. Dry rubble or riprap	0.023	0.033	0.036
e. Asphalt			
1. Smooth	0.013	0.013	---
2. Rough	0.016	0.016	---
f. Grassed	0.030	0.040	0.050

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6.6 Regional Treatment Controls

Existing and proposed flood control detention basins can be modified to improve the quality of stormwater discharges with the addition of stormwater quality outlet structures, vegetated swales and stormwater ponds and wetlands. Outlet structures, such as those presented on BMP Fact Sheet TC-40 Sedimentation Basins, can be incorporated into the design of flood control detention basins without changing the primary function of the structure. Stormwater quality outlet structures designed to detain stormwater runoff from the most frequently occurring storm events for an extended period allow suspended sediments and associated pollutants time to settle and collect in the basin. Vegetated swales can also be added as a pretreatment measure and can be incorporated into multiuse facilities. In areas where non-storm and dry weather flows produce a perennial flow into a flood control detention basins, stormwater ponds and wetlands can be incorporated into the design to enhance water quality.

Since the continued use of catch basins with sumps that retain stormwater for extended periods of time has become a public health concern (due to the concentrated breeding of mosquitoes), regional treatment of stormwater with underground vaults may be considered in the municipal storm drain system of new developments and areas of redevelopment. In addition to providing stormwater treatment, a single underground vault could potentially replace a number of catch basins with sumps and reduce municipal maintenance requirements.

6.7 Groundwater Recharge Considerations

Passive groundwater recharge technologies are an effective means of reducing stormwater volume runoff and supporting local groundwater resources. Onsite detention and infiltration, using structural treatment controls, can efficiently and cost effectively offset the loss of groundwater recharge resulting from the increase in impervious areas associated with development and redevelopment. In addition to providing stormwater treatment and aquifer recharge benefits, onsite or localized recharge facilities and BMPs play an important role in the reduction of stormwater conveyance infrastructure, decrease in the peak flow runoff, and provide stormwater attenuation so that treatment processes can occur.

In Washoe County, the Regional Water Planning Commission (RWPC) recognized the need for groundwater recharge for the continued protection of the area's groundwater resources. In 1999, the RWPC commissioned a study to delineate areas that have suitable conditions for natural or passive recharge to occur. These groundwater recharge protection areas are characterized by suitable soils and underlying lithography, land use and zoning that is supportive of recharge water quality and infrastructure, adequate depth to groundwater, slope, vegetation, proximity to other water resource facilities and numerous other recharge considerations. The final product was the Southern Washoe County Groundwater Recharge Analysis (Kennedy/Jenks 2001) which included GIS coverage to be incorporated in the Counties natural resource database that demarked areas that have suitable recharge conditions. These areas warrant greater investigation when development occurs. The areas in the Truckee Meadows that are conducive to groundwater recharge should be developed using recharge-promoting BMPs such as porous pavements that limit impervious areas and

infiltration systems that enhance recharge rates. The use of structural treatment controls that apply infiltration as a stormwater treatment measure will support a broad based aquifer recharge programs.

6.8 Public Domain Treatment Controls

This section describes the structural treatment control measures that can be incorporated into new public and private developments, as well as retrofitted into existing developments to meet federal, state, and local stormwater quality management objectives. The stormwater treatment control measures presented in this section are the more common public domain measures being implemented throughout the country. Numerous studies have shown these control measures to be effective if properly designed, installed and maintained. Therefore, a Nevada registered professional civil engineer must design all public domain treatment control measures using the design criteria presented in this manual. In addition, they must be properly operated and maintained in order to function as designed. Failure to properly operate and maintain a stormwater treatment control measure can result in no treatment, a discharge of pollutants from the measure into the storm drain system, and possible fines by state or local agencies.

This section discusses the structural treatment controls that can be implemented at a wide variety of land uses. They are grouped into the following general categories:

- 6.8.1 Vegetation Reliant Stormwater Treatment Systems
  - TC-10 Vegetated Swales
  - TC-11 Vegetated Buffer Strips
- 6.8.2 Infiltration Systems
  - TC-20 Infiltration Trenches
  - TC-21 Infiltration Basins
- 6.8.3 Bioretention Systems
  - TC-30 Landscape Detention
- 6.8.4 Extended Detention Basins
  - TC-40 Sedimentation Basins
  - TC-41 Sand Filter Basins
- 6.8.5 Stormwater Ponds and Wetlands
  - TC-50 Stormwater Ponds
  - TC-51 Stormwater Wetlands
- 6.8.6 Media Filtration Systems
  - TC-60 Surface Sand Filter
  - TC-61 Underground Sand Filter
  - TC-62 Porous Pavements

6.8.1 Vegetation Reliant Stormwater Treatment Systems

Vegetated swales and buffer strips can be effective stormwater treatment control systems if runoff depths are shallow and velocities are slow. These systems rely upon the vegetation and the subsoil matrix to filter pollutants from runoff and can provide infiltration and groundwater recharge. They can provide desirable open space buffers between developed impervious surfaces, the storm drain system, and receiving water bodies. Wherever possible, vegetated swales should be incorporated into natural drainage patterns. Vegetative treatment systems reduce the velocity of urban runoff and can serve as part of the storm drain system. They can be accessed by curb cuts or they can replace curbs, gutters and subsurface storm drainpipe systems. Swales sited on existing clayey or silty soils with low infiltration rates (less than 0.5 in/hr or 120 min/in) should also include underdrain systems.

The recommended plant species for vegetated swales and buffer strips should meet the following criteria:

- Native or easily naturalized,
- Low water requirements,
- Low fertilizer requirements,
- Low maintenance requirements, and
- Be attractive in all seasons.

Plant species located in the low zone of bioretention systems must be able to withstand periodic flooding and prolonged periods of inundation (e.g., up to 7 days). Fertilizer use should be minimized or slow release fertilizers can be used so that it does not become a pollutant in stormwater (e.g., never apply fertilizers when rain is predicted). Herbicides and pesticides are also not recommended unless absolutely required. Maintaining mulch and hand weeding are the recommended weed-control measures. If herbicides are necessary, use natural alternatives such as corn gluten and herbicidal/insecticidal soap or herbicides that degrade quickly such as glyphosate (e.g., Roundup). If pesticide use is necessary, biological pest and disease controls are recommended. Contact the University of Nevada Cooperative Extension for information on alternatives to herbicide and pesticide: https://www.unce.unr.edu/

Additional Public Resources that may be used to assist with existing site soil information and the selection of appropriate plant species for the Truckee Meadows are presented in **Appendix B** of this manual.

TC-10 VEGETATED SWALES

Description

Vegetated swales, also known as biofilters, biofiltration swales, landscaped swales, and grass swales, are wide, shallow earthen open channels covered with a dense vegetative growth (commonly grasses) along the bottom and side slopes. Stormwater runoff that enters a vegetated swale is treated by filtering sediments and associated pollutants through the vegetation and by infiltrating stormwater into underlying soils. Stormwater runoff is conveyed along the length of the low slope channel and vegetation traps sediments, decreases the velocity of overland flows, and reduces erosion. Since pollutant removal and treatment efficiency improve as contact time and infiltration increases the length of vegetated swales should generally not be less than 100 feet.

Vegetated swales are considered an LID practice and are relatively simple to design and install. They can serve as part of the storm drain system or can be used in place of curbs and gutters and can be used with other structural treatment controls as part of a treatment train. Vegetated swales can provide some reduction in peak flows during storm events by slowing the velocity of runoff and depending upon the properties of the underlying soils, they can facilitate infiltration. However, they do not typically reduce post construction flow rates and volumes to the levels required by local ordinances or NPDES stormwater permit requirements. Therefore, additional detention, retention and/or infiltration facilities typically may need to be added to vegetated swales to address local, regional, and/or state requirements.

Applications and Advantages

Vegetated swales can be used to convey and treat runoff from parking lots, buildings, roadways, and residential properties. They are typically located in parks, parkways or private landscaped areas (in rights of way) and can be used as pretreatment devices for other structural treatment controls. They can be designed as natural drainage features with temporary irrigation provided to establish the vegetation and annual maintenance, or they can be designed as landscaped areas with permanent irrigation systems.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	60 – 95%
Total Phosphorus	5 – 45%
Total Nitrogen	15 – 65%
Nitrate	25 – 65%
Metals	20 – 90%

Sources: UDFCD, 1999; CASQA, 2003

The large range in pollutant removal efficiencies reflects differences in design, variable influent concentration levels and flow rates and the permeability of underlying soils. Pollutant

removal efficiencies for vegetated swales generally increase when underlying soils provide for infiltration. The literature reviewed does not discuss the removal efficiency for organics or petrochemicals. Additional BMPs may be needed for treatment of these pollutants.

Limitations

- In the semi-arid climate of the Truckee Meadows, supplemental irrigation will be required.
- Effectiveness is decreased by compacted soils, frozen ground conditions, short grass heights, steep slopes, large storm events, high discharge rates, high velocities, and short runoff contact time.
- May not be appropriate for industrial sites or locations where spills may occur.
- Infiltration rates of local soils can limit the application of vegetated swales, unless underdrains are installed.
- Effectiveness may be limited in areas where gophers or other burrowing animals are abundant.
- Possible formation of mosquito breeding habitat if water does not drain or infiltrate.

Siting Criteria

- Maximum swale drainage area is 10 acres. Smaller drainage areas are preferred.
- Not to be applied in areas with adjacent slopes of five percent or greater or in areas with highly erodible soils.
- The seasonally high groundwater table should be a minimum of 3 feet below the swale to ensure proper drainage.
- If possible, the preferred installation site is in a natural topographic low to preserve natural drainage and recharge patterns.
- To provide adequate contact time for pollutant removal, the minimum recommended length of the swale should be 100 feet.
- In residential areas, design swales to blend with landscaping to encourage homeowners to assist with maintenance.
- Swales should be established with a minimum longitudinal slope of 0.5 percent and a maximum longitudinal slope of 2.5 percent. Swales or swale sections with longitudinal slopes between 2.5 and 5.0 percent may be allowed if check dams are installed to reduce runoff velocity to 2.0 ft./sec or less.

Design and Construction Criteria

- Design vegetated swales to convey the WQ_F rate based on the method presented in **Section 6.3**. This method and the following design criteria are embedded in Design-aid Worksheet TC-10 (www.TMstormwater.com)
- Registered professional civil engineers and landscape architects should work together on the design vegetated swales.
- At locations where concentrated flows will enter swale, install energy dissipation apron and flow spreader to prevent erosion and promote sheet flow.

- At locations where trash and debris may enter the swale, consider installing a rock apron to catch sediments and debris.
- If possible, flows in excess of the WQF rate should be diverted around vegetated swales with upstream diversion structures.
- If a swale is designed to be an on-line feature, providing treatment of the WQF and conveyance of flows produced by larger storm events, the swale may be required to have capacity for up to a 100-year event. Consult the Truckee Meadows Regional Drainage Manual for details on peak flow conveyance.
- Swale side slopes should be as flat as possible to aid in providing pre-treatment for lateral incoming flows and maximize the channel filtering surface and not be steeper than 4H:1V (see **Figure TC-10**).
- Trapezoidal channels are recommended where flow will enter the swale primarily at one end and flow in the longitudinal direction. However, where significant lateral flows will be entering along the side, triangular swales can be effective by providing additional side slope length, similar to a vegetated buffer strip.
- Use a dividing berm in center of a trapezoidal swale for bottom widths exceeding 10 feet to maintain sheet flow and prevent channelization.
- Improved pollutant removal efficiency occurs with a minimum 10-minute hydraulic residence time at the WQF. Pollutant removal and flow reduction effectiveness can be improved by installing check dams at regular intervals. However, this can reduce the flow capacity during high-flow events.
- The swale must not hold standing water for more than 7 days during May through October.

Vegetation Criteria

- A diverse selection of low growing plants that thrive under site specific soils and proposed watering conditions should be specified, see **Appendix B** for vegetation recommendations.
- A design vegetation height of 4 - 6 inches is recommended for turf grasses.
- For areas without regular irrigation, use drought tolerant vegetation. While pollutant removal efficiencies may be reduced, fertilizer and water use can be minimized.
- Use the Manning's equation at the WQF with a roughness coefficient (n) value appropriate to the vegetation selected. Recommended values include 0.25 for grass and 0.40 for mixed vegetation and rocks.
- Fertilizers and soil amendments should be specified based on soil testing results and vegetation requirements. Improper application of fertilizer can result in contamination of stormwater runoff.
- To determine the hydraulic capacity of the swale to convey peak flows in excess of the WQF, use roughness coefficients as directed by the TMRDM.

Infiltration and Underdrain Criteria

- Swales sited on existing soils with infiltration/percolation rates of 0.5 in/hr (120 min/in) or less should include underdrain systems.
- A 4-inch diameter PVC under drain should be provided in type C and D soils (e.g., silty or clayey soils) to improve drainage and prevent ponding.

Inspection and Maintenance Requirements

- With proper inspection and maintenance, vegetated swales can last indefinitely.
- Proper maintenance includes mowing, weed control, removal of trash and debris, watering during the dry season, and reseeding of non-vegetated areas.
- When mowing grass, do not cut shorter than the design flow (WQF) depth, and remove grass cuttings.
- Inspect swales at least twice annually for damage to vegetation, erosion, sediment accumulation and ponding water standing longer than 7 days.
- Periodic litter collection and removal will be necessary if the swale is located adjacent to a main road.
- Sediments should be removed when depths exceed 3 inches. Sediment should be removed while avoiding damage to vegetation.
- If a spill occurs and hazardous materials contaminate soils in vegetated swales, the affected areas should be removed immediately and the appropriate soils and materials replaced as soon as possible.

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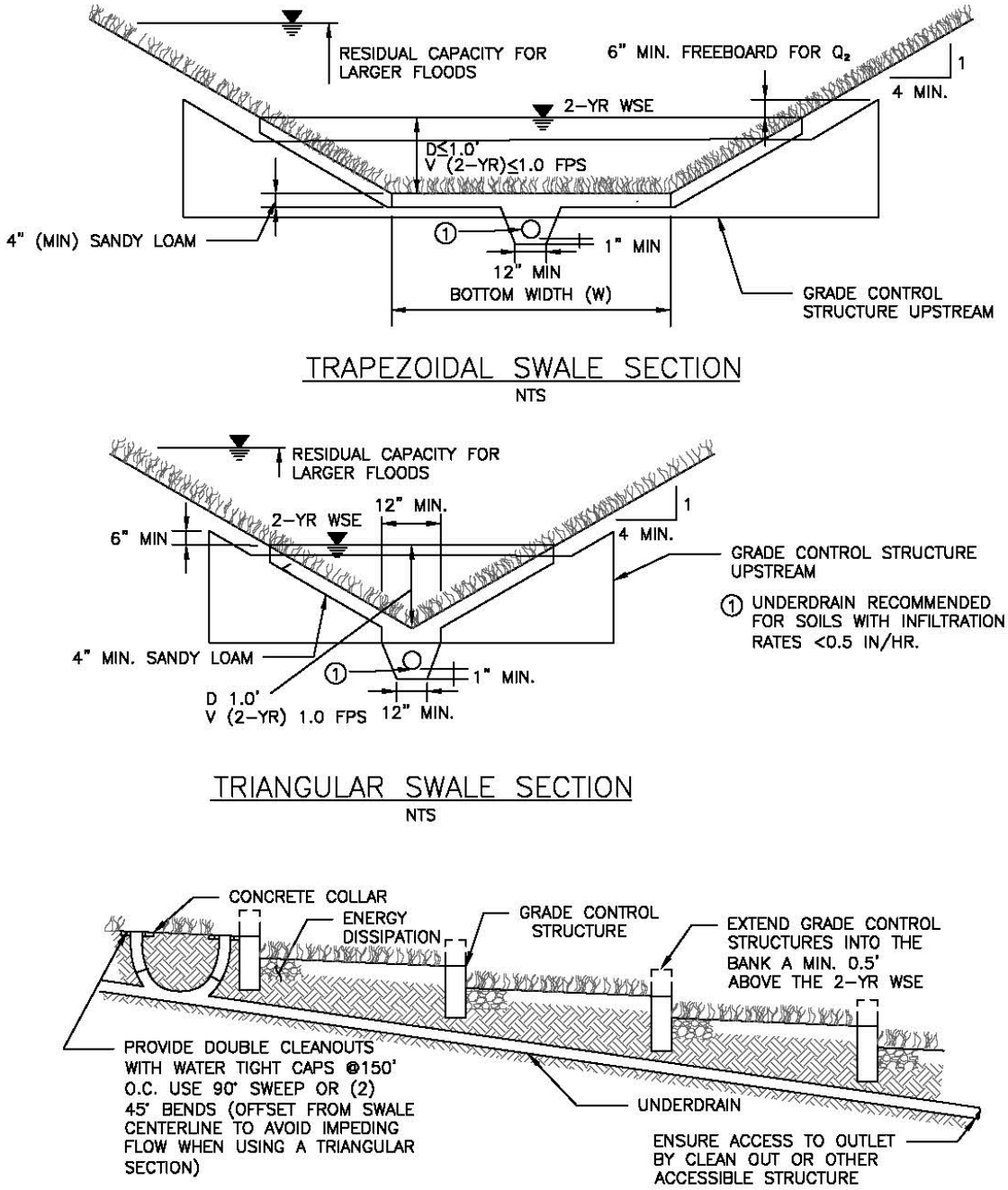

Figure TC-10 1. Typical design and structure of a Vegetated Swale (UDFCD, 2010).

TC-11 VEGETATED BUFFER STRIPS

Description

Also known as, vegetated filter strips, or grassed buffers, vegetated buffer strips consist of vegetated surfaces that can be interspersed with shrubs and trees to improve aesthetics and provide shade. They are gently sloping and uniformly graded and provide stormwater treatment to relatively small drainage areas. Vegetated buffer strips slow the velocity of runoff waters to promote infiltration and the filtration of sediments and pollutants. They require sheet flow to function properly and often require a flow spreader to distribute evenly runoff across the width of the buffer. Vegetated buffer strips can be used as pretreatment devices for other treatment controls and can be combined with riparian zones for treating sheet flows and stabilizing channel banks adjacent to drainage ways and receiving water bodies. In the semi-arid climate of the Truckee Meadows, irrigation is typically required to maintain the healthy and dense vegetative cover needed to filter sediments while also being capable of withstanding the erosive forces of runoff from adjacent impervious areas.

Applications and Advantages

Vegetated buffer strips are appropriate in the Truckee Meadows along the edge of residential and commercial developments where irrigated landscaping is planned.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	10 - 74
Total Phosphorus	0 - 10
Total Nitrogen	0 - 15
Total Recoverable Zinc	0 - 10

Sources: UDFCD, 1999; CASQA, 2003.

Pollutant removal depends on factors such as soil permeability, land uses and slopes of adjacent drainage area, runoff volumes and velocities, the flow path across the buffer strip and the type and density of the vegetation used. Vegetated buffer strips are efficient at reducing debris, TSS and dissolved metals. Reduction in nutrient concentrations is low.

Limitations

- In the semi-arid climate of the Truckee Meadows, supplemental irrigation will be required.
- A uniformly graded thick vegetative cover is required for a vegetated buffer strip to function properly and effectively.
- Impractical in urban areas with little pervious ground.
- Buffer strips are not capable of treating stormwater from large drainage areas.

- It may be difficult to establish the level slopes necessary for buffer strips.
- Sheet flow is required.
- Cannot be applied in areas with highly erodible soils.
- The volume and flow rate of intense rain events are not significantly attenuated via vegetated buffer strips.
- May not be applicable adjacent to industrial sites or locations where spills may occur.

Siting Criteria

- Best suited for treating runoff from roads, roofs, small parking lots, and pervious surfaces.
- Avoid areas that are highly trafficked, by both automobiles and people.
- When applying a vegetated buffer strip adjacent to a roadway, protect the vegetated buffer strip from automobiles.
- The seasonally high groundwater table should be a minimum of 3 feet below the buffer strip to ensure proper drainage.

Design and Construction Criteria

- Use Design Guidance Worksheet TC-11 (www.TMstormwater.com). The following design criteria are embedded in the Design Guidance Worksheet.
- Registered professional civil engineers and landscape architects should work together on the design of vegetated buffer strips.
- Slopes should not be greater than 8 percent (2 to 4 percent is preferred). Slopes flatter than 2 percent may result in ponding while slopes greater than 8 percent may result in concentrated flow and erosion.
- Maximum contributing drainage area is 5 acres.
- The top of the vegetated buffer strip should be installed 1 – 3 inches lower than the impervious surface that is being drained.
- If supplemental irrigation is not available, use drought tolerant species in the buffer strip to minimize irrigation in dry climates.
- If seeds are used to plant the vegetated buffer strip, they will need to be protected with mulch for a minimum of 75 days.
- The hydraulic load should not exceed 0.005 cfs/linear foot of the vegetated buffer strip during the 2-year storm (WQF) to maintain a sheet flow through vegetated buffer.
- The minimum length of a vegetated buffer strip (normal to flow) should be determined using the following equation:

$$L_G = WQ_F / 0.005$$

Where: L_G = minimum design length (ft.)
WQ_F = water quality flow (cfs)

- The width of the buffer strip should be at least 8 feet when vegetated with dense turf grass. For xeriscape buffer strips, use a minimum width of 14 feet. Increasing the width of the buffer strip will increase contact time, filtration of pollutants, and infiltration of runoff. Use the following equation to calculate the buffer strip width:

$W_G = 0.2L_L$ or 8 feet (whichever is greater)

Where: W_G = width of the buffer strip (in the direction of flow)

L_L = length of the flow path over the upstream impervious drainage area (ft.)

- To determine flow characteristics at the application site, use the following equations:

  Sheet flow: $L_L * S_I \leq 1$

  Concentrated flow: $L_L * S_I > 1$

  Where: L_L = the length of the flow path over the upstream impervious drainage area (ft.)

  S_I = interface cross slope (normal to flow direction) (ft./ft.)
- Sheet flow must be maintained across the buffer strip. If flow characteristics demonstrate concentrated flow, a level spreader must be applied to distribute flows evenly across the length of the buffer. Install a level spreader at the top edge of the buffer strip along an elevation contour adjacent to the roadway. See **Figure TC-11B**.
- Irrigation will likely be required to maintain desired plant densities in the Truckee Meadows.
- Plants for vegetated buffer strips should meet the following criteria: native or well adapted to the climate of the Truckee Meadows, low water use, low fertilizer requirements, minimal maintenance required, and attractive in all seasons. Select durable, dense, and drought tolerant grasses for the vegetated buffer strip. A mix of erosion-resistant species of native or adapted grasses, shrubs, and trees are preferred due to their drought resistance and a reduced need for fertilizer.
- Vegetated buffer strip should have a minimum cover of 65%. Studies have demonstrated that water quality treatment decreases dramatically as vegetative cover decreases below 80%.
- If seeds are used to plant the vegetated buffer strip, they will need to be protected with mulch for a minimum of 75 days, or until vegetation is well established.
- A vegetated swale can be used to collect outflow from a buffer strip and can provide additional treatment prior to conveying flows to the storm drain system or receiving waters.

Inspection and Maintenance Requirements

- Required maintenance includes weed removal as well as mowing and irrigation of grasses.
- Buffer strips should be irrigated during the dry season.
- Grasses or turf should be maintained at a height of 2 – 6 inches.
- Vegetation should be repaired/replaced as necessary to ensure full coverage and to prevent erosion.
- Buffer strips should be inspected at least two times a year, preferably before and after the winter/wet season for signs of erosion, vegetation coverage, debris build-up, and sediment deposition.
- Regularly inspect buffer strips for pools of standing water that may be acting as mosquito breeding habitat.

- Trash, litter, rocks, and branches should be frequently collected from buffer strips, especially those located along roadways.
- Sediments that accumulate along the upstream edge of buffer strips and/or in level spreaders should be collected and removed at least once a year.
- If a spill occurs and hazardous materials contaminate soils in vegetated buffer strips, the affected areas should be removed immediately and the appropriate soils and materials replaced as soon as possible.

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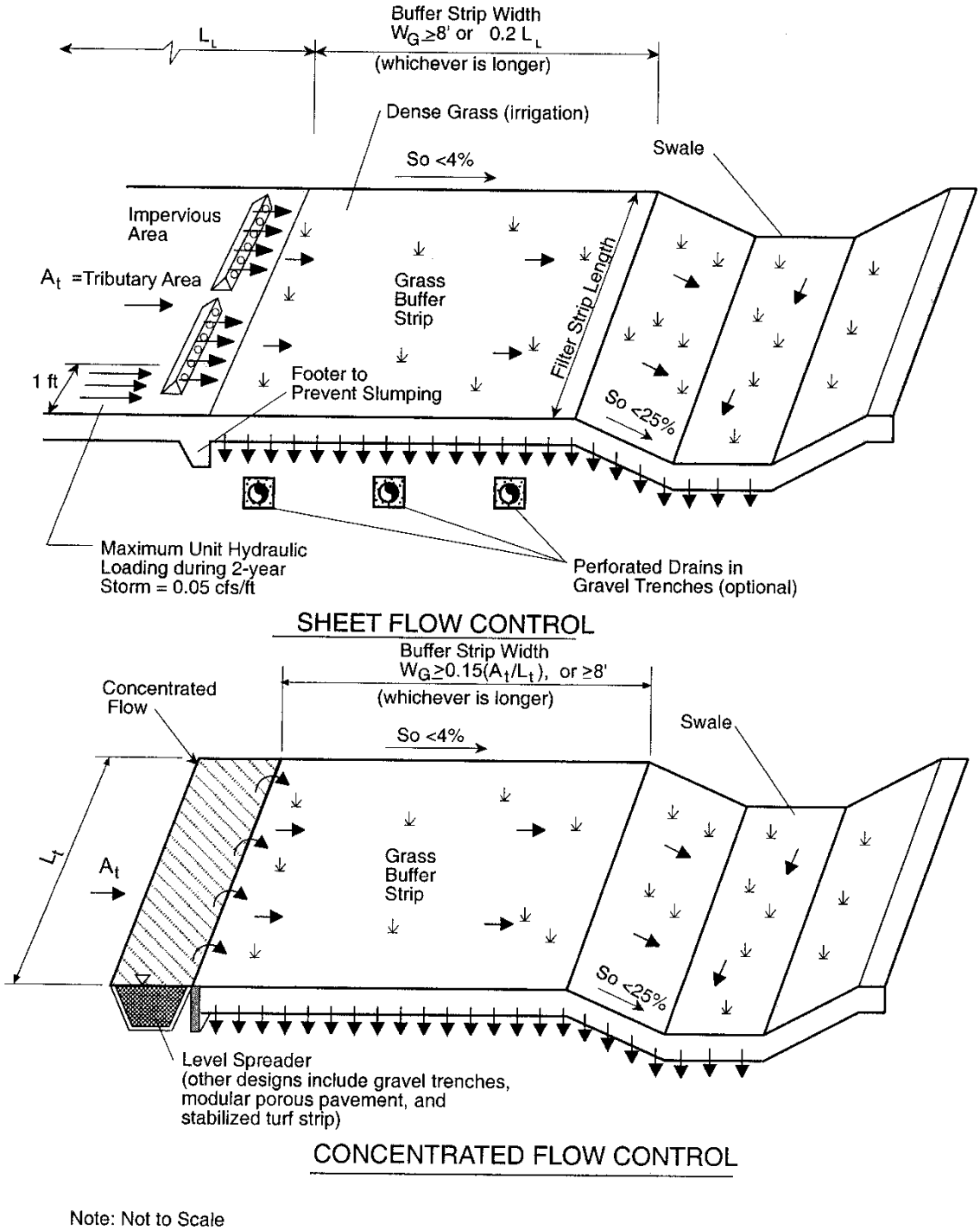

Figure TC-11 1. General design guidelines for a typical Vegetated Buffer Strip (modified from UDFCD, 1999).

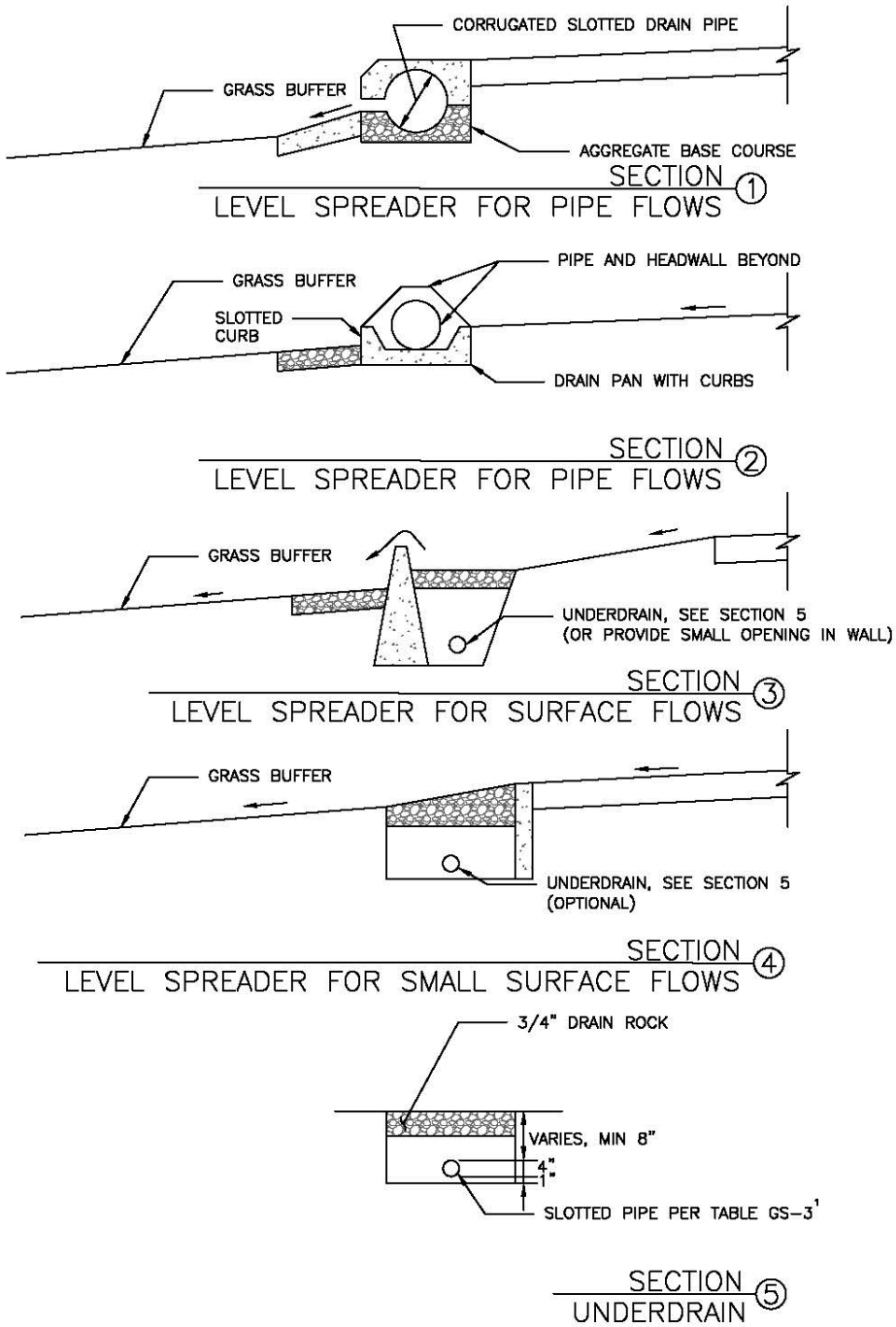

Figure TC-11B. General design guidelines for a typical Vegetated Buffer Strip (UDFCD, 2010).

6.8.2 Infiltration Systems

Infiltration systems allow stormwater to slowly enter the ground and migrate downward through the unsaturated zone while sediments and associated pollutants are retained in the near surface soils. Infiltration trenches and basins are examples of engineered facilities designed to treat stormwater through the process of infiltration. The process of infiltration can also provide additional treatment effectiveness for many structural treatment controls. Pretreatment of urban runoff using vegetated swales, buffer strips, or detention basins can be important components of infiltration systems by limiting the amount of coarse sediment entering infiltration systems that can clog and render the measures ineffective. Typically, infiltration systems are very effective at removing pollutants from stormwater and numerous studies have shown that infiltration of stormwater presents only a minor risk of contaminating either groundwater or soil. Natural soils are typically very effective at removing pollutants from stormwater because they utilize a number of natural processes such as physical filtering, ion exchange, adsorption, biological processing, conversion, and uptake. However, infiltration systems should not be implemented where there is a high potential for spills that may be conveyed directly to the storm drain system or a structural treatment control, such as at some industrial outdoor work and maintenance areas. In this case, runoff should be routed to the sanitary sewer system or to another type of treatment control measure that does not allow for infiltration.

As a preliminary screening tool, the Southern Washoe County Groundwater Recharge Analysis (Kennedy/Jenks, 2001) should be reviewed prior to considering infiltration devices for new developments. In areas noted as having suitable recharge conditions, the use of infiltration systems is encouraged. A minimum of three hydraulic conductivity tests should be conducted at each proposed infiltration system site. The minimum acceptable hydraulic conductivity for infiltration systems is 0.5 in/hr (120 min/in).

Numerous studies have shown that stormwater infiltration BMPs are effective at removing pollutants from urban runoff and typically present only a minor risk of contaminating either soil or groundwater. A comprehensive study of shallow infiltration systems with some sediment pretreatment conducted by the U.S. EPA indicated that of the 25 constituents listed, only one had a “high” potential (Chloride), and only two had “moderate” potentials (Fluoranthene and Pyrene) for polluting groundwater (Pitt et al., 1994). Pentachlorophenol, Cadmium, Zinc, Chromium, Lead, and all of the pesticides listed were classified as having a “low” contamination potential. In addition, Nitrate, which is soluble and mobile, was only given a “low/moderate” potential. Legret et al. (1999) concluded that the “long-term pollution risks for both soil and groundwater are low” for stormwater infiltration systems and “metals are generally well retained in the upper layers of 0 to 8 inches of the soil.” A study of a thirty year-old stormwater infiltration BMP by Barraud et al. (1999) found that both metal and hydrocarbon concentrations in the soil under the infiltration device decreased rapidly with depth “to a low level after a few decimeters down” (3 dm = 1 ft.). A study of the infiltration of highway runoff by Dierkes and Geiger (1999) found that polycyclic aromatic hydrocarbons (PAH) were effectively removed in the upper 4 inches of the soil and that runoff that had passed through 14 inches of soil met drinking water standards for Cadmium, Zinc, and Copper. The high pollutant removal efficiency of stormwater infiltration BMPs is due to the

retention capacity of soils and a number of natural processes including physical filtering, ion exchange, adsorption, biological processing, conversion, and uptake.

TC-20 INFILTRATION TRENCHES

Description

An infiltration trench is a trench that has been lined with filter fabric and filled with a rock matrix to form a subsurface basin that captures, filters, and infiltrates stormwater runoff. Trenches allow for water retention such that the partial or total infiltration of stormwater runoff into the underlying soil occurs. Infiltration trenches remove pollutants in stormwater through the processes of adsorption, sedimentation, filtering, and bacterial degradation. Efficiency of pollutant removal depends upon the types and concentration of pollutants in the stormwater influent, the porosity of rock matrix, and the infiltration capacity of the underlying soils. However, the concentration of most pollutants in stormwater typically decreases rapidly within the first one foot of soil matrix.

Applications and Advantages

Infiltration trenches typically drain areas less than 5 acres in size. Their relatively small size allows them to fit easily along the margins, perimeter, and unused sections of developed sites and thus they are a good choice for retrofitting. They are commonly installed in median strips or in parking lot islands.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	75 - 90
Total Phosphorus	50 - 70
Total Nitrogen	45 - 60
Metals	75 - 90
BOD	70 - 80
Bacteria	75 - 90

Source: Schueler, 1987

Pollutant removal efficiency can be improved by adding organics and loam to the subsoil.

Limitations

- Do not install in areas with highly erodible soils.
- Do not apply on slopes greater than 20 percent.
- Infiltration rates of existing site soils must be greater than 0.5 in/hr (120 min/in)
- Where infiltration rates exceed 2.4 in/hr (25 min/in), consideration should be taken to avoid groundwater contamination.

- Should not be applied in areas with clay or silty soils.
- Frozen soil conditions can severely affect the pollutant removal efficiency of infiltration trenches.
- Contributing drainage area should not be larger than 5 acres.

Siting Criteria

- Infiltration trenches should not be installed at sites with Hydrologic Soil Types C or D.
- Seasonally high groundwater should not be within 3 ft. of the bottom of the infiltration trench.
- Due to the potential of groundwater to contamination, infiltration trenches should not be installed in areas of high-risk land use such as near gas stations or heavy industrial sites where hazardous or toxic materials may be stored.
- Infiltration trenches should be installed at least 100 ft. upslope or 20 ft. downslope from building foundations and bridge structures.
- Do not install within a wellhead protection zone, or within 100 ft. from drinking wells, 100 ft. from surface water supplies to be used as drinking water, and 50 ft. from other surface water supplies.

Design and Construction Criteria

- Infiltration trenches must be designed by professional civil engineers using Design-aid Worksheet TC-20 (www.TMstormwater.com). The following design criteria are embedded in the Design Guidance Worksheet.
- The locally available sand and gravel is often washed with a high pH, recycled wastewater. Sand and gravel must be rinsed with potable water prior to installation and construction of the sand filter. Rinse water must be disposed of according to jurisdictional requirements.
- Size the infiltration trench to capture and treat the WQ_V using the method outlined in **Section 6.3**.
- Flows in excess of the WQ_V should be diverted around the infiltration trench with an upstream diversion structure.
- Provide pretreatment such as grassed swales or vegetated filter strips designed to reduce the sediment load on the trench.
- An energy-dissipating flow spreader should be constructed upstream of the infiltration trench, and should consist of riprap or rocks sized to resist any flows not diverted around the trench.
- Determine the trench volume by assuming that the WQ_V will fill the void spaces of the rock matrix. Compute the porosity of the rock matrix based on the materials used.
- Infiltration trenches may be subject to regulation as Class V injection wells. Contact NDEP for more information: http://ndep.nv.gov/bwpc/storm_drainagewell.htm.
- The trench should be designed to drain the entire WQ_V within a maximum of 7 days.
- From May to October, water should not be allowed to pond for longer than 7 days.

- The longitudinal slope of the floor of the infiltration trench should not exceed 1 percent.
- Determine the depth of the trench (D) based on the available surface area (SA) using the following equation:

$$D = V_T / SA$$

Where: V_T = total trench volume (ft^3)

$V_T = WQ_V$ / porosity (ft^3)

porosity = void ratio of the rock matrix (unitless)

- At least one observation well should be installed in the infiltration trench to monitor drainage and rates of sediment accumulation.
- Berms should be created around the infiltration basin during construction to ensure that no sediment or runoff enters the filter media.
- During construction, an easily removable filter cloth can be installed over the rock matrix to prevent clogging of the trench from construction related sediments.

Infiltration Media Criteria

- A 12-inch filter layer consisting of pea gravel specified by Class B backfill in accordance with Section 200.03.03 of the SSPWC should be installed at the top of the trench to maximize pollutant removal and improve sediment filtering in the top of the trench.
- To allow for infiltration and prevent migration of fine-grained sediments, install a geotextile filter fabric between the filter layer and the trench rock matrix, and along the walls and bottom of the trench. Frequently specified fabrics include Geotex 117F, Mirafi 140N, or an approved equivalent.
- The rock matrix should consist of Class D backfill in accordance with Section 200.03.05 of the SSPWC. This material is a nominal 1 and ½-inch diameter clean stone.
- Void ratio of the rock aggregate should be between 0.30 and 0.40.
- A 6 to 12-inch sand filter layer meeting the grading requirements of fine aggregate in Section 200.05.04 of the SSPWC or permeable filter fabric should be installed on the bottom of the trench between the subbase and the trench rock matrix.
- Sufficient technical knowledge of the vertical and lateral movement of infiltrated runoff through soil and the interaction with groundwater should be established through a geotechnical investigation.
- Minimum acceptable hydraulic conductivity of underlying native soil is 0.5 in/hr (120 min/in) as tested with a minimum of three in-hole conductivity tests.

Inspection and Maintenance Requirements

- Life span of infiltration trenches ranges from 5 – 15 years, depending on maintenance.
- Inspect following major storm events during the first year after installation.
- Inspect for water levels in the trench, clogging of inlets and outlets, accumulation of sediments, and ponding of water on the surface.

- Non-routine maintenance involves rehabilitation of the trench if it becomes clogged. Clogging is most likely to occur in the top surface of the trench, between the filter fabric and the top gravel layer. Clogging can be alleviated by removing the top layer of gravel, removing the clogged filter fabric and replacing it, and either cleaning or replacing the top gravel layer.

- If a spill occurs and hazardous materials contaminate sands or gravels in infiltration trenches, the affected areas should be removed immediately and the appropriate soils and materials replaced as soon as possible.

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California Stormwater Quality Association (CASQA), 2003. Stormwater Best Management Practice Handbook – New Development and Redevelopment.

Dierkes and Geiger, 1999. Pollution Retention Capabilities of Roadside Soils, Water Science and Technology. Vol. 39, No. 2, pp. 201-208.

Legret et al., 1999. Simulation of Heavy Metal Pollution from Stormwater Infiltration through a Porous Pavement with Reservoir Structure, Water Science and Technology. Vol. 39, No. 2, pp. 119-125.

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Pitt et al., 1994. Potential Groundwater Contamination from Intentional and Nonintentional Stormwater Infiltration, U.S. Environmental Protection Agency's Risk Reduction Engineering Laboratory, May 1994. EPA/600/SR-94/051.

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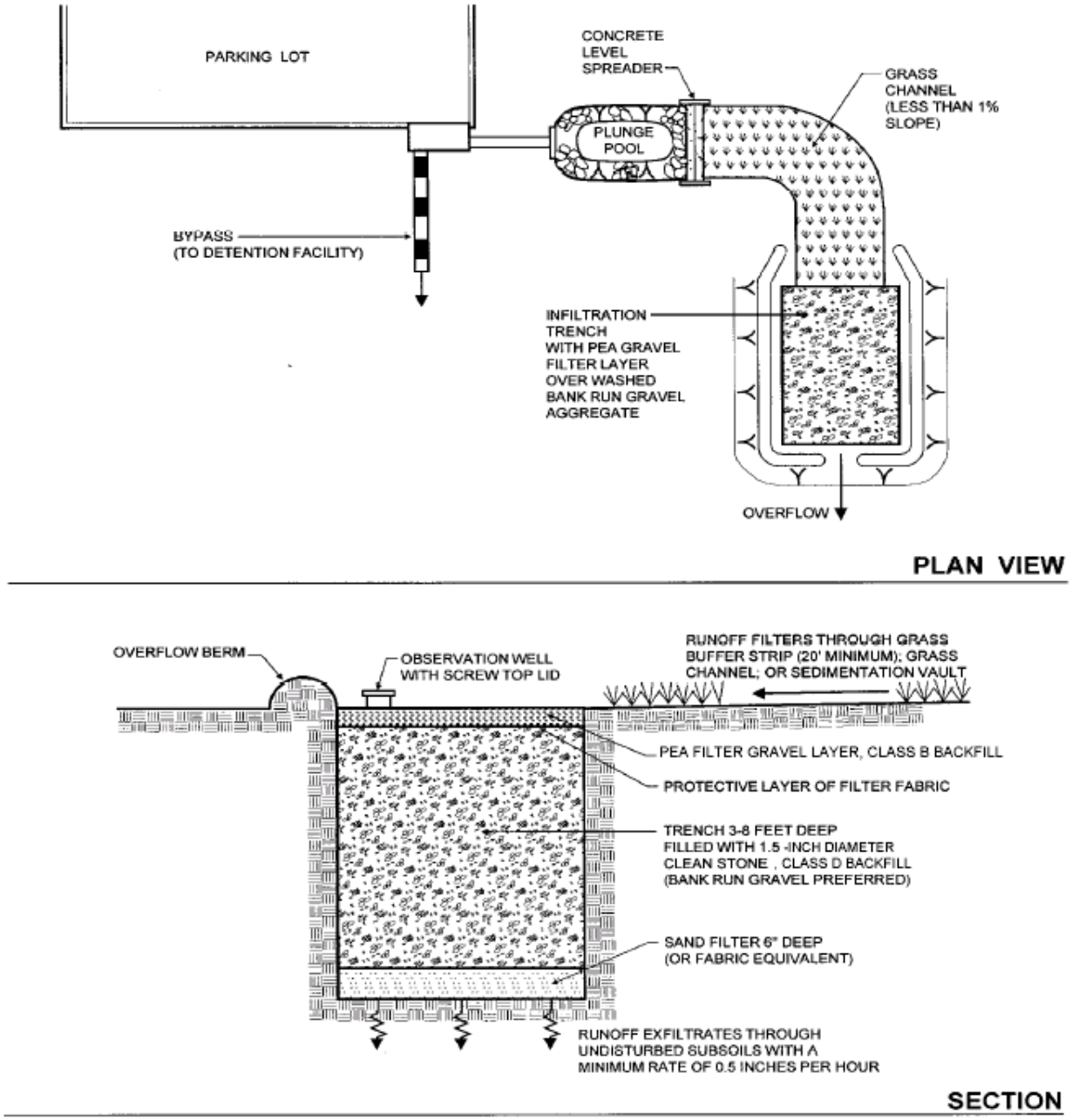

Figure TC 20A. Example of an Infiltration Trench with an energy dissipation device and a bypass structure (modified from CASQA, 2003).

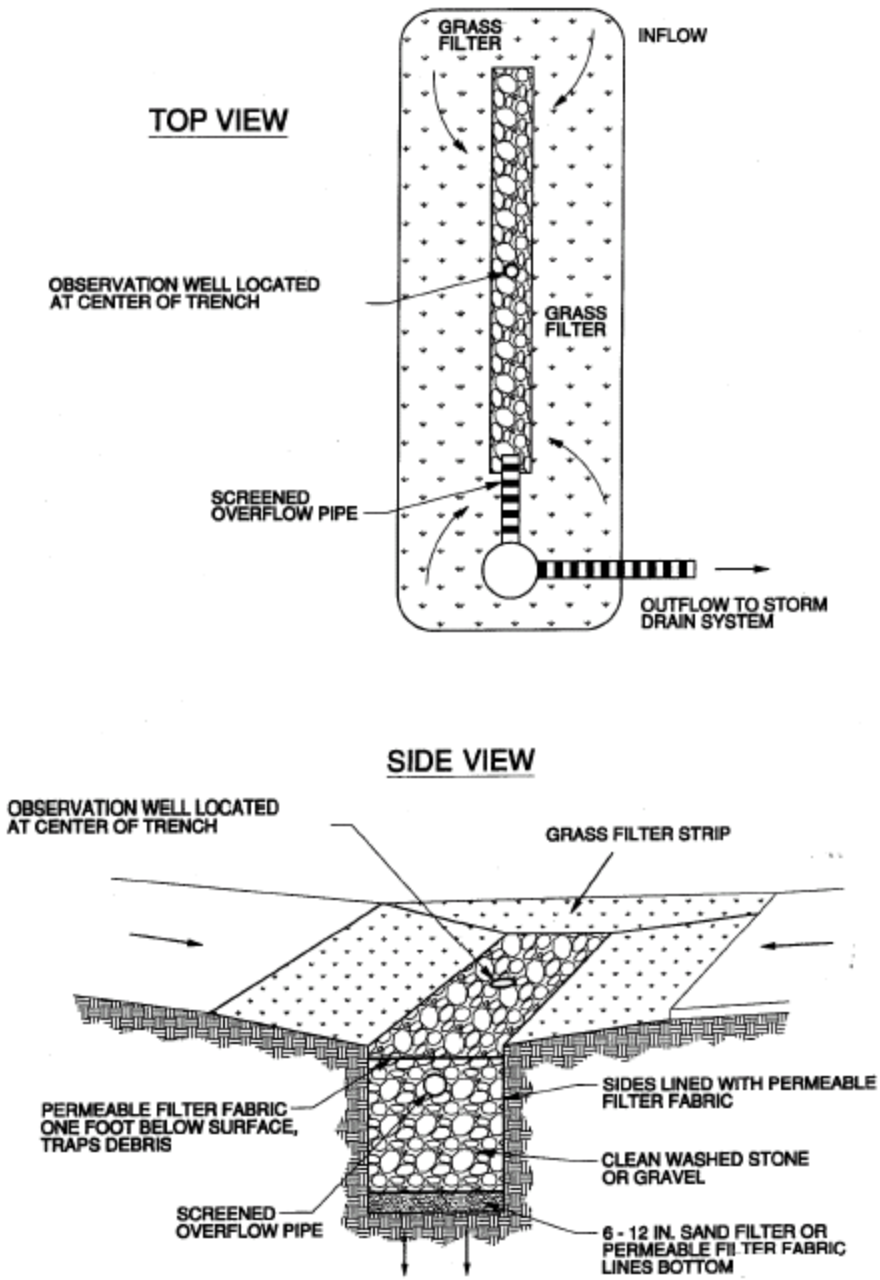

Figure TC-20B. Example of a median strip Infiltration Trench with a grass buffer strip (modified from Sacramento, 2000).

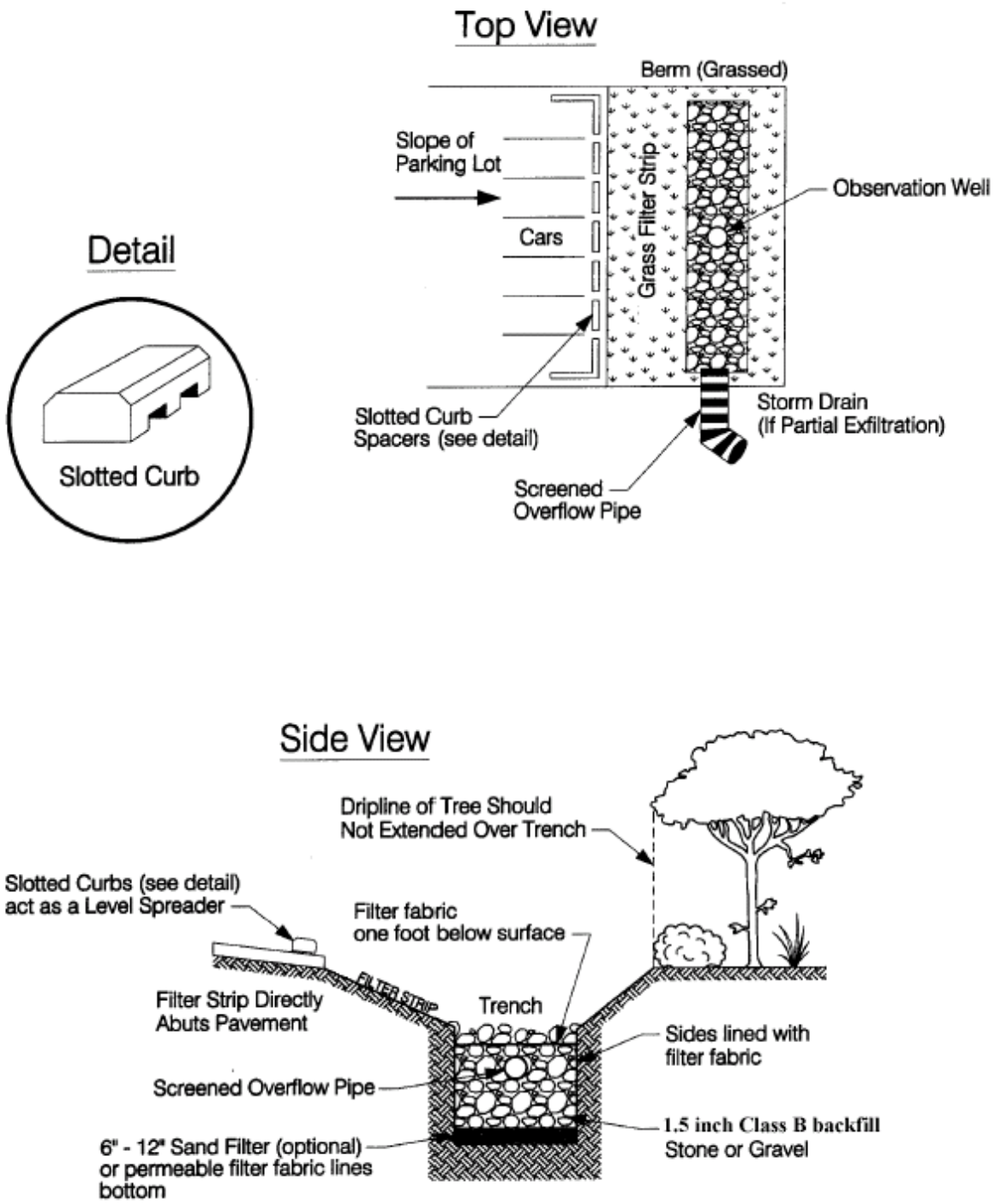

Figure TC-20C. Example of a parking lot Infiltration Trench with a grass buffer strip (modified from Sacramento, 2000).

TC-21 INFILTRATION BASINS

Description

Infiltration basins capture stormwater runoff and allow it to infiltrate into the ground. They are similar to sedimentation basins or detention basins; however, their purpose is not only to detain the water but also to promote infiltration. They are also similar to infiltration trenches; however, they can use a wider variety of filter media, can be vegetated on the bottom and can serve larger drainage areas. Pollutants such as suspended solids, metals, nutrients, and bacteria are removed through sedimentation, adsorption, and physical filtration through permeable media and soil thereby improving water quality.

Applications and Advantages

Infiltration systems are applied in areas with well-drained and pervious soils. They are typically applied to drainage areas up to 5 acres. On select sites, it is relatively easy to incorporate an infiltration basin into a site's open space design and layout. Infiltration basins are ideal for areas adjacent to roadways and near interchanges. However, they should not be used in industrial or commercial areas where hazardous or toxic materials are stored outdoors and the potential for spills is relatively high.

Performance Data

Infiltration basins can provide 100 percent reduction in pollutant loading directly to surface waters. Infiltration basins can also provide high pollutant removal efficiency for particulates and moderate efficiency for soluble pollutants when functioning as designed. Actual loading to the subsurface may vary significantly depending on site-specific conditions. Studies in the Pacific Northwest have shown improved long-term performance for basins developed in highly permeable soils.

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	55 – 75
Total Phosphorus	45 – 55
Total Nitrogen	10 – 20
Total Recoverable Zinc	30 – 60
Total Recoverable Lead	55 – 80

Source: UDFCD, 1999.

Limitations

- There may be significant concerns regarding the potential to degrade groundwater.
- Should not be applied in locations where hazardous or toxic materials may be stored.
- Areas with highly erodible soils will require greater maintenance.

- Large drainage areas may require a large amount of space for an infiltration basin. The recommended maximum drainage area is 5 acres.
- Not to be applied in areas with existing soil or groundwater contamination.
- Not to be applied in areas with clay or silty soils or in areas of fill.
- Infiltration may not occur under frozen soil conditions.
- Infiltration basins that pipe stormwater directly underground may be subject to Underground Injection Control (UIC) regulations.

Siting Criteria

- Not to be used in areas where existing site soils have infiltration (percolation) rate of less than 0.5 in/hr (120 min/in).
- Do not install in fill areas or on slopes greater than 15 percent.
- Seasonally high groundwater should not be within 3 feet of the bottom of the infiltration basin.
- Infiltration basins should be installed at least 100 ft. from drinking wells, 100 ft. from surface water supplies to be used as drinking water, and 50 ft. from other surface water supplies.
- Infiltration basins should not be installed within a Wellhead Protection Zone.
- Locate the infiltration basin away from buildings, slopes, wells, and bridge structures.
- Infiltration basins can be joined with detention basins to improve water quality.
- A pretreatment device, such as an oil and water separator, may be required in areas where petroleum hydrocarbons in stormwater are anticipated.

Design and Construction Criteria

- Use Design Guidance Worksheet TC-21 (www.TMstormwater.com). The following design criteria are embedded in the Design Guidance Worksheet.
- Registered professional civil engineers should design infiltration basins.
- If an embankment is necessary, it should be designed by a qualified geotechnical engineer. Check with state engineer about maximum heights and dam regulation.
- Size the basin to capture and treat the WQ_V using the method outlined in **Section 6.3**.
- Flows in excess of the WQV should be diverted around the infiltration basin with an upstream diversion structure. If excess flows are routed through the infiltration basin, provide an overflow spillway and design as a detention facility per the Truckee Meadows Regional Drainage Manual.
- Infiltration trenches may be subject to regulation as Class V injection wells. Contact NDEP for more information: http://ndep.nv.gov/bwpc/storm_drainagewell.htm.
- The basin should be designed to drain the entire WQ_V within a maximum of 7 days.
- Sufficient technical knowledge of the vertical and lateral movement of infiltrated runoff through soil and the interaction with groundwater should be established through a geotechnical investigation.

- Minimum acceptable hydraulic conductivity is 0.5 in/hr (120 min/in) as tested with a minimum of three in-hole conductivity tests.
- Installation of an inlet energy dissipation structure is recommended where inflow velocities may cause erosion of the filter media.
- The basin drain down time (t) should be determined using the following equation:

$$t = WQ_V/(0.5(K_h/12)*A)$$

Where: A = Basin invert area (ft^2)

WQ_V = water quality volume (ft^3)

K_h = the lowest field measured hydraulic conductivity (in/hr)

t = maximum drain time (hours)

- To avoid mosquito breeding, t should not exceed 168 hours, or 7 days.
- Basin side slopes should be 3H:1V or flatter.
- The slope of the floor of the basin should not exceed 5 percent.
- Disturbed soils within the drainage area of the infiltration basin should be stabilized with vegetation within one week of construction.
- Berms should be created around the infiltration basin during construction to ensure that no sediment or runoff enters the filter media.
- During construction, an easily removable filter cloth can be installed over the permeable media to prevent clogging of the basin from construction related sediments.
- A large area, a flat bottom, and a dense-turf buffer zone will improve the performance of an infiltration basin.

Inspection and Maintenance Requirements

- Inspect following major storm events during the first year after installation.
- Inspect annually for settling, cracking, erosion, leakage, condition of the riprap, state of the turf vegetation, and amount of sedimentation. If necessary, repair immediately.
- If the drain down time becomes more than 7 days, maintenance and replacement of the filter media is required.
- Debris and litter must be periodically removed from the infiltration basin and vegetation should be mowed when growth exceeds 6 inches in height.
- If barren and eroded areas are present in the drainage area near the infiltration basin, vegetation and/or additional stabilization methods may be required to prevent premature clogging.
- Every 5 – 10 years the area should be tilled, fine materials removed and the base of the basin regraded.
- If a spill occurs and hazardous materials contaminate soils, sands or gravels in an infiltration basin, the affected areas should be removed immediately and the appropriate soils and materials replaced as soon as possible.

References

California Stormwater Quality Association (CASQA), 2003. Stormwater Best Management Practice Handbook – New Development and Redevelopment.

Sacramento Stormwater Quality Partnership, 2007. Stormwater Quality Design Manual for the Sacramento and South Placer Regions. http://www.beriverfriendly.net/newdevelopment/stormwaterqualitydesignmanual/

Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, Fact Sheet – Infiltration Basin, http://www.fhwa.dot.gov/environment/ultraurb/3fs2.htm

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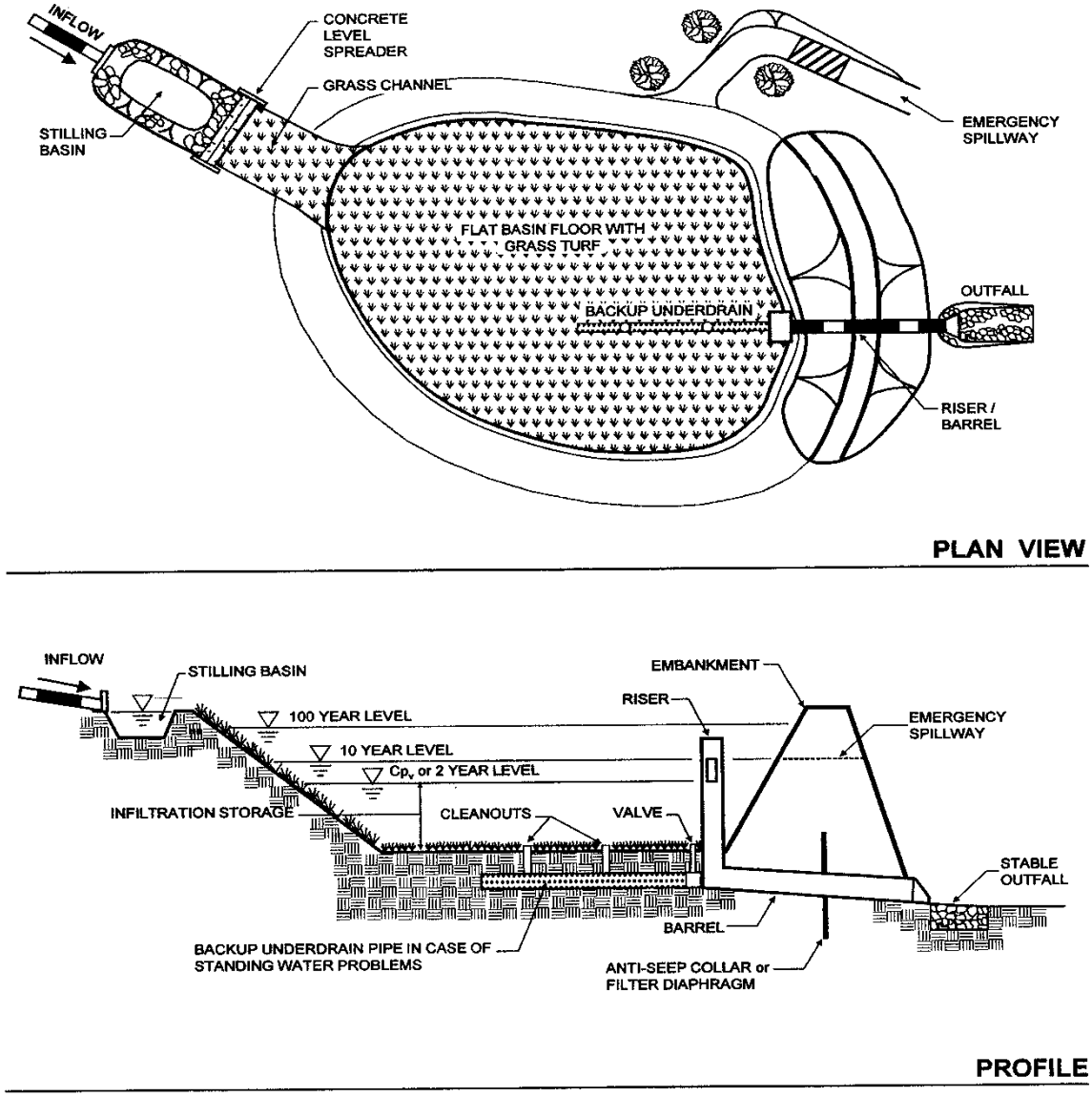

Figure TC-21. Example of a typical Infiltration Basin design (CASQA, 2003).

6.8.3 Bioretention Systems

Bioretention systems are also referred to as biofiltration systems, rain gardens or landscape detention systems. They also include tree box filters and stormwater planters. Depending on underlying soils and activities and pollutants of concern within the drainage area, infiltration can provide additional treatment effectiveness. These treatment control systems use soil and plant-based filtration to remove pollutants through a variety of physical, biological and chemical treatment processes. Runoff can enter a bioretention system either directly off an impervious surface, via a curb cut or a pipe. The upper surface of bioretention systems is typically located several inches below the grade of the surrounding impervious drainage area. Overflow should be routed to the conventional storm drain system. Infiltration of the treated urban runoff stored in the engineered soils into underlying natural soils or into the storm drain system occurs over a period of days. Bioretention systems sited on existing clayey or silty soils with low infiltration rates (less than 0.5 in/hr or 120 min/in) should include underdrain systems.

The recommended plant species for bioretention systems should meet the following criteria:

- Native or easily naturalized,
- Low water requirements,
- Low fertilizer requirements,
- Low maintenance requirements, and
- Attractive in all seasons.

Plant species located in the low zone of bioretention systems must be able to withstand periodic flooding and prolonged periods of inundation (e.g., up to 7 days). Fertilizer use should be minimized or slow release fertilizers can be used so that it does not become a pollutant in stormwater (e.g., never apply fertilizers when rain is predicted). Herbicides and pesticides are also not recommended unless absolutely required. Maintaining mulch and hand weeding are the recommended weed-control measures. If herbicides are necessary, use natural alternatives such as corn gluten and herbicidal/insecticidal soap or herbicides that degrade quickly such as glyphosate (e.g., Roundup). If pesticide use is necessary, biological pest and disease controls are recommended. Contact the University of Nevada Cooperative Extension for information on alternatives to herbicide and pesticide: https://www.unce.unr.edu/

Additional Public Resources that may be used to assist with existing site soil information and the selection of appropriate plant species for the Truckee Meadows are presented in **Appendix B** of this manual.

TC-30 LANDSCAPE DETENTION

Description

Landscape detention, also known as bioretention basins or porous landscape detention, consists of a vegetated basin underlain by a layer of permeable growing media, a drain rock layer, and in some cases, an underdrain system. If underlying existing site soils allow for a significant amount of infiltration (minimum 0.5 in/hr (120 min/in)), an underdrain pipe may not be needed. This type of BMP uses soils and plants to remove pollutants from stormwater runoff through physical and biological processes. A typical landscape detention design includes a depressed ponding area, a topsoil or mulch layer, an engineered soil mix of peat or leaf compost and clean sand, and a gravel sub-base layer with an underdrain system consisting of a perforated pipe in a gravel layer. Water ponded to approximately 6 inches gradually infiltrates into the underdrain system, underlying soils or is evapotranspirated over a period of days. The surrounding area should be graded to divert excess runoff from large events away from the landscape detention area towards the conventional storm drain system. A vegetated buffer strip can be added to provide pretreatment. Stormwater runoff from small events passes through slotted curb or curb cuts, which slows its velocity and distributes it evenly along the length of the ponding area.

Applications and Advantages

Landscape detention may be used for commercial, residential, and industrial areas. It is well suited for street median strips, parking lot islands, and roadside swales. In addition to providing significant water quality benefits, landscape detention facilities can provide shade and wind breaks, absorb noise, improve an area's aesthetics, reduce irrigation needs, and reduce or eliminate the need for an underground storm drain system. Landscape detention areas may be integrated into a site's overall landscaping. Designers may use existing natural surface depressions and swales on the site.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	75 - 90
Total Phosphorus	70 - 80
Total Nitrogen	65 - 80
Total Zinc	75 - 80
Total Lead	75 - 80
Organics	75 - 90
Bacteria	75 - 90

Sources: CASQA, 2003; UDFCD, 1999.

Limitations

- Not suitable for locations where the seasonally high groundwater table is within 3 feet of the ground surface.
- Clogging may be a problem in areas with high sediment loads in the runoff.
- Freezing may prevent infiltration of the runoff.
- If located near active construction sites, sediment controls and fencing should be installed to prevent clogging and compaction of engineered and existing site soils from heavy equipment.

Siting Criteria

- Drainage area should generally be less than 1 acre.
- May be located on-line or off-line of the primary drainage system.
- Not recommended for areas with slopes greater than 20 percent.
- Layout should be determined based on site constraints such as location of utilities, underlying soil conditions, existing vegetation, and drainage patterns.
- Not to be used in areas with infiltration rate of existing site soils is less than 0.5 in/hr (120 min/inch) and no adjacent storm drain system or other acceptable drainage feature is available for discharging underdrain system.

Design and Construction Criteria

- Use Design-aid Worksheet TC-30 (www.TMstormwater.com). All of the equations described below are encoded in the worksheet.
- Registered professional civil engineers and landscape architects should work together on the design landscape detention basins.
- Appropriate plant species can stabilize banks and increase the infiltration capacity and stormwater treatment effectiveness of landscape detention basins.
- A typical landscape detention design includes a depressed ponding area, a topsoil or mulch layer, an engineered soil mix of peat or leaf compost and clean sand, and a gravel sub-base layer.
- Size the landscape detention area to capture and treat the WQ_V using the method outlined in **Section 6.3.2**.
- Flows in excess of the WQV should be diverted to the conventional storm drain system.
- The size of the landscape detention area is a function of the drainage area and the runoff generated from the area. A length to width ratio of approximately 2:1 is recommended.
- Determine the ponding depth of the landscape detention area (DWQV) based on the available surface area (SA) using the following equation:

$$D_{WQV} = (WQ_v / SA) \times 12$$

Where:

D_{WQV} = ponding depth of the temporary ponded water (inches)

WQ_v = water quality volume using the method outlined in **Section 6.3.2**. (ft^3)

SA = Surface area of ponding area based on the length and width at the toe of the side slopes

- Maximum recommended ponding depth is 12 inches and minimum ponding depth is 6 inches with water standing no longer than 7 days. This prevents problems with mosquito breeding.
- Curb cuts can provide entrance into new and retrofitted landscape detention areas.
- A vegetated swale or buffer strip can be added to provide pretreatment.
- An impermeable liner should be installed around and under the bioretention facility in the following circumstances:
  - In areas where existing site soils are expansive clays
  - If there is outdoor storage or use of chemicals or materials within the drainage area that could threaten groundwater quality if a spill were to occur.

Planting Soils and Drain Rock Layer Criteria

- Planting soils should have infiltration rates greater than 0.5 in/hr (120 min/in). The maximum infiltration rate should not exceed 3.0 inches per hour.
- The recommended engineered soil mixture is 50-60 percent clean sand (ASTM 33), 20-30 percent peat or certified compost with a low P-index, and 20-30 percent topsoil. The pH of the soil should be between 5.5 and 6.5.
- The gravel layer should be Class C backfill, Section 200.03.04 of the SSPWC.
- The locally available sand and gravel is typically washed with a high pH recycled wastewater. Sand and gravel must be rinsed with potable water prior to installation and construction of the sand filter. Rinse water must be disposed of according to jurisdictional requirements.
- A permeable filter fabric should be installed between the engineered soil mix and the gravel sub base, as well as at the interface between the entire bioretention facility and the adjacent existing soil.
- Frequently specified fabrics include Geotex 117F, Mirafi 140N, or an approved equivalent.

Infiltration and Underdrain Criteria

- An underdrain system consisting of a perforated pipe in a gravel layer is typically required where the infiltration rate of existing site soils is less than 0.5 in/hr (120 min/inch). If underlying existing site soils allow for a significant amount of infiltration (0.5 in/hr or more), an underdrain pipe may not be needed.
- Soils classified as type A or B may be suitable for infiltration of stormwater and underdrain systems may not be necessary.
- Infiltration testing should be conducted at the location and bottom depth of the proposed bioretention system. A boring or test pit may be acceptable provided it is

installed to a minimum depth of 5 ft. below the bottom of the proposed bioretention system. See **Section 6.4** for more information on infiltration testing.

Vegetation and Planting Criteria

- Approximately 3 inches of shredded hardwood mulch should be applied to the area.
- Plan for at least 1 tree or shrub for each 50 ft2 of landscape detention area. EPA guidance suggests the shrubs to trees ratio between 2:1 and 3:1.
- Refer to **Appendix B** for plant selection guidance. Plant selection and layout should consider aesthetics, maintenance, native versus non-native invasive species, and regional landscaping practices.
- Some trees should be planted on the perimeter to provide shade and shelter.
- Provide irrigation for all vegetation when first established, modify irrigation depending on needs of vegetation.

Inspection and Maintenance Requirements

- Regular landscape maintenance includes pruning and weeding as necessary.
- Replacement of mulch is generally required every two to three years.
- Upon installation, landscape detention basins should be inspected monthly and after large storm events.
- Inspections may be reduced to semi-annual frequency once the landscape detention basin has proven to work efficiently and properly and vegetation is established.
- A health evaluation of trees and shrubs should be conducted biannually.
- If ponding is observed for seven (7) consecutive days or longer from May through October (the local mosquito breeding season), cleaning of the underdrain system or replacement of engineered soils may be required.
- Key maintenance areas include inlet areas, under drain, and overflow structures.
- If a spill occurs and hazardous materials contaminate soils in landscape detention areas, the affected materials should be removed immediately and the appropriate soils and materials replaced as soon as possible.

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U.S. EPA Stormwater Technology Fact Sheet: Bioretention http://water.epa.gov/scitech/wastetech/upload/2002_06_28_mtb_biortn.pdf

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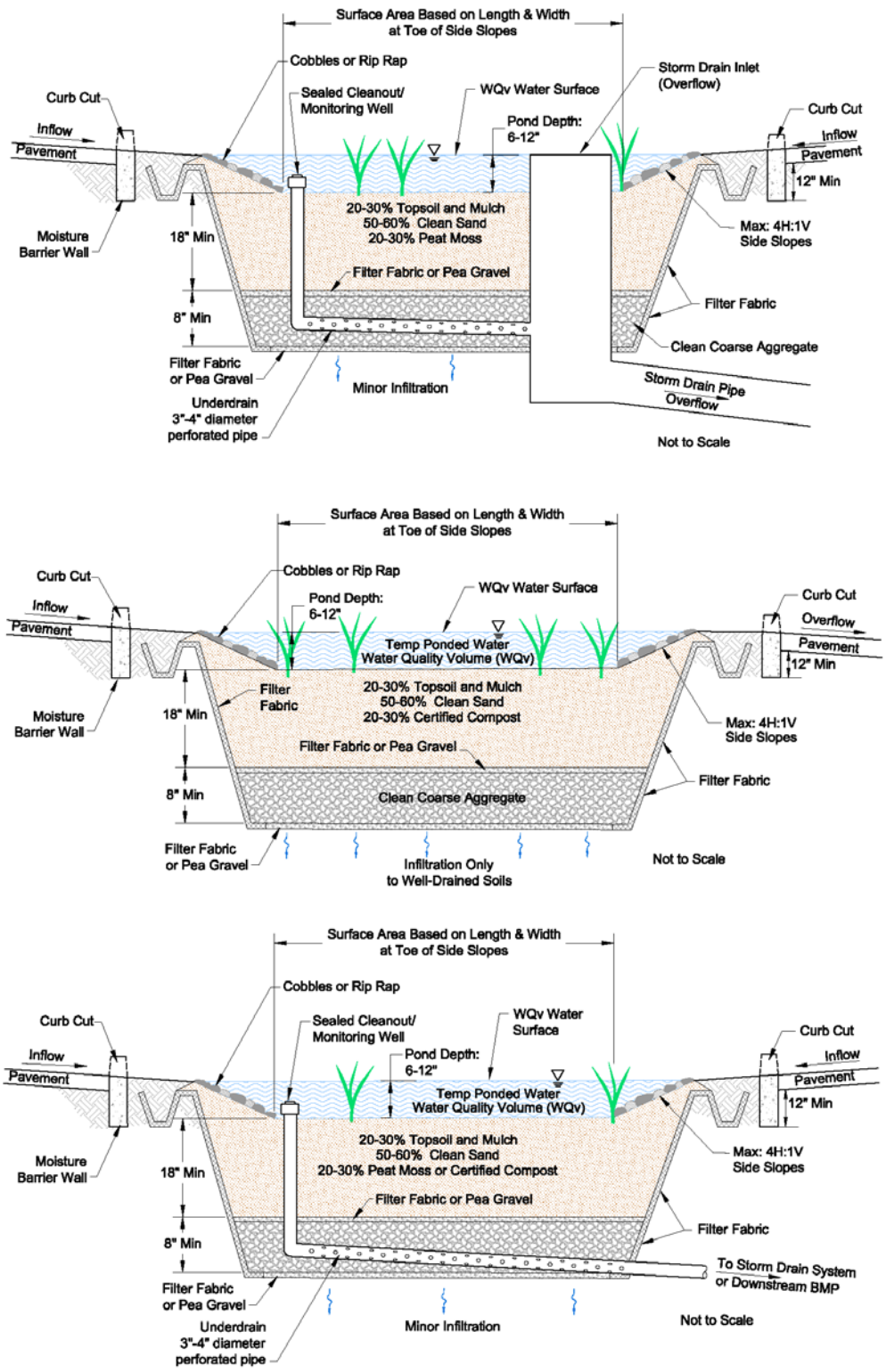

Figure TC-30. Schematics of a Landscape Detention facility

6.8.4 Extended Detention Basins

Extended detention basins, including sedimentation basins and sand filter basins, are designed to detain the WQ_V produced by frequently occurring storm event. They have outlet structures designed to detain the WQ_V for a longer period than is typical for flood control detention basins in order to allow fine-grained sediments and associated pollutants time to settle (e.g., 48 hours to 7 days). Stormwater is slowly released by the outlet structure and pollutants are removed through settling and biochemical processes as the water stands in the basin. Infiltration into underlying soils can substantially improve pollutant removal effectiveness. Unlike wet ponds or constructed wetlands, these treatment controls do not have a permanent pool and water is not retained between storm events. Extended detention basins can also be used for flood control by including additional flood detention storage and appropriate outlet and overflow structures.

TC-40 SEDIMENTATION BASINS

Description

Also known as extended detention basins or dry ponds, sedimentation basins allow for the collection and detention of frequently occurring runoff-producing storm events. The basin geometry and outlet structure are specifically designed to detain the WQ_V for a minimum of 48 hours to allow fine-grained sediments and associated pollutants to settle. Between storm events, the basin is typically dry. Sedimentation basins are typically unlined and depending on the characteristics of the local soils, some infiltration typically occurs, providing additional pollutant load reduction. Sedimentation basins not only improve water quality, but can also provide flood control by including additional flood detention storage. Existing flood control structures can be converted to sedimentation basins by modifying the existing outlet structure, providing a significant stormwater quality treatment enhancement. This type of control measure requires a minimal amount of hydraulic head and has few siting constraints, making it one of the most flexible and applicable technologies for stormwater treatment.

Applications and Advantages

Typically used as a regional method of improving urban runoff stormwater quality from residential, commercial, and industrial areas. However, this treatment technology can also be used on a small scale as a pretreatment device for additional treatment controls.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Influent	Effluent
Total Suspended Solids (mg/l)	87.7 (48.4-159)	41.4 (30.8-55.5)
Total Copper (ug/l)	32.3 (22.7-46)	18.9 (16.6-23.4)
Dissolved Copper (ug/l)	12.1 (8-18.3)	14.7 (11.4-20.9)
Total Lead (ug/l)	69.2 (33.6-143)	15.0 (9.2-23.8)
Dissolved Lead (ug/l)	3.4 (2-5.8)	2.33 (1.7-3.3)
Total Zinc (ug/l)	274 (178-422)	85.3 (50.6-143.7)

Pollutant	Influent	Effluent
Dissolved Zinc (ug/l)	n/a	n/a
Total Phosphorus (mg/l)	0.4 (0.3-0.5)	0.3 (0.2-0.44)
Total Nitrogen (mg/l)	n/a	n/a
TKN (mg/l)	1.99 (1.6-2.5)	1.87 (1.46-2.39)

Source: UDFCD, 2005.

Pollutant removal efficiencies may be improved by adding a small, shallow permanent pool or wetland to the floor of the sedimentation basin.

Limitations

- Unless landscaped and properly maintained, sedimentation basins can detract from the value of surrounding homes.
- Discharges from sedimentation basins can increase water temperatures downstream, which may be a problem if the outlet is located next to a stream or a wetland,
- May not be effective at settling very fine sediment particles.
- May pose some safety concerns where there is public access.
- Stagnant water may provide vector habitat.
- Cannot be placed on steep, unstable slopes.

Siting Criteria

- Do not place sediment basins adjacent to sensitive wetlands or perennial streams.
- Existing flood control detention basins can be retrofitted with sedimentation basin outlet structures.
- Appropriate for sites with drainage area greater than 5 acres.
- Can be applied in areas underlain by all soil and rock types (except clayey soils).
- Sedimentation basins should not intersect the groundwater table.
- If part of a regional flood control facility, the area within a sedimentation basin that detains the WQ_V is not recommended for ballparks, picnic areas, or playing fields.

General Design Criteria

- Registered professional civil engineers and landscape architects should work together on the design of sedimentation basins.
- An access and maintenance ramp must be provided.
- If outdoor storage of chemicals occurs within the drainage basin, an impermeable liner may be needed to prevent infiltration and groundwater contamination.
- If an embankment is necessary, it should be designed by a qualified geotechnical engineer. Check with state engineer about maximum heights and dam regulation.
- A trash rack should be provided and sized such that the hydraulic capacity of the outlet is not affected.

- Basin sidewalls should be stabilized with either riprap or vegetation. If sidewalls are to be stabilized with vegetation, a planting plan should be prepared by a landscape architect using the plant list found in **Appendix B**. If sidewalls are to be stabilized with riprap, a Professional Civil Engineer should design the riprap per the selected side slope.

Hydraulic Design Criteria

- Use Design Guidance Worksheet TC-40 (www.TMstormwater.com). The following design criteria are embedded in the Design Guidance Worksheet.
- Calculate the WQ_V for the drainage area based on the method presented in **Section 6.3**.
- The basin should be designed with sufficient freeboard to detain a total volume equal to 120 percent of the WQV.
- The outfall structure should be designed to meet the following criteria:
  - The recommended detention time for the WQ_V is 72 hours. The maximum detention time for the WQ_V is 7 days (to prevent vector breeding).
  - The minimum detention time for the WQ_V is 48 hours.
- The outfall structure should be equipped with an isolation valve to contain potential spills occurring within the basin or watershed upstream of the basin.
- The basin should have a minimum length to width ratio of 2:1 (3:1 is preferable).
- Optimal depth of sedimentation basins ranges from 2 – 5 feet. If an embankment is necessary, it should be designed by a qualified geotechnical engineer. Check with state engineer about maximum heights and dam regulation.
- Side slopes within the sedimentation basin should be 4H:1V or flatter. Exterior side slopes should not be steeper than 3H:1V.
- If the structure is an in-line treatment control (e.g., no upstream diversion structure), an emergency spillway should be provided capable of safely passing the 100-year storm event.
- A forebay will aid in the settling out of particles by dissipating energy and collecting coarser grained sediments and debris. The forebay should be surrounded with a 0.5' to 1' high gravel/cobble/riprap flow spreader, with particle sizes capable of resisting movement from maximum flow rate expected to enter the basin.
- For perforated pipe outlet structures and structures with vertical plates and multiple orifices (**Figures TC-40C and 40D**), use the following equation to determine the required area per row of perforations (from UDFCD, 2010):

$$A_o = \frac{88WQ_V\left(\frac{0.95}{H^{0.085}}\right)}{tS^{0.09}H^{2.6S^{0.3}}}$$

Where: A_O = Area per row of orifices spaced on 4" centers (in²)

WQ_V = water quality volume (acre-ft.)

H = the depth of water above the centerline of the bottom row of perforations when the basin is retaining the WQ_V (ft.)

t = time to drain the WQ_V (hours)

S = bottom slope of the sedimentation basin (ft./ft.)

Design Guidance Worksheet TC-40 uses this equation to select the appropriate orifice diameter and number of orifices per row (e.g., number of columns) with the objective of minimizing the number of columns and using a maximum orifice diameter of 2 inches.

- A minimum ¼-inch steel screen should be placed over the outlet perforations to prevent debris from clogging the perforations. Stainless steel screen is recommended for long-term durability and performance.

Inspection and Maintenance Requirements

- Inspect after the first large storm event to ensure that the basin is draining as designed.
- Inspect before and after the rainy season for standing water, accumulation of sediments, debris and trash, presence of animal burrows, and the stability of surrounding slopes.
- Remove debris from screen covering perforations and overflow grate as needed.
- Vector control, vegetation maintenance, and debris removal comprise the majority of maintenance activities.
- Install a staff gage in the basin to indicate depth of accumulated sediment. When the volume of accumulated sediments exceeds 10 percent of the basin volume, the sediments should be removed and the area should be regraded.
- If a spill occurs and hazardous materials contaminate soils in a sedimentation basin, the affected areas should be removed immediately and the appropriate soils and materials replaced as soon as possible.

References

California Stormwater Quality Association (CASQA), 2003. California Stormwater Best Management Practice Handbook, New Development and Redevelopment. https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook

City and County of Sacramento, 2007. Stormwater Quality Design Manual for the Sacramento and South Placer Regions.

MacKenzie, K. 2010. Urban Drainage and Flood Control District (UDFCD). *Technical Memorandum: Water Quality orifice sizing equation for EURV and WQCV detention basins*. July 13, 2010. Denver, Colorado.

Maryland Department of the Environment (MDE), 2000. Maryland Stormwater Design Manual, Revised May 2009.

Urban Drainage and Flood Control District (UDFCD), 2010. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices. Denver, Colorado.

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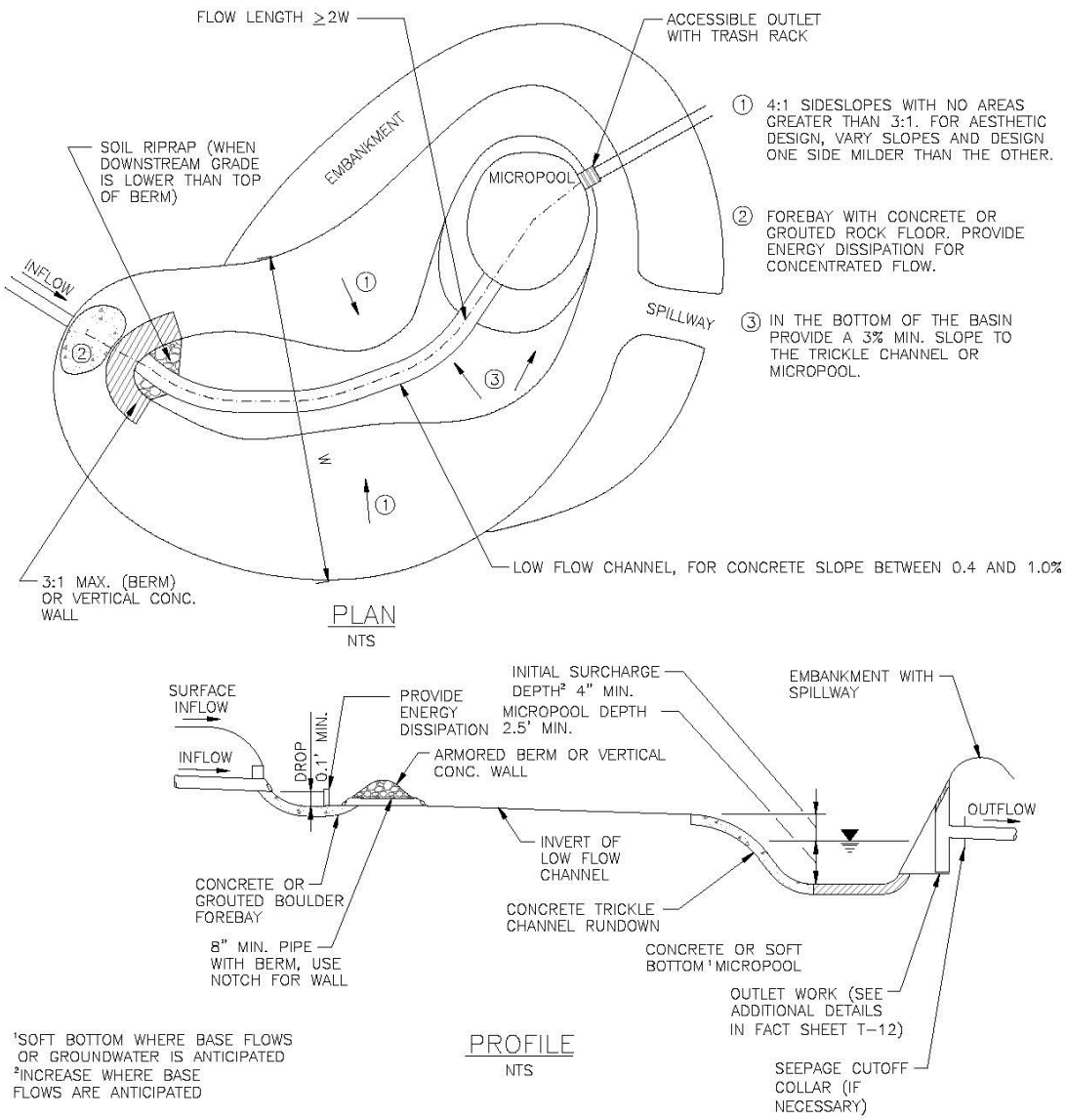
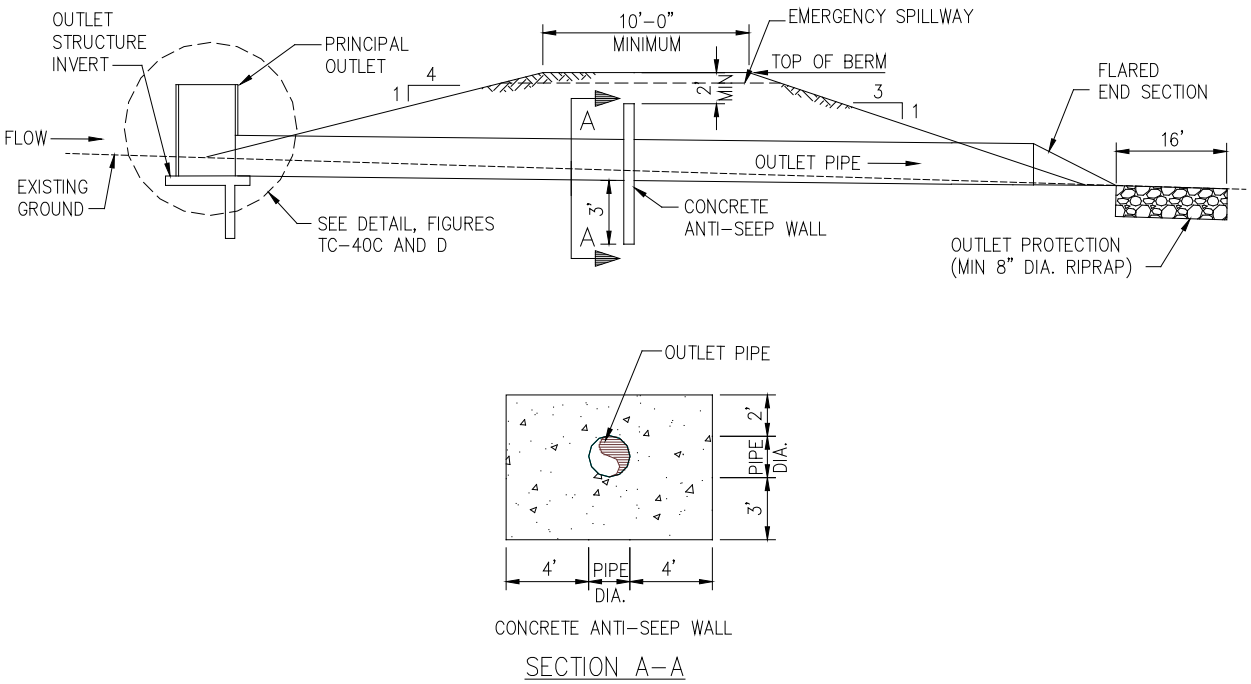


Figure TC-40A. Typical components of a Sedimentation Basin (UDFCD, 2010).



NOT TO SCALE

Figure TC-40B. Example design of a sedimentation basin embankment and outlet structure (Kennedy/Jenks, 2003).

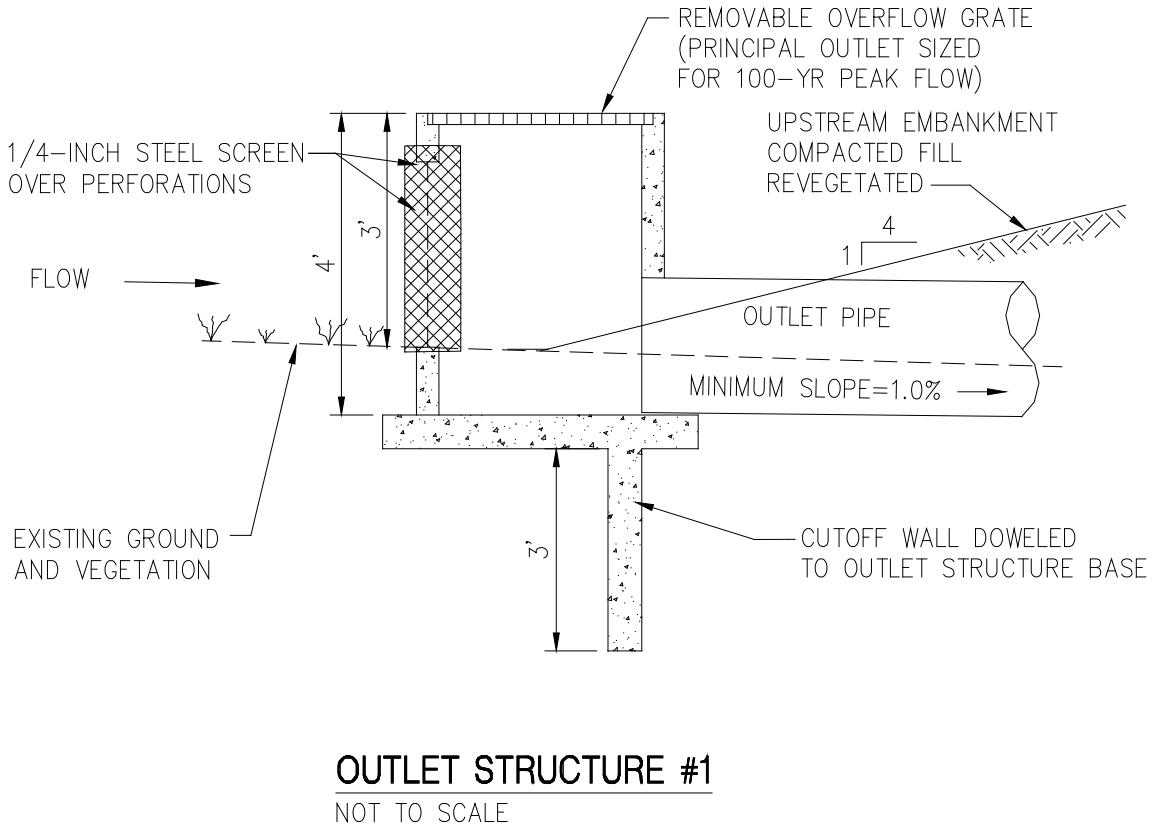


Figure TC-40C. Example sedimentation basin outlet structure #1 – vertical plate with multiple orifices (Kennedy/Jenks, 2003).

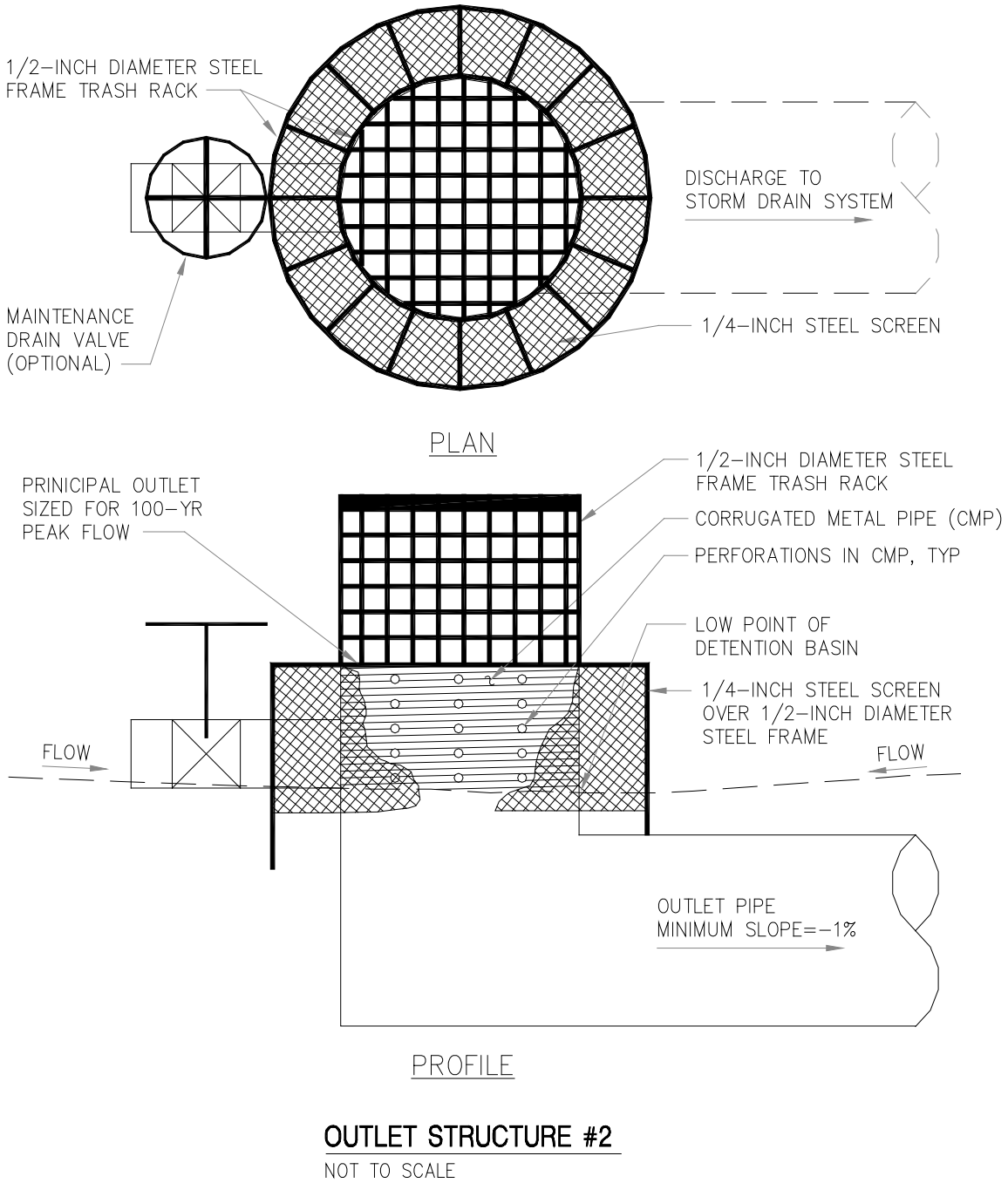


Figure TC-40D. Example sedimentation basin outlet structure #2 – perforated pipe (Kennedy/Jenks, 2003).

TC-41 SAND FILTER BASINS

Description

A sand filter basin is a combination of a sedimentation basin and a sand filter. The WQ_V collects in the basin and gradually infiltrates into an underlying sand bed with an under drain system. Fine grained sediments and associated pollutants are filtered out of the stormwater and collected in the void spaces of the sand. The under drain system gradually dewaters the sand bed and filtered stormwater then discharges into a vegetated swale, a channel or the storm drain system.

Applications and Advantages

Sand filter basins can be applied in urban areas with low infiltration rates. They are generally used as offline treatment devices with an upstream diversion that diverts the WQ_V into the basin and allows larger flows to bypass. They should be sited in drainage areas with relatively low sediment loads and no baseflows.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	80 – 90
Total Phosphorus	45 – 55
Total Nitrogen	35 – 55
Total Recoverable Zinc	50 – 80
Total Recoverable Lead	60 – 80
Biochemical Oxygen Demand	60 – 80

Source: UDFCD, 1999.

Limitations

- Potential of clogging exists if runoff contains high amounts of clays and silts.
- Sand filter basins should not be installed in new development until construction is complete and disturbed soils are stabilized.

Siting Criteria

- Sand filter basins should not be installed near building foundations or in areas containing expansive soils.
- Due to the horizontal design of this BMP, it may be difficult to install a sand filter basin on a steep slope.
- Not to be used in areas where there is a high water table.
- Should not be used in drainage areas that have a perennial base flow because a preferential flow path through the sand filter may occur as well as clogging of the filter media.

Design and Construction Criteria

- Use Design-aid Worksheet TC-41 (www.TMstormwater.com)
- Registered professional civil engineers should design sand filter basins.
- The locally available sand and gravel is typically washed with a high pH, recycled wastewater. Sand and gravel must be rinsed with potable water prior to installation and construction of the sand filter.
- Size the basin to capture and treat the WQ_V using the method outlined in **Section 6.3.2**.
- Flows in excess of the WQ_V should be diverted around or through the basin without re-suspending collected sediments.
- The basin should be designed with a minimum drain time of 48 hours.
- The maximum depth of the basin should be 3 feet.
- The minimum sand filter surface area (SA in ft^2) at the base of the basin should be determined using the following equation:

  $$SA = WQ_V / 3 \text{ ft.}$$

- The bottom of the sand filter basin should be lined with 18 inches of fine aggregate meeting the grading requirements of Section 200.05.04 SSPWC overlying a 9-inch gravel layer of Class B backfill (Section 200.03.03 SSPWC).
- If chemicals are stored or handled within the catchment area, install an impermeable layer beneath the gravel layer.
- The following types of under drains can be applied: center collector pipe or a longitudinal pipe in a 9-inch gravel backfill containing a collector pipe at the outlet.
- Collector under drainpipes should have a minimum slope of 0.5 percent.
- The under drainpipes should have a minimum diameter of 4 inches and should be composed of perforated schedule 40 PVC.
- Basin side slopes should be 4H:1V or flatter.

Inspection and Maintenance Requirements

- Routinely remove debris and litter from the sand filter basin to minimize clogging and to maintain aesthetics.
- Replace vegetation and perform maintenance on the sand filter basin every 2 – 5 years by removing vegetation and the top 3 inches of the sand layer.
- Rake the top 3 – 5 inches of the filter surface a minimum of once a year.
- Inspect at least twice a year (with one inspection following a significant storm event) to ensure proper drainage and no ponding of water.
- If a spill occurs and hazardous materials contaminate the sand layer in a sand filter basin, the affected areas should be removed immediately and the appropriate soils and materials replaced as soon as possible.

References

Urban Drainage and Flood Control District (UDFCD), 2005. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices. Denver, Colorado.

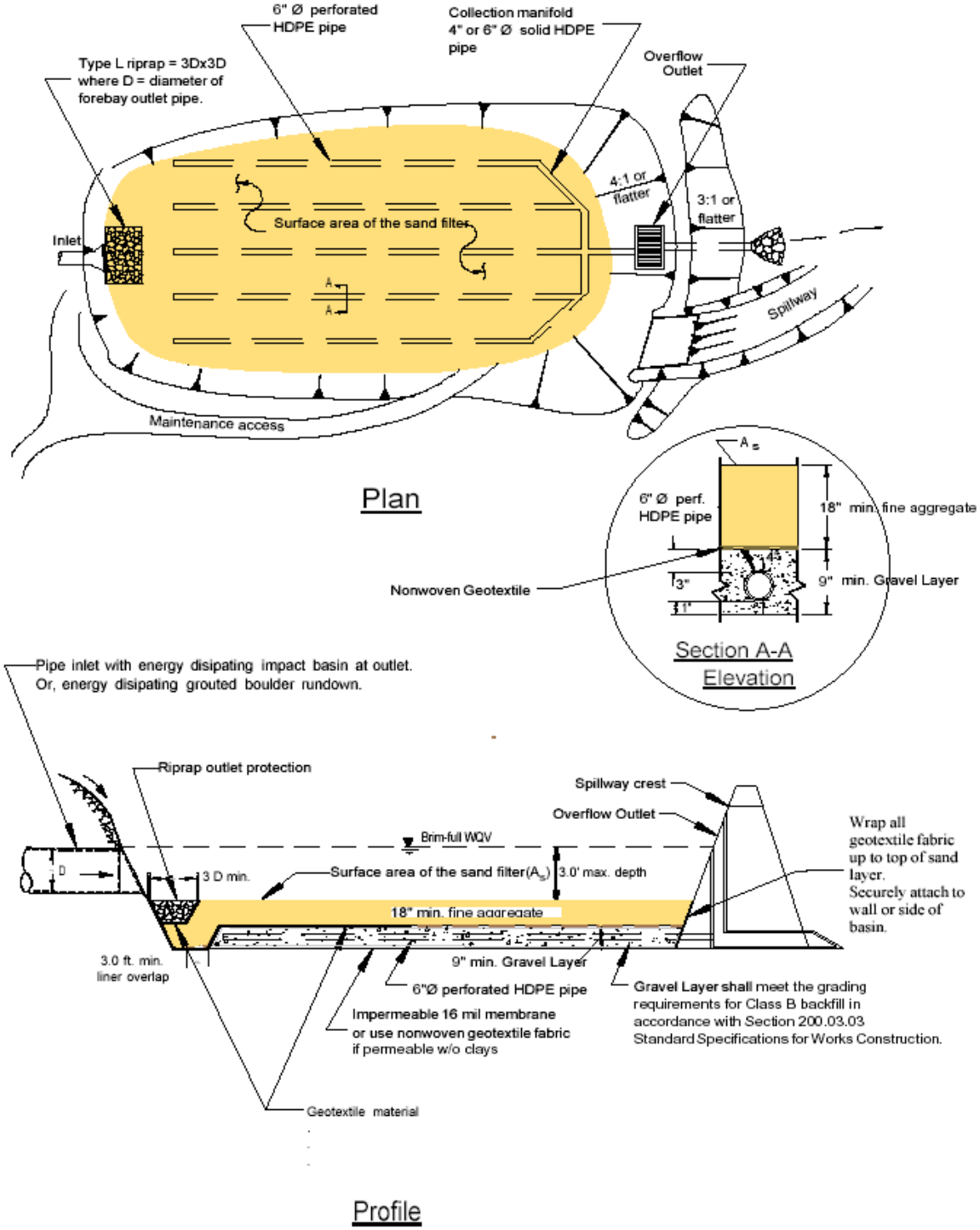


Figure TC-41. Example of a Sand Filter Basin design (modified from UDFCD, 2005).

6.8.5 Stormwater Ponds and Wetlands

Stormwater ponds and wetlands are constructed basins that have a permanent pool of water at least throughout the wet season. Stormwater ponds are typically deeper and have less micro topography and wetland vegetation than stormwater wetlands. In arid locations such as the Truckee Meadows, they require a dependable source of water to sustain the wetland vegetation. These treatment controls are among the most effective in terms of pollutant removal and can offer aesthetic value. Stormwater pollutant removal is achieved through settling and biological uptake within the pond or wetlands.

TC-50 STORMWATER PONDS

Description

Stormwater ponds are also known as wet ponds, sediment retention ponds, or wet extended detention ponds. They are typically deeper, have more open water, and contain less wetland vegetation than stormwater wetlands. Stormwater ponds contain a permanent pool of water and the excess capacity of the structure is used to collect and treat the WQ_V. Between storm events, pollutants are removed from the water through sedimentation, biological processes and chemical processes. Given proper design and maintenance, these ponds provide valuable wetland habitat, increase the aesthetic value of the area, and improve water quality.

Applications and Advantages

Stormwater ponds can be applied over a range of storm sizes, storm frequencies, and drainage areas. However, they are limited in application in urban settings and arid climates because they require a perennial water source. Stormwater ponds can be installed either on-line or off-line.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Influent	Effluent
Total Suspended Solids (mg/l)	88.8 (48.9-156)	19.7 (16.6-23.4)
Total Copper (ug/l)	18.0 (7.4-43)	6.92 (4.7-10.3)
Dissolved Copper (ug/l)	8.87 (5.4-14.6)	5.09 (3.1-8.3)
Total Lead (ug/l)	33.3 (10.2-109)	6.68 (2.9-15.6)
Dissolved Lead (ug/l)	9.48 (0.9-101.4)	4.16 (2.0-8.9)
Total Zinc (ug/l)	75.3 (44-128.9)	28.6 (21.4-38.3)
Dissolved Zinc (ug/l)	57.4 (20.1-163)	16.9 (2.6-109)
Total Phosphorus (mg/l)	0.53 (0.3-0.9)	0.16 (0.12-0.21)
Total Nitrogen (mg/l)	1.49 (0.6-3.6)	1.17 (0.77-1.78)
TKN (mg/l)	1.06 (0.8-1.4)	0.84 (0.68-1.04)

Source: UDFCD, 2005.

Limitations

- Unless a perennial base flow is available to support a permanent pool, this technology is typically not practical in arid climates.
- May create a public health hazard and require fencing.
- Can create mosquito-breeding habitat.
- Increased water temperatures within the pond may lead to warming downstream.
- If not regularly maintained, permits may be required to perform necessary maintenance.
- May provide a habitat for waterfowl that may lead to increased nutrient loads.

Siting Criteria

- Apply in areas with high volumes of suspended sediments and dissolved contaminants.
- Applicable to drainage areas greater than 25 acres.
- Must be sited in an area with available open space.
- Not to be located on steep unstable slopes.

Design and Construction Criteria

- Use Design-aid Worksheet TC-50 (www.TMstormwater.com)
- Registered professional civil engineers and landscape architects should work together on the design of stormwater ponds.
- Stormwater ponds should be sized to contain the permanent pool plus the WQ_V.
- The WQ_V should be determined using the method outlined in **Section 6.3.2**.
- The permanent pool volume should be equal to twice the WQ_V.
- A sediment forebay can be installed to aid in the settling of coarse sediments.
- The forebay should be a minimum of 3 feet deep and should hold 15 to 25 percent of the permanent pool volume.
- An impermeable liner may be needed if the pond is located in an area with porous soils.
- Water depth in the pond should not exceed 8 feet and should range between 4 and 6 feet.
- The minimum length to width ratio of the pond should be 1.5:1.
- The basin should be narrow at the inlet and wide at the outlet.

Ponds having a depth greater than 4 feet should have an aquatic bench extending around their perimeter. The aquatic bench should be 5 to10 feet wide and less than 18 inches deep.

- Side slopes above the permanent pool should be 4H:1V or flatter and should be stabilized with vegetation on slopes as long as it is kept 2 feet from the water's edge.
- Littoral zone side slopes should be 40H:1V or flatter.
- Wetland vegetation should not cover more than 25 percent of the ponds surface and should be maintained as isolated islands away from the pond's perimeter edge.

- The emergency spillway should be consistent with local flood control design standards [100-year peak flow, probable maximum flood (PMF), or standard project flood (SPF)].
- The outlet structure should be designed to drain the WQV within a minimum of 48 hours.
- Where permissible with local fish and game officials, stock pond with mosquito fish (*Gambusia* sp.) to aid in controlling mosquito populations.
- A pretreatment device, such as a hydrodynamic separator can be used to remove litter and debris before being discharged to the pond for further treatment.
- The design of these ponds should include a meandering low-flow channel connecting all micro pools or place aerator(s) in these ponds with a two-hour operation in the morning and evening.
- Vegetation can be installed on the bottom of the pond excluding 2 feet on both sides of the low-flow channel.

Inspection and Maintenance Requirements

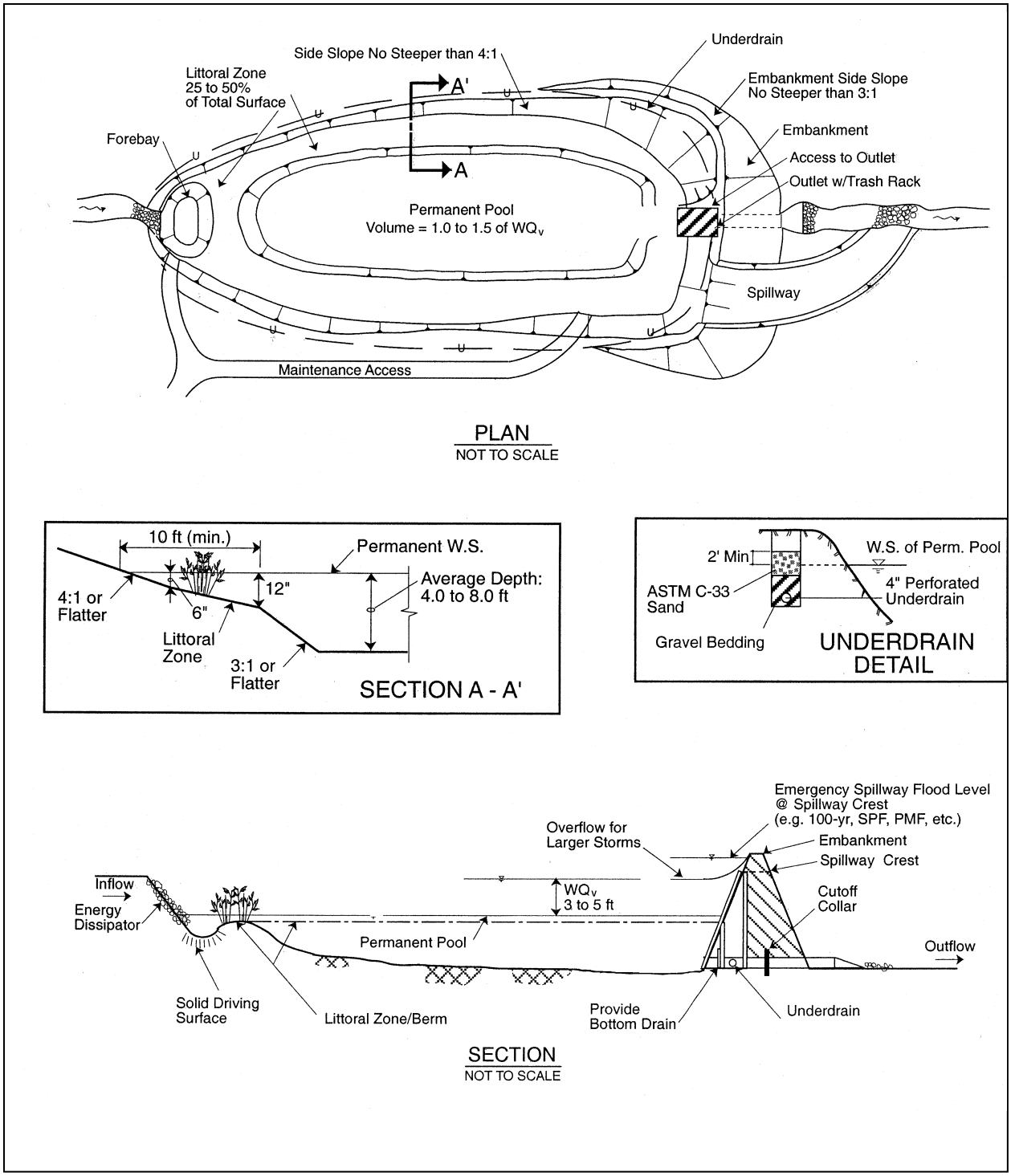
- Biannual performance and maintenance inspections should be conducted.
- Cut and remove wetland plants every 5 - 15 years to remove nutrients and metals retained in the vegetation.
- Sediments may need to be removed from the pond every 5 – 20 years.
- To maintain an attractive pond, litter and debris must be regularly removed.
- A non-clogging outlet such as the reverse-slope pipe or a weir outlet with a trash rack should be installed in the pond.
- Properly maintain the access road as well as the shoreline vegetation.

References

California Stormwater Quality Association (CASQA), 2003. California Stormwater Best Management Practice Handbook, New Development and Redevelopment.

City and County of Sacramento, 2000. Guidance Manual for On-site Stormwater Quality Control Measures, Sacramento Stormwater Management Program.

Urban Drainage and Flood Control District (UDFCD), 1999. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices. Denver, Colorado.



*SSPWC

Figure TC-50. Example of a Stormwater Pond (modified from UDFCD, 1999).

TC-51 STORMWATER WETLANDS

Description

Stormwater wetlands or constructed wetlands are shallow ponds that have a perennial base flow that supports the growth of rushes, willows, cattails, reeds and other wetland vegetation. They differ from stormwater ponds by having relatively large shallow areas with complex micro-topography that supports a greater and larger variety of wetland vegetation. The purpose of stormwater wetlands is to slow the flow of water and allow sediments to settle out of suspension as well as the biological uptake of nutrients by the vegetation. Nutrient and pollution removal efficiencies are dependent upon the design of the wetland, the concentration of pollutants in runoff, local hydrology, climate conditions, soils and diligence of maintenance activities. Stormwater wetlands are artificial structures, although sections of "natural" wetlands along ephemeral streams may be incorporated following federal and state regulations.

Application

Can be applied to treat stormwater runoff from large tributary catchment areas, provided a perennial base flow is available to sustain wetland vegetation.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Influent	Effluent
Total Suspended Solids (mg/l)	82.1 (65.7-103)	19.7 (16.6-23.4)
Total Copper (ug/l)	n/a	n/a
Dissolved Copper (ug/l)	n/a	n/a
Total Lead (ug/l)	12.6 (3.8-42)	3.25 (1.9-5.6)
Dissolved Lead (ug/l)	n/a	n/a
Total Zinc (ug/l)	164 (54.6-494)	1119 (32.8-429)
Dissolved Zinc (ug/l)	n/a	n/a
Total Phosphorus (mg/l)	2.91 (1.9-4.6)	0.15 (0.07-0.33)
Total Nitrogen (mg/l)	2.56 (1.6-4)	2.42 (1.46-4.0)
TKN (mg/l)	1.23 (1-1.6)	1.33 (0.84-2.11)

Source: UDFCD, 2005.

Limitations

- A perennial base flow is needed to maintain water levels and vegetation.
- Periodic maintenance and/or removal of wetland sediments and vegetation are required.
- Can provide a mosquito-breeding habitat.
- Requires a relatively large area.

Siting Criteria

- Apply in areas where runoff contains relatively high volumes of suspended sediments and dissolved contaminants.
- Must site in drainage areas with perennial base flow.
- Site should be underlain by loamy soils to allow plants to take root.
- Not to be located on steep unstable slopes.
- It is preferable to site the wetland and design for inflow offline from other high flow or flood flow conveyance.

Design and Construction Criteria

- Use Design-aid Worksheet TC-51 (www.TMstormwater.com)
- Registered professional civil engineers and landscape architects should work together on the design stormwater wetlands.
- Sized to contain a permanent pool with wetland vegetation plus the WQ_V.
- The WQ_V should be determined using the method outlined in **Section 6.3.2.**
- The permanent pool volume should be twice as large as the WQ_V.
- A sediment forebay can be installed to aid in the settling of coarse sediments. The forebay should be a minimum of 3 feet deep and should hold 15 to 25 percent of the permanent pool volume.
- An impermeable liner may be needed if the pond is located in an area with porous soils.
- A minimum length to width ratio of 1.5:1 should be applied.
- The basins should be narrow at the inlet and wide at the outlet.
- Maximum water depth is 4 feet in open water areas.
- The outlet of the wetland should allow for drainage of the WQ_V within a minimum of 48 hours.
- A maintenance access ramp must be provided for cleaning of forebay and wetland.
- Side slopes should be 4H:1V or flatter and should be stabilized with vegetation slopes as long as it is kept 2 feet from the water's edge.
- Wetland vegetation should not cover more than 50 percent of the ponds surface area and vegetation should be maintained as isolated islands away from the pond's perimeter edge.
- The design of this structure should include a meandering low-flow channel connecting the inlet to the outlet pipe or place aerator(s) operating for a two-hour period in the morning and evening.
- Use the methods outlined in TC-40 (Sedimentation Basins) for sizing perforated pipe outlet structures and structures with vertical plates and multiple orifices with the bottom row of perforations located at the top of the permanent pool.

Inspection and Maintenance Requirements

- Where permissible with local fish and game agencies, stock pond with mosquito fish (*Gambusia* sp.) to aid in controlling mosquitoes.
- Wetlands should be inspected semi-annually for structural integrity, sediment accumulation, and burrows.
- Cut and remove wetland plants annually to remove nutrients.
- Sediments may need to be removed from the forebay every five years.
- Remove litter and debris from the wetland pond before the onset of the storm season.

References

California Stormwater Quality Association (CASQA), 2003. California Stormwater Best Management Practice Handbook, New Development and Redevelopment.

City and County of Sacramento, 2000. Guidance Manual for Onsite Stormwater Quality Control Measures, Sacramento Stormwater Management Program.

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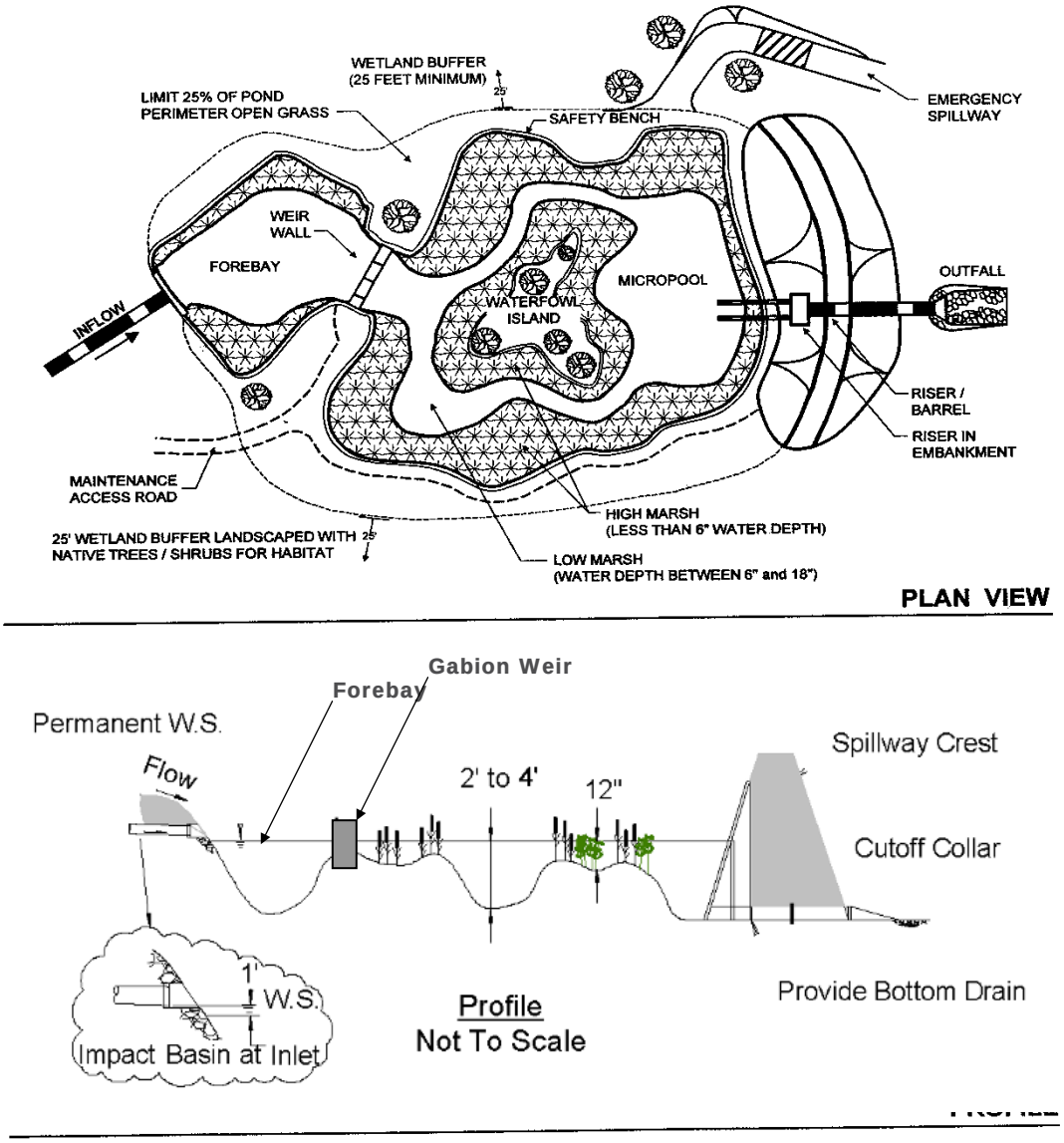

Figure TC-51 1. Example design of a Stormwater Wetland (from MDE, 2000; CASQA, 2003)

6.8.6 Media Filtration Systems

These treatment control devices typically consist of two chambers, a pretreatment settling basin and a filter bed filled with sand or some other absorptive filtering media. Large particles transported in stormwater runoff settle in the pretreatment basin while finer particles and associated pollutants are removed by filtering through the media in the second chamber. There are a number of design variations including the surface or Austin sand filter and the underground, DC or Delaware sand filter. When used with a sand filter bed, porous pavement can also be considered a media filtration system.

TC-60 SURFACE SAND FILTER

Description

Surface sand filters, also known as Austin sand filters, are a type of media filter that applies a combination of sedimentation, filtration, and adsorption to remove sediment and associated pollutants. The surface sand filter is constructed of an upstream bypass structure (e.g., a weir), a sedimentation chamber, a flow distribution cell, and a sand filter bed. The purpose of the sedimentation chamber is to remove floatables and heavier suspended sediments. The sand filter bed removes lighter suspended sediments and additional contaminants. This BMP is widely used across the country. Site design configurations can vary significantly depending on local conditions and site constraints.

Applications and Advantages

Applied to drainage areas ranging between 0.5 and 50 acres and containing both pervious and impervious surfaces. Surface sand filters are commonly applied at transportation facilities, large parking areas, and around commercial developments. They can also be applied in highly developed areas, on sites with steep slopes, and to retrofit existing sites. However, sand filters should not be applied where high sediment loads are expected unless a pretreatment device is to be applied.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	80 - 90
Total Phosphorus	45 - 55
Total Nitrogen	35 - 55
Total Zinc	50 - 80
Total Lead	60 - 80
BOD	60 - 80

Source: UDFCD, 1999.

Limitations

- Can frequently become clogged in areas with highly erodible or unstable soils.
- Clogging of the sand media in surface sand filters installed along roadways commonly occurs 2 – 10 years after installation if not maintained.
- Can only be used in areas where sufficient vertical relief in the land topography is available to allow the system to drain by gravity.

Siting Criteria

- Sufficient vertical relief in land topography is required to allow the system to drain by gravity.
- Relatively large drainage areas require large surface sand filters. Therefore, a significant amount of available open space may be required.
- A minimum distance of 3 feet should exist between the high seasonal water table and the bottom of the filter bed.
- Do not install in areas with highly erodible or unstable soils.

Design and Construction Criteria

- Use Design-aid Worksheet TC-60 (www.TMstormwater.com)
- Registered professional civil engineers should design surface sand filters.
- The locally available sand and gravel is typically washed with a high Ph, recycled wastewater. Sand and gravel must be rinsed with potable water prior to installation and construction of the sand filter.
- In areas where large sediments loads in runoff are present, a pre-treatment BMP should be installed upstream of the surface sand filter.
- In areas of shallow groundwater, a liner may need to be installed below the sand filter to prevent potential groundwater contamination.
- Do not use as a sediment basin during construction.
- An upstream diversion structure should be used. The diversion structure must effectively isolate the WQ_V and convey flows greater than the WQV past the basin.
- The sedimentation chamber should be sized to capture and detain the WQ_V plus a minimum freeboard of 0.5 ft.
- The WQ_V sizing method is described in **Section 6.3.2**.
- Minimum depth of the sedimentation chamber (df) is 3 feet.
- The sedimentation chamber length to width ratio should be a minimum of 2:1.
- The sedimentation chamber should not drain in less than 24 hours.
- The minimum surface area of the sedimentation chamber (AS) should be determined using the following equation:

$$AS = WQ_V / df$$

Where: AS = Surface area of the sedimentation chamber in ft2

WQ_V = water quality volume in ft3

df = Sediment basin depth in feet

- The sedimentation chamber design criteria are summarized in **Table TC-60A**.
- A trash rack should be provided around the outlet structure from the sedimentation chamber. Openings in the trash rack should not exceed 1/3 the diameter of the vertical riser pipe. The trash rack should be made of a durable rust resistant material. A cone of 1 to 3-inch gravel should be placed around the base of the riser pipe to prevent clogging of the bottom perforations.

Table TC-60A. Sand Filter Sedimentation Chamber Design Criteria

Parameter	Design Criteria
Maximum drainage area	50 acres
Minimum sedimentation basin depth, df	3 ft.
Minimum allowable surface area, AS	WQ_V /10
Minimum length to width ratio	2:1
Maximum WQ_V drawdown time	24 hrs.
Minimum freeboard	0.5 ft. above WQ_V water level
Minimum basin volume	WQ_V + 1 ft. freeboard
Maximum inlet entrance velocity	3 fps

- The primary design parameter of the sand filter basin is the surface area, which is a function of the sand permeability, the sand bed depth, the hydraulic head and the expected sediment loading.
- The required sand filter basin surface area (Af) can be determined using the following equation, and the design criteria provided in **Table TC-60B**:

$$Af = (WQ_V)(df)/k(h + df)tf$$

Where:

Af = surface area of the filter basin in ft2

WQ_V = water quality volume in ft3

df = sand bed depth in feet

k = coefficient of permeability for the sand filter in ft./hr. (typically 1.18 ft./hr. for clean, well graded sand with d10=0.1 mm)

h = one half of the maximum allowable water depth (2h) over the filter bed in ft.

tf = time required for the WQ_V to pass through the filter in hrs.

- A gravel layer and under drain system should be placed below the sand filter layer.
- A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal should be installed between the sand filter and the gravel under drain.

- Additional design criteria for the sand filter basin are summarized in **Table TC-60B**.

Table TC-60B: Sand Filter Basin Design Criteria

Parameter	Design Criteria
Minimum sand depth, df	18 in
Filter sand size	concrete sand per Sec. 200.05 SSPWC*
Minimum under drain gravel bed depth	16 in
Under drain gravel size	Size No. 357 coarse aggregate per Sec. 200.05 SSPWC*
Minimum water depth over sand filter, h	3 ft.
Minimum gravel depth under sand filter	2 in
Minimum filtration rate of sand filter, k	3.5 ft./day
Slope of sand filter surface	0 (horizontal)
Minimum gravel cover over under drain pipes	2 in
Minimum under drain pipe size and type	6 in Schedule 40 PVC
Minimum under drain pipe slope	1 percent
Minimum under drain perforation size, diameter	3/8 in
Minimum number of perforation holes per row	6
Maximum spacing between rows of holes	6 in
Maximum WQ_V drawdown time, tf	40 hrs.

*SSPWC

Inspection and Maintenance Requirements

- Inspect the system at least 3 times a year, once at the beginning of the rainy season and after major storm events to remove litter and debris and to keep the filter from clogging.
- Access must be provided for maintenance and repairs.
- Excess plant growth within the filter is not recommended.
- Rake the top 3 – 5 inches of sand once per year or when drainage begins to slow or pond. Remove sediments when accumulation exceeds 0.5 inches.
- If sand filter does not drain within 40 hours, maintenance is required.
- Every 2 – 5 years the vegetative cover should be removed for maintenance of the sand filter.
- Sand and gravel filter media may need to be replaced every 3 to 5 years.

References

California Stormwater Quality Association (CASQA), 2003. California Stormwater Best Management Practice Handbook, New Development and Redevelopment.

City of Austin, 2003. Environmental Criteria Manual.

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Urban Drainage and Flood Control District (UDFCD), 1999. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices. Denver, Colorado.

U.S. Department of Transportation, Federal Highway Administration, Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, Fact Sheet – Surface Sand Filters, http://www.fhwa.dot.gov/environment/ultraurb/3fs8.htm

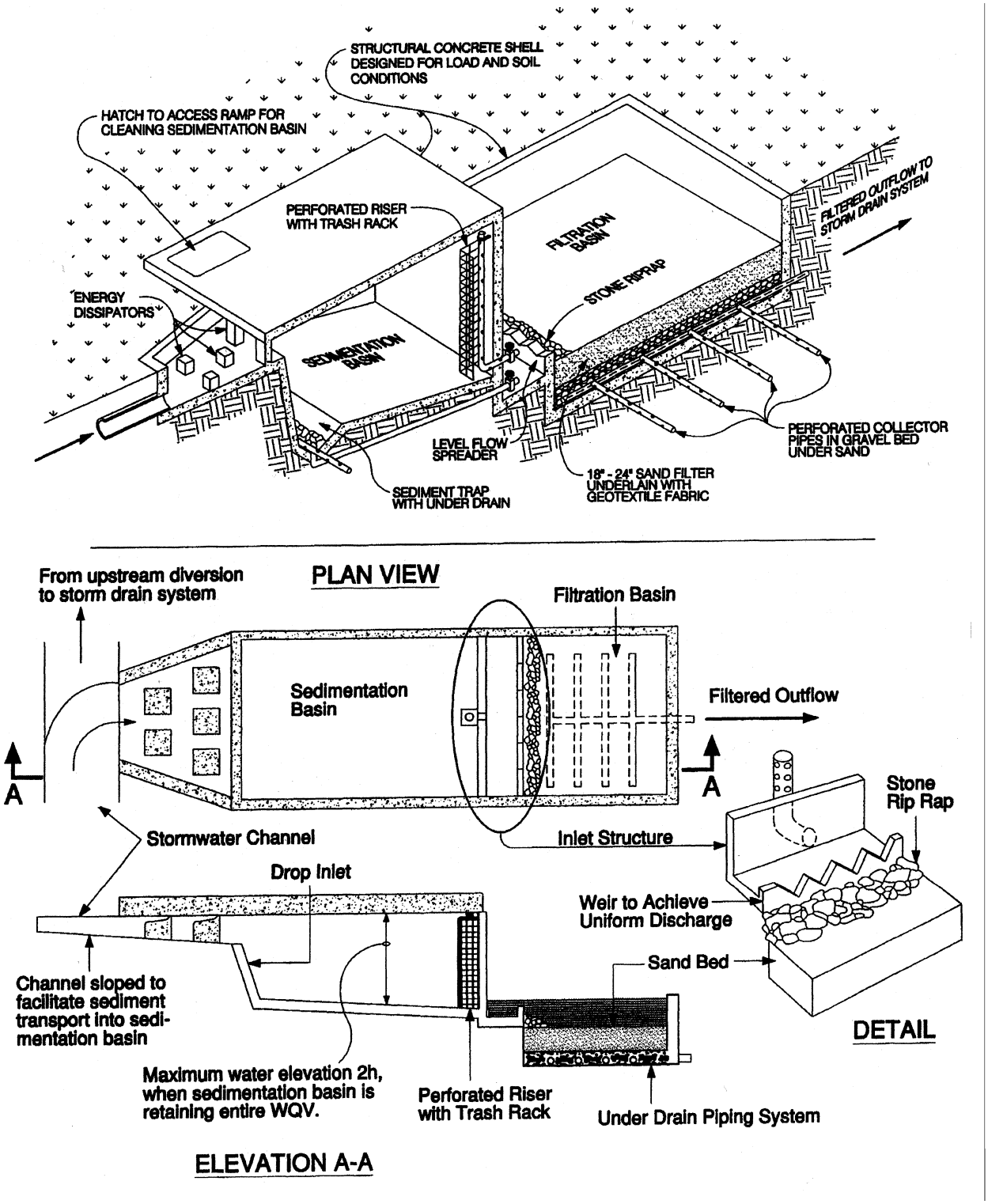


Figure TC-60. Conceptual Surface Sand Filter design (modified from Austin, 2003).

TC-61 UNDERGROUND SAND FILTER

Description

Also known as the D.C. or a Delaware sand filter, the underground sand filter is composed of three main chambers and is located underground. The underground sand filter is constructed of a bypass chamber, a sedimentation chamber, a flow distribution cell, and a sand filter bed. The purpose of the sedimentation chamber is to remove floatables and heavy sediments. The sand filter bed removes suspended sediments and associated pollutants such as fecal coliform bacteria, trace metals, and oil and grease from the stormwater runoff.

Applications and Advantages

Generally applicable for treating runoff from drainage areas containing a significant percentage of impervious area such as roadways, parking lots, commercial and industrial areas. Underground installation allows for placement under parking lots, sidewalks, and close to buildings. These filters are well adapted for locations with limited land area. Because the filter is located below grade, vandalism is not a concern and climate does not have a large impact on effectiveness.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	80 - 90
Total Phosphorus	45 - 55
Total Nitrogen	35 – 55
Oil and Grease	70 - 80
Total Recoverable Zinc	50 – 80
Total Recoverable Lead	60 - 80
Biochemical Oxygen Demand	60 - 80
Fecal Coliform Bacteria	40 - 80

Sources: UDFCD, 1999; FHWA, 2003.

Limitations

Standing water in the sediment chamber may provide mosquito habitat if access through manhole covers or other points of entry is available. Prevent vector entrance by covering the manhole covers and other points of entry.

Siting Criteria

- The D.C. type underground sand filter can be placed under roadways, parking lots, sidewalks or landscaped areas and can treat drainage areas of up to 1.5 acres.
- The Delaware type underground sand filter is typically placed along the perimeter of parking lots and can treat drainage areas of up to 5 acres.

- Issues of buoyancy must be considered in areas with high groundwater tables.
- Do not install in drainage areas with highly erodible or unstable soils.
- Design and Construction Criteria
- The following design criteria apply to both D.C. and Delaware type underground sand filters.
- Registered professional civil engineers should design underground sand filters.
- The locally available sand and gravel is typically washed with a high Ph, recycled wastewater. Sand and gravel must be rinsed with potable water prior to installation and construction of the sand filter.
- Design the structure to detain the WQ_V based on the method presented in **Section 6.3.2**.
- Flows in excess of the WQ_V should be diverted around the underground sand filter with an upstream diversion structure.
- Determine the maximum allowable depth of water in the underground sand filter (hmax) by considering the difference between the inlet and outlet invert elevations.
- The sand filter layer should consist of a minimum 16-inch gravel bed (dg) covered with a minimum 18-inch sand filter layer (ds) and a minimum 2-inch gravel layer above the sand filter layer. Geotextile fabric liners should be placed between the sand and gravel layers (e.g., above and below the sand layer).
- A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal should be installed between the sand filter and the gravel under drain.
- The top of the sand and gravel filter should not have any slope or grade.

For D.C. type underground sand filters, use Design-aid Worksheet TC-61(a) at www.TMstormwater.com and apply the following equations and the design criteria summarized in **Table TC-61A**.

The required sand filter basin surface area (A_f) can be determined using the following equation:

$$A_f = (WQ_V)(d_f)/k(h + d_f)t_f$$

Where: A_f = surface area of the filter basin in ft^2

WQ_V = water quality volume in ft^3

d_f = filter depth in ft. ($d_f = d_g + d_s$)

k = coefficient of permeability for the sand filter (typically 1.18 ft./hr. for clean, well graded sand with d_{10}=0.1 mm)

h = one half of the maximum allowable water depth (2h) over the filter bed in feet, $2h = (h_{max} – d_f)$

t_f = time required for the WQ_V to pass through the filter in hrs. (max = 48 hrs.)

- Considering site constraints, assume a filter width (Wf) and calculate the filter length (Lf) using: Lf = Af/Wf
- Determine the volume of storage available above the filer bed using Vtf = Af x 2h
- Compute the storage volume of the filter voids (Vv) by assuming a 40 percent void space and using:

  Vv = 0.4 x Af x df

- Compute the flow through the filter during filling assuming 1 hour to fill the voids using:

  Vq = kAf(df + h)tf / df (assume k = 0.0833 ft./hr. and tf = 1 hr)

- Compute net volume to be stored in the permanent pool awaiting filtration using:

  $Vst = WQ_V - Vtf - Vv - Vq$

- Compute the minimum length of the permanent pool using:

  Lpm = Vst/(2h)(Wf)

Table TC-61A. D.C. Type Underground Sand Filter Design Criteria.

Parameter	Design Criteria
Maximum drainage area	1.5 acres
Filter sand size	concrete sand per Sec. 200.05.04 SSPWC*
Typical sand coefficient of permeability (k) for sand with Dmax=10 mm and Effective Size D10=0.1 mm	1.18 ft/hr**
Maximum diameter of gravel in upper gravel layer	1 in, Class C backfill (Sec. 200.03.04 SSPWC*)
Diameter of gravel in under drain gravel layer	½ to 1 in, Class B or C backfill (Sec. 200.03.03 & 200.03.04 SSPWC*)
Minimum size of under drain pipes	6-in Schedule 40 PVC
Minimum size of perforations in under drain pipes	3/8-in diameter
Minimum number of perforations per under drain pipe	6
Minimum spacing of perforations	6 in
Maximum spacing of under drain pipes	27 in center to center
Minimum volume of sediment chamber	20 percent of the WQV
Minimum length of the clear well chamber	3 ft

*SSPWC
**USCOE, 2001 EM 1110-2-1100 Part VI

Inspection and Maintenance Requirements

- The life of a well-maintained underground sand filter is between 5 and 20 years.
- Upon installation, water levels should be monitored every 3 months and after each big storm for the first year. Once the system is functioning properly, monitor 3 times a year.
- Monitor and record the depth of oil and grease ponding in the first chamber, depth of water over the sand medium, and the amount of material accumulated over the sand medium.
- Pump out the sediment chamber at least twice every year. After cleaning, refill the first chamber to a depth of 3 feet with clean water to reestablish the seals.
- The filter cloth and ballast gravel must be removed and replaced when drawdown takes longer than 72 hours.
- The three chambers need built-in ladders and manholes to allow access for cleaning and maintenance. May require confined space entry.
- Filter media may need to be replaced every 3 to 5 years.

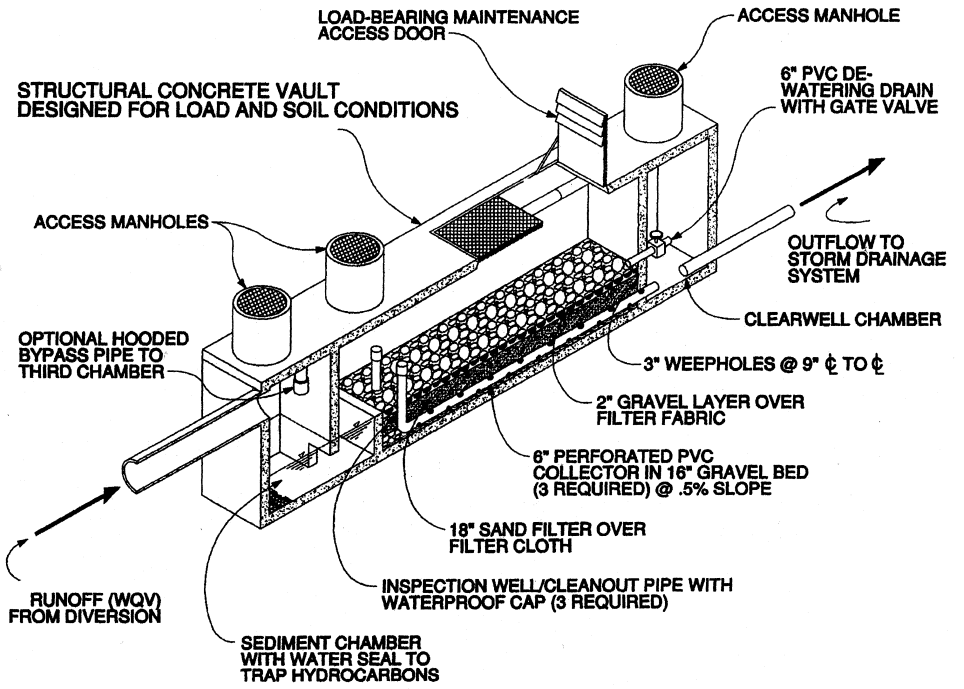
References

California Stormwater Quality Association (CASQA), 2003. California Stormwater Best Management Practice Handbook, New Development and Redevelopment.

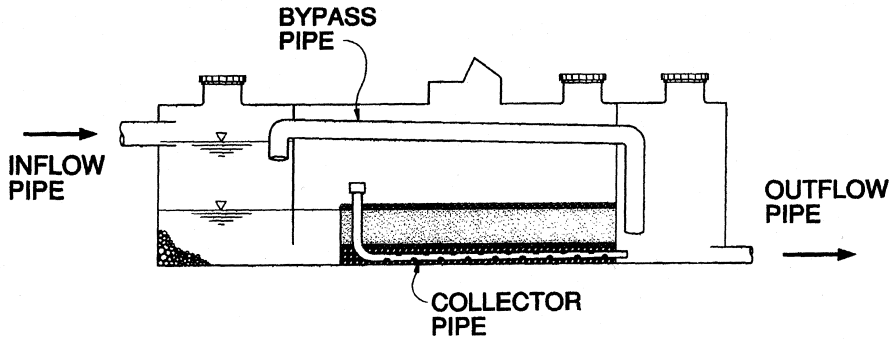
City and County of Sacramento, 2000. Guidance Manual for Onsite Stormwater Quality Control Measures, Sacramento Stormwater Management Program.

Urban Drainage and Flood Control District (UDFCD), 1999. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices. Denver, Colorado.

U.S. Department of Transportation, Federal Highway Administration, Stormwater Best Management Practices in an Ultra-Urban Setting: Selection and Monitoring, Fact Sheet – Underground Sand Filters, http://www.fhwa.dot.gov/environment/ultraurb/3fs7.htm



D.C. UNDERGROUND SAND FILTER SYSTEM



D.C. UNDERGROUND SAND FILTER HOODED BYPASS ILLUSTRATION

Figure TC-61A. Example of a D.C. type Underground Sand Filter (modified from Sacramento, 2000).

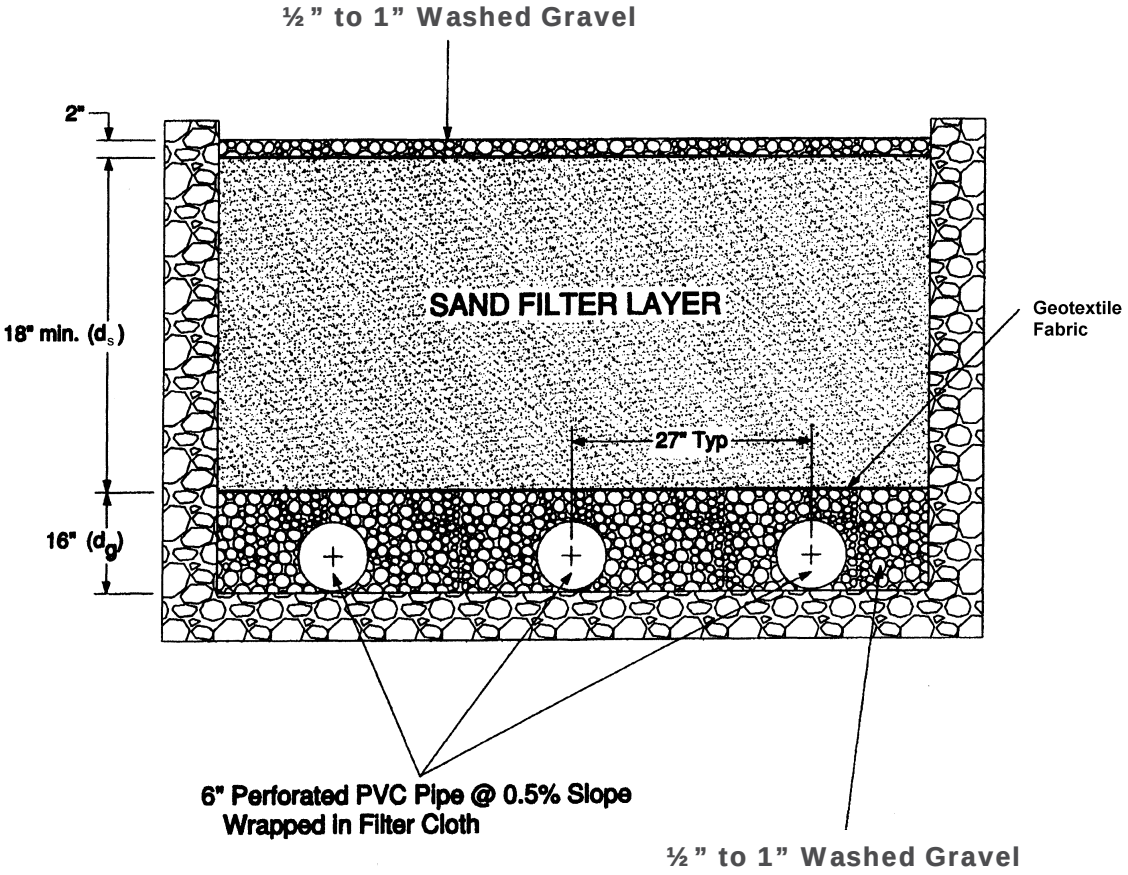


Figure TC-61B. Cross-section of a D.C. type Underground Sand Filter (modified from Sacramento, 2000).

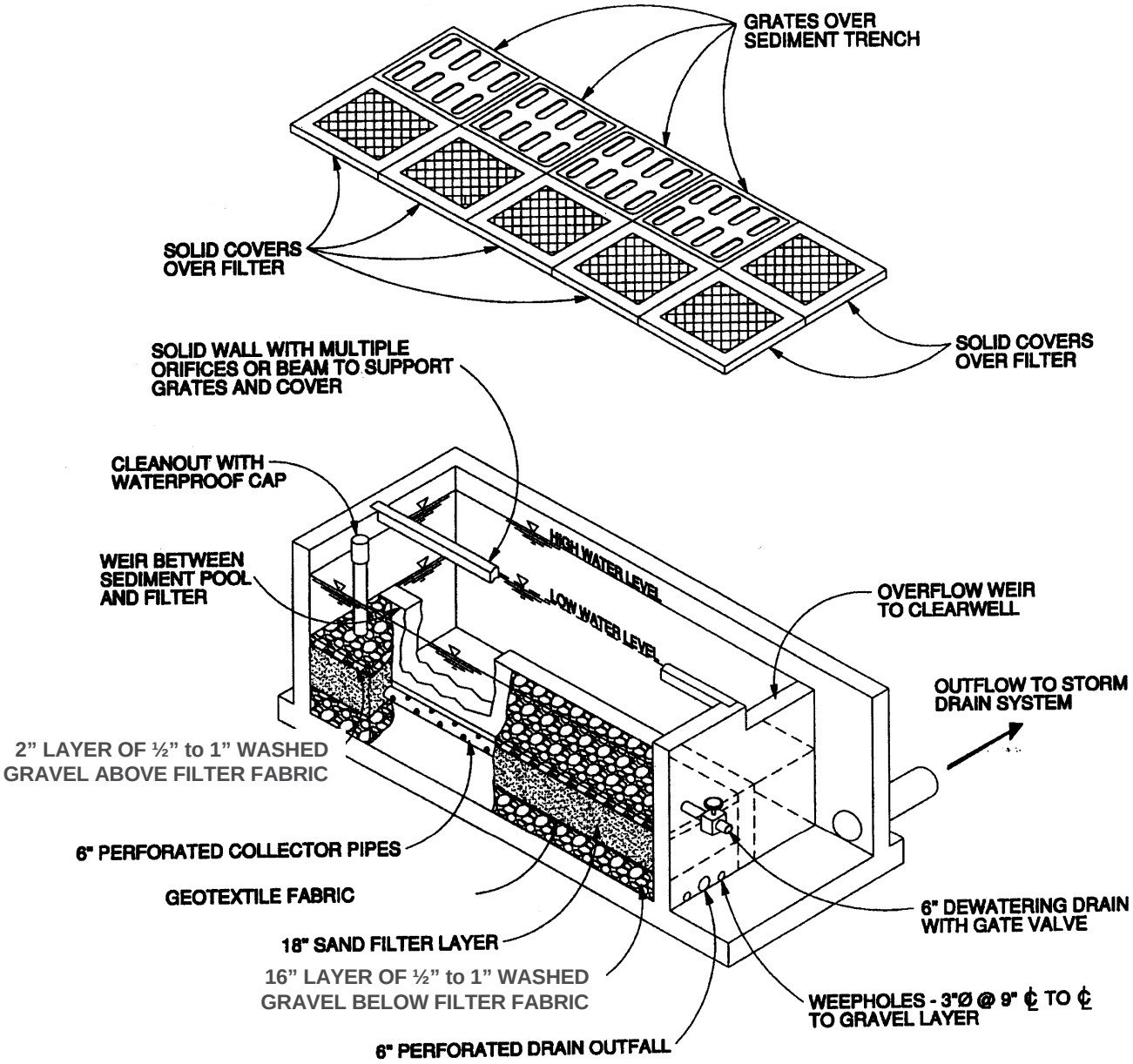
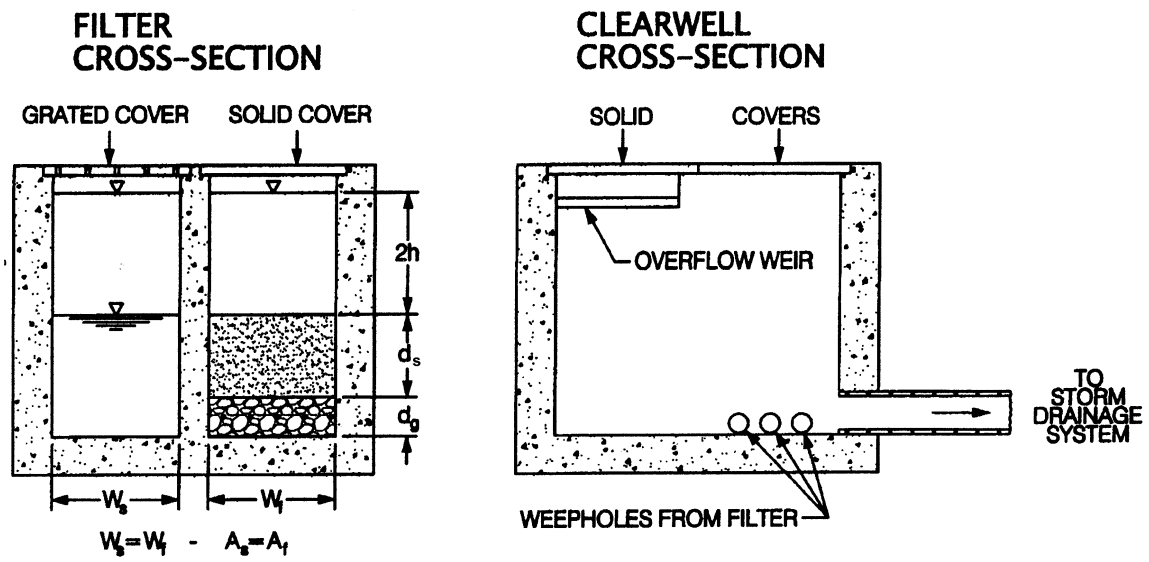


Figure TC-61C. Example of a Delaware type Underground Sand Filter (modified from Sacramento, 2000).



Where:
W_s = Width of sediment chamber
W_f = Width of filter
A_s = Area of sediment chamber
A_f = Area of filter
2h = Maximum achievable ponding depth over filter
d_s = Depth of sand
d_g = Depth of gravel underdrain

Figure TC-61D. Cross-sections of a Delaware type Underground Sand Filter showing dimensional relationships (modified from Sacramento, 2000).

TC-62 POROUS PAVEMENTS

Porous paving systems allow infiltration of stormwater while providing a stable load-bearing surface for walking and driving. These systems contain void spaces to provide infiltration of runoff into their underlying engineered porous materials and then into existing site soils. Generally, underlying engineered materials consist of clean sands or gravels separated from existing site soils by a synthetic filter fabric. Underlying engineered materials detain and filter pollutants prior to infiltration into underlying soils or discharge to a conventional storm drain system through an underdrain system. Porous paving systems can preserve natural drainage patterns, enhance groundwater recharge and soil moisture, and can help establish and maintain roadside vegetation. Although a good substitute for conventional concrete and asphalt, porous paving systems are typically not suitable for heavily trafficked applications. There are several different types of porous paving systems, which are referred to here as:

- TC-62A Porous Pavement Detention
- TC-62B Open Celled Block Pavers
- TC-62C Open Jointed Block Pavers
- TC-62D Porous Concrete and Asphalt
- TC-62E Porous Turf Pavement
- TC-62F Porous Gravel Pavement
- TC-62G Open Celled Plastic Grids

TC 62A - POROUS PAVEMENT DETENTION

Description

Porous pavement detention is an installation of open-celled block pavers (TC-62(b)) that is flat and is provided with a 2-inch deep surcharge zone to store temporarily the WQ_V. Open-celled block pavers consist of blocks or slabs made of concrete or brick with open surface voids that penetrate their surface area. The modular blocks are placed over a porous sub-base and the openings within and between the blocks are filled with pervious materials (e.g., open-graded aggregate). Porous materials such as clean gravels placed below the porous pavement detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system.

Applications and Advantages

Porous pavement detention can be used as a substitute for conventional pavement, but should be limited to parking areas and low traffic volume roadways where little to no truck traffic is anticipated. Examples include residential driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, emergency vehicle and fire access lanes, stopping lanes on divided highways, equipment storage areas, and patios.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	70 - 90
Total Phosphorus	40 - 55
Total Nitrogen	10 - 20
Total Zinc	40 - 80
Total Lead	60 - 70

Source: UDFCD, 1999.

Limitations

- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.
- Care must be taken when applying in commercial or industrial areas.
- May become clogged if not properly installed and maintained.
- Maintenance costs can be relatively high if the blocks frequently become clogged with sediment from offsite sources.
- Porous pavements may cause uneven driving surfaces and may be problematic for high heel shoes.
- May not be suitable for areas that require wheelchair access because of the pavement texture.
- Snow removal may be difficult, since plows may damage blocks if not installed correctly or performed above the block surface; sand application can result in clogging; and use of salt can result in groundwater contamination.
- Do not install sand or pavers during rain or heavy snowfall.
- Do not install over frozen base materials.

Siting Criteria

- Porous pavement detention installations should be installed in areas that are flat in all directions (i.e., 0% slope).
- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).
- The seasonal high water table should be more than 4 feet below the ground surface

Design and Construction Criteria

- Use Design-aid Worksheet TC-62(a) (www.TMstormwater.com)
- Registered professional civil engineers should design porous pavements.

- Calculate the WQ_V as discussed in **Section 6.3.2** to determine the minimum required surface area for the porous pavement detention:
- Minimum surface area = WQ_V /0.17ft
- Sub-base layers should be capable of bearing an appropriate load without deforming.
- Pervious pavements should be the last thing to install during construction or redevelopment.
- Block patterns should have a minimum surface area void space of 40 percent.
- Use an open-graded aggregate base course to provide a permeable reservoir. Class C backfill, as specified in Section 200.03.04 in SSPWC, is a locally available open-graded aggregate.
- When designing the base course, or base reservoir, to detain the WQ_V, select the appropriate porosity value for the material used.
- Strength and durability of materials under saturated conditions must be considered.
- When installing the base course, it must be compacted as it is placed in lifts.
- A bedding layer should be laid over the base course as level bedding for the blocks consisting of relatively small open-graded aggregate meeting criteria for a filter layer, or "choke layer". Class B backfill, as specified in Section 200.03.03 SSPWC, is recommended for this purpose.
- Appropriate gradations of aggregate material must be used to prevent migration of particles from one layer to the next. If this cannot be achieved, a woven geotextile should be used under the bedding layer above the base course to prevent migration. A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal can be used.
- For aggregate fill in the cells, material should consist of open-graded sand and can be the same material as the bedding material.
- An overflow, possibly with an inlet to a storm sewer, should be installed at 2 inches above the level of the porous pavement surface.
- A concrete perimeter wall should be installed to confine the edges of the block installation. The perimeter wall should be 6 inches thick and to extend 6 inches deeper than the base course, bedding layer, and block depth combined.
- Direct sediment-laden runoff away from the porous pavements.
- Filter fabrics should be placed on the bottom and sides of the sub-base layer.
- An impermeable liner should be installed under the base course to inhibit infiltration when installing over expansive soils or if the tributary area contains activities that store, manufacture, or handle fertilizers, chemicals, or petroleum products.
- To allow infiltration and prevent clogging, the filter fabric should be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- Follow pavement manufactures specifications.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.

- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.
- The storage capacity of the stone reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the WQ_V as discussed in **Section 6.3.2**.

Inspection and Maintenance Requirements

- Accumulated debris and litter removal as needed.
- Maintenance is required to prevent clogging of the pervious surface.
- Inspect sand filter routinely and after storm events to insure proper infiltration and drainage.
- Frequently inspect the pavement to insure proper infiltration and drainage during the first wet season, and then once a year following that time.
- Replacement of surface sand filter layer may occur when runoff does not infiltrate readily into the surface.
- Ensure that future slurry seals and overlays are not allowed over the porous pavement sections.

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Balades et al., 1995. Permeable Pavements: Pollution Management Tools, Water Science and Technology. Vol. 32, No. 1, pp. 49-56, 1995.

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Pratt et al., 1999. Mineral Oil Bio-Degradation within a Permeable Pavement: Long Term Observations, Water Science and Technology. Vol. 39, No. 2, pp. 103-109, 1999.

Urban Drainage and Flood Control District (UDFCD), 2005. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices.

TC-62B OPEN CELLED BLOCK PAVERS

Description

Open-celled block pavers, also known as modular block pavers, consist of blocks or slabs made of concrete or brick with open surface voids that penetrate their surface area. The modular blocks are placed over a porous sub-base and the openings within and between the blocks are filled with pervious materials (e.g., open-graded aggregate). Porous materials such as clean gravels placed below the porous pavement detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system. This type of surface reduces runoff from paved areas and the ponding that typically occurs in parking lots during and after storm events.

Applications and Advantages

Open-celled block pavers can be used as a substitute for conventional pavement, but should be limited to parking areas and low traffic volume roadways where little to no truck traffic is anticipated. Examples include residential driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, emergency vehicle and fire access lanes, stopping lanes on divided highways, equipment storage areas, and patios as well as alternative to conventional paving in areas where tree protection and preservation is a concern.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	70 - 90
Total Phosphorus	40 - 55
Total Nitrogen	10 - 20
Total Zinc	40 - 80
Total Lead	60 - 70

Source: UDFCD, 1999.

Limitations

- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.
- Care must be taken when applying in commercial or industrial areas.
- May become clogged if not properly installed and maintained.
- Maintenance costs can be relatively high if the blocks frequently become clogged with sediment from offsite sources.
- Porous pavements may cause uneven driving surfaces and may be problematic for high heel shoes.

- May not be suitable for areas that require wheelchair access because of the pavement texture.
- Snow removal may be difficult, since plows may damage blocks if not installed correctly or performed above the block surface; sand application can result in clogging; and use of salt can result in groundwater contamination.
- Do not install sand or pavers during rain or heavy snowfall.
- Do not install over frozen base materials.

Siting Criteria

- Ideally, pervious pavement should be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces (see **Figure TC-64 A**). However, they can also be placed on gentle slopes that do not exceed 5 percent.
- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).
- The seasonal high water table should be more than 4 feet below the ground surface

Design and Construction Criteria

- Use Design-aid Worksheet TC-62(b) (www.TMstormwater.com)
- Registered professional civil engineers should design porous pavements.
- Sub-base layers should be capable of bearing an appropriate load without deforming.
- Pervious pavements should be the last thing to install during construction or redevelopment.
- Block patterns should have a minimum surface area void space of 20 percent.
- Use an open-graded aggregate base course to provide a permeable reservoir. Class C backfill, as specified in Section 200.03.04 in SSPWC, is a locally available open-graded aggregate.
- When designing the base course, or base reservoir, to detain the WQ_V, select the appropriate porosity value for the material used.
- Strength and durability of materials under saturated conditions must be considered.
- When installing the base course, it must be compacted as it is placed in lifts.
- A bedding layer should be laid over the base course as level bedding for the blocks consisting of relatively small open-graded aggregate meeting criteria for a filter layer, or “choke layer”. Class B backfill, as specified in Section 200.03.03 SSPWC, is recommended for this purpose.
- Appropriate gradations of aggregate material must be used to prevent migration of particles from one layer to the next. If this cannot be achieved, a woven geotextile should be used under the bedding layer above the base course to prevent migration. A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal can be used.
- Open-celled block pavers are vibrated into place into the bedding layer.
- Filter fabrics should be placed on the bottom and sides of the base layer.

- An impermeable liner should be installed under the base course to inhibit infiltration when installing over expansive soils or if the tributary area contains activities that store, manufacture, or handle fertilizers, chemicals, or petroleum products.
- To allow infiltration and prevent clogging, the filter fabric should be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- Edge restraints should be installed on compacted subgrade or base material, not on the bedding.
- For aggregate fill in the cells, material should consist of open-graded sand and can be the same material as the bedding material.
- A concrete perimeter wall should be installed to confine the edges of the block installation. The perimeter wall should be 6-inches thick and to extend six inches deeper than the base course.
- Lateral-flow cut-off barriers should be installed using 16 mil or thicker PE or PVC impermeable membrane liner or concrete walls installed normal to flow. This prevents flow of water downstream resurfacing at the toe of the block installation.
- Distance between cut-off barriers shall not exceed:

$$L_{MAX} = D/(1.5*So)$$

Where, L_{MAX} = Max distance between cut-off barriers normal to flow (ft.)

D = Depth of the aggregate base course (ft./ft.)

S_o = Slope of the base course (ft.)

- An underdrain should be installed where impermeable liners are installed or when soils inhibit proper infiltration rates. Locate each underdrain pipe just upstream of the lateral-flow cut-off barrier.
- For rooting vegetation in the joints, planting medium should be sandy and open-graded. In bedding and base course, a limited amount of planting medium could be mixed into open-graded aggregate to deepen rooting.
- Plant grass in open-joints as plugs or broadcast seed at a reduced rate to account for concrete grids.
- All installations should be designed and constructed to pavement manufactures specifications.
- Follow pavement manufactures specifications.
- Direct sediment-laden runoff away from the porous pavements.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.
- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.
- The storage capacity of the base reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the WQ_V as discussed in **Section 6.3.2**.

Inspection and Maintenance Requirements

- Open-celled block pavers should not be washed to remove debris and sediment in the openings between pavers, rather sweeping with suction should be utilized annually. Replace lost sand infill.
- Joints between block pavers may require occasional weed suppression.
- Pavers can be removed individually and replaced when utility work is needed.
- Top course aggregate can be removed or replaced in pavers if they become clogged or contaminated.
- Replace surface filter layer by vacuuming out sand media from blocks when it becomes evident that runoff does not rapidly infiltrate into the surface.

For pavers planted with turf, regular turf maintenance will be necessary. However, pesticides, fertilizers and other chemicals can have adverse effects on concrete products, so their use should be restricted.

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TC-62C OPEN JOINTED BLOCK PAVERS

Description

Open-jointed block pavers consist of solid block units made of concrete, clay, or stone that form an interlocking, flexible pavement surface. Open voids are created, by beveling the corners of each block or creating wider spacing between the blocks. The blocks themselves also commonly contain small voids to increase permeability. The modular blocks are placed over a porous sub-base and the openings within and between the blocks are filled with pervious materials (e.g., clean sand). The pavers are placed on a gravel sub-grade to detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system. This type of surface reduces runoff from paved areas and the ponding that typically occurs in parking lots during and after storm events

Applications and Advantages

Open-jointed block pavers can be used as a substitute for conventional pavement, but should be limited to parking areas and low traffic volume roadways where little to no truck traffic is anticipated. Examples include residential driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, emergency vehicle and fire access lanes, stopping lanes on divided highways, equipment storage areas, and patios, as well as alternative to conventional paving in areas where tree protection and preservation is a concern.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	70 - 90
Total Phosphorus	40 - 55
Total Nitrogen	10 - 20
Total Zinc	40 - 80
Total Lead	60 - 70

Source: UDFCD, 1999.

Limitations

- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.
- Care must be taken when applying in commercial or industrial areas.
- Do not install sand or pavers during rain or heavy snowfall.
- Do not install over frozen base materials.
- May become clogged if not properly installed and maintained.
- Maintenance costs can be relatively high if the blocks frequently become clogged with sediment from offsite sources.

- Porous pavements may cause uneven driving surfaces and may be problematic for high heel shoes.
- May not be suitable for areas that require wheelchair access because of the pavement texture.
- Snow removal may be difficult, since plows may damage blocks if not installed correctly or performed above the block surface; sand application can result in clogging; and use of salt can result in groundwater contamination.

Siting Criteria

- Do not install pavers on slopes greater than 15 percent.
- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).
- The seasonal high water table should be more than 4 feet below the ground surface

Design and Construction Criteria

- Use Design-aid Worksheet TC-62(c) (www.TMstormwater.com)
- Registered professional civil engineers should design porous pavements.
- Sub-base layers should be capable of bearing an appropriate load without deforming.
- Pervious pavements should be the last thing to install during construction or redevelopment.
- Consult a qualified engineer, architect, and/or landscape architect for paver applications.
- To be installed by a qualified contractor experienced in paver applications.
- Block patterns should have a minimum surface area void space of 8 percent.
- Use an open-graded aggregate base course to provide a permeable reservoir. Class C backfill, as specified in Section 200.03.04 in SSPWC, is a locally available open-graded aggregate.
- When designing the base course, or base reservoir, to detain the WQ_V, select the appropriate porosity value for the material used.
- Strength and durability of materials under saturated conditions must be considered.
- When installing the base course, it must be placed and compacted in maximum 12-inch thick lifts.
- A bedding layer should be laid over the base course as level bedding for the blocks consisting of relatively small open-graded aggregate meeting criteria for a filter layer, or “choke layer”. Class B backfill, as specified in Section 200.03.03 SSPWC, is recommended for this purpose.
- Do not use concrete sand, which is traditionally used for interlocking concrete pavement bedding layer construction and has been shown to have low permeability.
- Appropriate gradations of aggregate material must be used to prevent migration of particles from one layer to the next. If this cannot be achieved, a geotextile should be used under the bedding layer above the base course to prevent migration.

- Filter fabrics should be placed on the bottom and sides of the base layer.
- Impermeable liner should be installed under the base course to inhibit infiltration when installing over expansive soils or if the tributary area contains activities that store, manufacture, or handle fertilizers, chemicals, or petroleum products.
- To allow infiltration and prevent clogging, the filter fabric should be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- Edge restraints are required around the perimeter and should be installed on compacted subgrade or base material, not on the bedding.
- Joint-fill material should consist of Class D backfill, Section 200.03.04 SSPWC.
- Do not sweep sand into the joints after the pavers are installed to fill joints as this can compromise the permeability and porosity of pavers.
- A concrete perimeter wall should be installed to confine the edges of the block installation. The perimeter wall should be 6-inches thick and to extend six inches deeper than the base course.
- Lateral-flow cut-off barriers should be installed using a 16 mil or thicker PE or PVC impermeable membrane liner or concrete walls installed normal to flow. This prevents flow of water downstream resurfacing at the toe of the block installation.
- Distance between cut-off barriers shall not exceed:

$$L_{MAX} = D/(1.5*S_o)$$

Where, L_{MAX} = Max distance between cut-off barriers normal to flow (ft.)

D = Depth of the aggregate base course (ft./ft.)

S_o = Slope of the base course (ft.)

- An underdrain should be installed where impermeable liners are installed or when soils inhibit proper infiltration rates. Locate each underdrain pipe just upstream of the lateral-flow cut-off barrier.
- For rooting vegetation in the joints, planting medium should be sandy and open-graded. In bedding and base course, a limited amount of planting medium could be mixed into open-graded aggregate to deepen rooting.
- Cut pavers with a paver splitter or masonry saw. Cut pavers should be no smaller than one-third of the full unit size along edges subject to vehicular traffic.
- All installations should be designed and constructed to pavement manufactures specifications.
- Direct sediment-laden runoff away from the porous pavements.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.
- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.

- The storage capacity of the base reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the WQ_V as discussed in **Section 6.3.2**.

Inspection and Maintenance Requirements

- Blocks should not be washed to remove debris and sediment in the openings between pavers, rather sweeping with suction should be utilized annually. Replace lost sand infill.
- Joints between pavers may require occasional weed suppression.
- Pavers can be removed individually and replaced when utility work is needed.
- Replace surface filter layer by vacuuming out sand media from blocks when it becomes evident that runoff does not rapidly infiltrate into the surface. If vacuuming does not adequately remove fill, blocks can be lifted and reset with new joint fill material.
- If soils swell or subside, blocks can be removed individually, the base leveled, and blocks reset.

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TC-62D POROUS CONCRETE AND ASPHALT

Description

Porous concrete and asphalt both make a continuous, smooth paving surface like their impervious counterparts. However, they are made by binding open-graded aggregate, and therefore contain void spaces that allow water to pass through to a permeable subbase layer. Porous materials such as clean gravels placed below the porous concrete or asphalt detain and filter pollutants prior to infiltration into the underlying soils or discharge to an underdrain and the conventional storm drain system.

Applications and Advantages

Porous concrete and asphalt are ideal for light to medium duty applications such as residential access roads, residential street parking lanes, parking lot stalls in parking lots, overflow parking areas, utility access, sidewalks, bike paths, maintenance walkways/trails, residential driveways, stopping lanes on divided highways, and patios. Porous asphalt has, however, also been used in heavy applications such as airport runways and highways because its porosity creates a favorable driving surface in rainy weather (BASMAA, 1999).

Porous concrete and asphalt can also reduce icing hazards during winter freeze and thaw cycles as runoff will tend to infiltrate rather than freeze onto the surface of roadways, parking lots, driveways and sidewalks.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	70 - 90
Total Phosphorus	40 - 55
Total Nitrogen	10 - 20
Total Zinc	40 - 80
Total Lead	60 - 70

Source: UDFCD, 1999

Limitations

- Typically not to be applied on streets where speeds exceed 30 mph or streets that experience high-traffic loads.
- Not recommended for slopes over 5 percent.
- Not applicable where the seasonal high groundwater table is less than 3 feet below the bottom of the gravel sub-base.
- Sand and salt applied to porous roadways, parking lots, and sidewalks in winter can clog void spaces and render permeability ineffective if not removed annually.
- Porous concrete may experience raveling if not properly installed.

- Porous asphalt and concrete may become clogged if not protected from nearby construction activities, areas of bare soil without landscaping, downslope of steep, erosion-prone areas, or when not maintained.
- Applications with underdrain systems are typically more expensive than conventional asphalt and concrete.
- Porous asphalt and concrete should be avoided in drainage areas with activities generate highly contaminated runoff.
- Not to be applied in areas where wind erosion supplies significant amounts of windblown sediments.

Siting Criteria

- Ideally, pervious pavement should be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces (see **Figure TC-64A**). However, they can also be placed on gentle slopes that do not exceed 5 percent.
- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).
- The seasonal high water table should be more than 3 feet below the bottom of the gravel sub-base.

Design and Construction Criteria

- Use Design-aid Worksheet TC-62(d) (www.TMstormwater.com)
- Registered professional civil engineers should design porous pavements
- Avoid installing in high traffic areas.
- Slopes should be flat or very gentle (less than 5 percent).
- Pretreatment recommended treating runoff from surrounding areas.
- Filter fabric should be placed on the bottom and sides of the subbase reservoir.
- Impermeable liner should be installed under the base course to inhibit infiltration when installing over expansive soils or if the tributary area contains activities that store, manufacture, or handle fertilizers, chemicals, or petroleum products.
- To allow infiltration and prevent clogging, the filter fabric should be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- Use an open-graded aggregate to provide open voids in the gravel subbase.
- Erosion and sediment introduction from surrounding areas must be strictly controlled during and after construction to prevent clogging of void spaces in base material and permeable surface.
- Install porous asphalt and concrete towards the end of construction activities to minimize sediment problems.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.
- During emplacement of porous concrete, boards should be used to separate individual pours and to produce uniform seams between adjacent pours.

- The surface of each pour should be finished as soon as possible as porous concrete can set up very rapidly in our local arid environment.
- Overall project cost savings can be realized where porous asphalt or concrete is installed in well-draining soils (e.g., infiltration rates of 0.5 in/hr (120 min/in) or greater), and conventional storm drainpipes and catch basins can be reduced.

Inspection and Maintenance Requirements

- The overall maintenance goal is to avoid clogging of the void spaces.
- Accumulated debris and litter should be routinely removed as a source control measure.
- Inspect porous asphalt and concrete several times during the first few storms to insure proper infiltration and drainage. After the first year, inspect at least once a year.
- Permeable pavements and materials should be cleaned with a vacuum-type street cleaner a minimum of twice a year (before and after the winter).
- Hand held pressure washers can be effective for cleaning the void spaces of small areas and should follow vacuum cleaning.
- Maintenance personnel must be instructed not to seal or pave with non-porous materials.
- In winter, avoid using traction abrasives or snow melting salts to prevent clogging void spaces and degrading the concrete.
- Snowplows should be equipped with plastic skids to prevent damaging the porous concrete surface.
- Ensure that future slurry seals and overlays are not allowed over the porous pavement sections.

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TC-62E POROUS TURF PAVEMENT

Description

Porous turf pavement is a stabilized grass surface that can support intermittent pedestrian or vehicular traffic, underlain by an open-graded (single-sized) sandy root zone, and a permeable aggregate base course. Porous turf pavement applications should be applied when the appearance of grass is desired, but a load bearing capability of a pavement surface is needed. The turf surface can be either reinforced or unreinforced, with reinforced turf containing synthetic reinforcement that assists the turf in resisting wear and compaction, allowing it to bear a heavier traffic load. Advantages of porous turf pavement include the appearance of a "green space" when not used for parking, as well as the benefit of a living surface which actively cools by transpiration counteracting the urban heat island effect (Ferguson, 2005).

Applications and Advantages

Porous turf pavement is suitable for any area that desire turf application and for parking areas with frequencies of up to once per week. Ideal settings are sports fields, overflow parking areas, church and football stadium parking lots, event parking, roadway shoulders, parking lanes, crossover lanes on divided highways, flea market parking, and maintenance roads and trails. The suitable application of these porous turf pavement applications for parking lots would be to have the vehicle movement lanes leading up to the porous turf constructed of another type of material such as porous concrete or asphalt pavement (i.e. porous turf parking pads with porous concrete or asphalt lanes). This reduces grass wear from excessive traffic on the porous turf surface, decreasing the porosity and increasing maintenance. Porous turf applications can also be multiuse facilities, for example a sports field that also serves as a special event parking lot.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	70 - 90
Total Phosphorus	40 - 55
Total Nitrogen	10 - 20
Total Zinc	40 - 80
Total Lead	60 - 70

Source: UDFCD, 1999.

Limitations

- Not to be applied in heavily trafficked areas, grass wear can result.
- Until grass is established, surface cannot be used.
- Requires supplemental irrigation.

- A uniformly graded vegetative cover is required to function properly.
- Excessive traffic can cause soil compaction and reduce infiltration.
- Weed invasion can result from thinning of grass cover.
- Turning action of vehicles can be problematic for porous turf, damaging structure of the leaves and sometimes causing root damage.
- May be problematic for high-heeled shoes. Smooth-soled shoes can slip on wet grass.
- Grass species should be selected based on wear tolerance and irrigation needs for specific site conditions.
- Grass selection, traffic control, and good maintenance for health and vigor are all important for turf grass wear prevention and recovery.

Siting Criteria

- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).
- The seasonal high water table should be more than 4 feet below the ground surface.
- Must be installed only in settings where they will be free of traffic on a predictable schedule for maintenance.

Design and Construction Criteria

- Use Design-aid Worksheet TC-62(e) (www.TMstormwater.com)
- Registered professional civil engineers should design porous pavements.
- Sub-base layers should be capable of bearing an appropriate load without deforming.
- Pervious pavements should be the last thing to install during construction or redevelopment.
- When designing the sub-base reservoir to detain the WQ_V, select the appropriate porosity value for the sub-base material used.
- Direct sediment-laden runoff away from the porous pavements.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.
- The surface course, or root zone, should consist of an aggregate meeting the gradation requirements from Section 200.05.04 of SSPWC.
- The sandy root zone should have a thickness of 12 inches.
- A permeable aggregate base course should be constructed of Class C or Class B backfill, Section 200.03.03 and Section 200.03.04 SSPWC.
- If Class C backfill is used, a woven filter fabric should be installed between the root zone and the aggregate base course.
- To allow infiltration and prevent clogging, the filter fabric should be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- The aggregate base course should be at least several inches thick.

- The storage capacity of the open-graded aggregate base course depends upon local detention requirements and can be sized to capture, detain and filter the WQ_V as discussed in **Section 6.3.2**.
- If needed, a filter fabric or a filter layer of coarse sand 2 to 4 inches in depth can be installed between the root zone and aggregate base course.
- An impermeable liner is required under the base course when installing over expansive soils or if the tributary may have activities that store, manufacture, or handle fertilizers, chemical, or petroleum products.
- Underdrains are required for installations over NRCS type C or D soils with infiltration rates of 0.5 in/hr (120 min/in) or less or when an impermeable membrane liner is needed.
- Turf should be installed by laying sod, seeding, or sprigging. Root zone material should be tested by a qualified lab and soil treated with appropriate lime or fertilizer as recommended for establishment success.
- Proprietary meshes, mats, and fibers are available for reinforcing turf root zones.
- Turf can also be installed in open-celled grids or pavers.
- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.
- Allow turf at least one full growing season to establish before use.
- If seeding, seed in the fall or early spring to avoid heat stress.

Inspection and Maintenance Requirements

- Porous turf requires regular maintenance associated with regular lawns such as irrigation, mowing, fertilization, aeration, topdressing, over seeding, disease control, insect control, and weed management.
- Soil testing should be conducted at least once every other year to determine proper fertilization, which will help to maintain turf stress tolerance.
- Routine mowing will be required in the growing season.
- Above ground biomass is important in wear tolerance, therefore high mowing can increase a grasses resistance to traffic stress. Mowing patters should also be altered regularly to limit wear from repetitive wheel action.
- Reseeding may be required to maintain a uniform turf cover.
- Topdressing material should be at least as coarse and open-graded as the root zone.
- To aid in water conservation, irrigation operations should be scheduled as follows:
    - After the ground has thawed, or in the month of March – two deep waterings
    - As the weather begins to warm in April and May – once per week
    - In June, July and August – up to twice per week
    - As the weather begins to cool in September – cut back to deep watering once a week, then once every two weeks
    - Do not water from November to March while lawn is dormant!

    - Water in the early morning during the summer to reduce water lost to evaporation and spray drift caused by wind.
- Traffic routes can be spread out or rotated to give the turf time to recover between uses. Traffic control can also divert traffic away from areas that are showing signs of wear.
- Snow removal operations can damage turf surfaces. Equip snowplow blades with skids or rollers to keep the plow surface one or two inches above the turf surface.

References

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TC-62F POROUS GRAVEL PAVEMENT

Description

Porous gravel pavement, or crushed aggregate, consists of a loose gravel-surface paving placed over a porous sub-base. Porous materials such as clean gravels placed below the porous pavement detain and filter pollutants prior to infiltration into underlying soils or discharge to drainage to a conventional storm drain system. This type of pavement reduces runoff from paved areas and the ponding that typically occurs in parking lots during and after storm events.

Application

Porous gravel pavement can be used as a substitute for conventional pavement. It is most appropriate for industrial sites and uses such as storage yards or for vehicle parking. Other examples include residential driveways, residential street parking, low vehicle movement zones such as parking lots and maintenance roads, maintenance walkways/trails, and stopping lanes on divided highways.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	70 - 90
Total Phosphorus	40 - 55
Total Nitrogen	10 - 20
Total Zinc	40 - 80
Total Lead	60 - 70

Source: UDFCD, 1999.

Limitations

- Not to be applied in heavily trafficked areas or where speeds exceed 30 miles per hour.
- Care must be taken when applying in commercial or industrial areas.
- May become clogged if not properly installed and maintained.
- Porous pavements may cause uneven driving surfaces and may be problematic for high heel shoes.

Siting Criteria

- Ideally, pervious gravel pavement should be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces (see **Figure TC-64A**). However, they can also be placed on gentle slopes that do not exceed 5 percent.
- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).

- The seasonal high water table should be more than 4 feet below the ground surface.

Design and Construction Criteria

- Use Design-aid Worksheet TC-62(f) (www.TMstormwater.com)
- Registered professional civil engineers should design porous pavements.
- Sub-base layers should be capable of bearing an appropriate load without deforming.
- Pervious pavements should be the last thing to install during construction or redevelopment.
- Use a single size grading to provide open voids between sand or gravel sub-bases.
- When designing the sub-base reservoir to detain the WQ_V, select the appropriate porosity value for the sub-base material used.
- Direct sediment-laden runoff away from the porous pavements.
- Thickness of porous gravel layer should be designed to support the traffic and vehicle loads pavement will need to carry.
- Filter fabrics should be placed on the bottom and sides of the sub-base layer.
- An impermeable liner is required under the base course when installing over expansive soils or if the tributary may have activities that store, manufacture, or handle fertilizers, chemical, or petroleum products.
- To allow infiltration and prevent clogging, the filter fabric should be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- Lateral-flow cut-off barriers should be installed using a 16 mil or thicker PE or PVC impermeable membrane liner or concrete walls installed normal to flow. This prevents flow of water downstream resurfacing at the toe of the block installation.
- Distance between cut-off barriers shall not exceed:

  $$LMAX = D/(1.5*So)$$

  Where, LMAX = Max distance between cut-off barriers normal to flow (ft.)

  D = Depth of the aggregate base course (ft./ft.)

  So = Slope of the base course (ft.)
- Underdrains are required for installations over NRCS type D soils or when an impermeable membrane liner is needed. Locate each underdrain pipe just upstream of the lateral-flow cut-off barrier.
- A sand filter layer is required for installations over expansive soils or when underdrains are required.
- A woven geotextile fabric layer such as SI Corporation Geotex 117F or equal should be placed on top of and below the sand filter layer.
- During construction, do not allow construction or heavy vehicles to traverse excavated recharge beds or areas of completed porous pavement.

- Once porous pavement is in place, ensure contributing drainage areas of the construction site have erosion and sediment control measures in place and are maintained until the site is stabilized.
- The storage capacity of the stone reservoir beneath porous pavements depends upon local detention requirements and can be sized to capture, detain and filter the WQ_V as discussed in **Section 6.3.2**.

Inspection and Maintenance Requirements

- Accumulated debris and litter removal as needed.
- Maintenance is required to prevent clogging of the pervious surface.
- Occasional weed suppression may be required.
- Periodic replenishing and/or raking of displaced gravel may be required.
- Inspect sand filter routinely and after storm events to insure proper infiltration and drainage.
- Frequently inspect the pavement to insure proper infiltration and drainage during the first wet season, and then once a year following that time.
- Replacement of surface sand filter layer may occur when runoff does not infiltrate readily into the surface.
- Inspect surface gravels once a year. When inspections show accumulation of sediment and debris on top of gravel or slow infiltration, remove and replace top few inches of gravel.

References

Balades et al., 1995. Permeable Pavements: Pollution Management Tools, Water Science and Technology. Vol. 32, No. 1, pp. 49-56, 1995.

California Stormwater Quality Association (CASQA), 2003. Stormwater Best Management Practice Handbook – New Development and Redevelopment.

City and County of Sacramento, 2000. Guidance Manual for Onsite Stormwater Quality Control Measures.

Legret and Colandini, 1999. Effects of a Porous Pavement with Reservoir Structure on Runoff Water: Water Quality and Fate of Heavy Metals, Water Science and Technology. Vol. 39, No. 2, pp. 111-117, 1999.

Newman et al., 2002. Oil Bio-Degradation in Permeable Pavements by Microbial Communities, Water Science and Technology. Vol. 45, No. 7, pp. 51-56, 2002.

Pratt et al., 1999. Mineral Oil Bio-Degradation within a Permeable Pavement: Long Term Observations, Water Science and Technology. Vol. 39, No. 2, pp. 103-109, 1999.

Urban Drainage and Flood Control District (UDFCD), 1999. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices.

TC-62G OPEN CELLED PLASTIC GRIDS

Description

Open-celled plastic grids, also known as geocells, are manufactured plastic lattices that can be filled with aggregate or topsoil and planted with turf. Many of these systems are made from recycled plastics. The grid systems contain hollow rings or hexagonal cells from 1 to 2 inches thick and a few inches wide. Since the cells occupy very little surface area in most systems, they appear as a turf or gravel surface. Some models are also joined at the bottom by either a perforated plastic sheet or geotextile fused to the bottom of the grid that is placed on the underlying base course. It is important that this area is open for rooting of grasses. Most open-celled grid systems are flexible, so they are tolerant of swelling or freezing soils and are applicable on uneven sites.

Applications and Advantages

Open-celled grids should be limited to low intensity use and areas with low traffic speeds. Examples include driveways, residential street parking lanes, parking stalls in commercial or retail parking lots, overflow parking areas, maintenance walkways/trails, utility access, ATV and off-road bike trails, golf cart paths, emergency vehicle and fire access lanes, loading areas, and alleys.

Performance Data

The literature reported range of removal for various pollutants is as follows:

Pollutant	Percent Removal Efficiency
Total Suspended Solids	70 - 90
Total Phosphorus	40 - 55
Total Nitrogen	10 - 20
Total Zinc	40 - 80
Total Lead	60 - 70

Source: UDFCD, 1999.

Limitations

- Sharp turning on grids should be avoided.
- May be problematic for high-heeled shoes.
- Irrigation of porous turf installation in open-celled grids has the potential to require heavier irrigation than normal due to the low water holding capacity of the soil in grids.
- Slopes should not exceed 5%.
- Not to be applied in heavily trafficked areas or where speeds exceed 20 miles per hour.

Siting Criteria

- Ideally, pervious pavement should be installed on flat surfaces adjacent to gently sloping conventional pavement surfaces (see **Figure TC-64A**). However, they can also be placed on gentle slopes that do not exceed 5 percent.
- Do not use in areas where the potential for spills is high (e.g., near service/gas stations, truck stops or industrial sites).
- The seasonal high water table should be more than 4 feet below the ground surface.

Design and Construction Criteria

- Use Design-aid Worksheet TC-62(g) (www.TMstormwater.com)
- Registered professional civil engineers should design porous pavements.
- Sub-base layers should be capable of bearing an appropriate load without deforming.
- Pervious pavements should be the last thing to install during construction or redevelopment.
- An open-graded permeable base course should be constructed according to manufacturers' specifications.
- The storage capacity of the open-graded aggregate base course depends upon local detention requirements and can be sized to capture, detain and filter the WQ_V as discussed in **Section 6.3.2**.
- Lattices come in pre-assembled panels or rolls in various dimensions, from a few square feet to rolls that can be spread out to cover large areas.
- Grids need to be anchored to the base in some applications, depending on the model, to prevent being jarred by moving traffic. Anchors may consist of plastic spikes, pins, or rods, or even boulders, logs, or wheel stops over the surface.
- A setting bed of smaller aggregate may be needed over the base course to make a uniform surface for the open-celled grids.
- Woven filter fabrics should be placed on the bottom and sides of the base course layer.
- An impermeable liner is required under the base course when installing over expansive soils or if the tributary may have activities that store, manufacture, or handle fertilizers, chemical, or petroleum products.
- To allow infiltration and prevent clogging, the filter fabric should be woven geotextile fabric layer such as SI Corporation Geotex 117F or an approved equivalent.
- Underdrains are required for installations over NRCS type D soils or when an impermeable membrane liner is needed.

For Open-Celled Grids filled with Aggregate

- Aggregate fill must be open-graded aggregate, with common installation sizes being Class B backfill, Section 200.03.03 SSPWC.
- Aggregate is compacted into place with a vibrating plate or roller.
- Follow manufacturer's specifications for top course installation.

For Open-Celled Plastic Grids planted with Turf

- The planting medium should be settled into cells by vibrating or watering.
- The planting medium should consist of open-graded fine aggregate conforming to SSPWC Section 200.05.04.
- Sod should only be installed with thin-walled grid systems.
- Sod can be installed by pressing into empty cells. Sod should be cut to a depth of the grid system.
- Anchoring may protect growing grass roots and promote deeper rooting, which will add strength to pavement structure.
- If filter fabric is needed on top of the base course, instead an open-graded aggregate filter layer may be used.
- Traffic should not be allowed on the surface until after turf is established.

Inspection and Maintenance Requirements

- Equip snowplow blades with skids or rollers to keep the plow surface one or two inches above the surface.
- Sections can be removed and replaced for utility access and pavement repair.
- Remove and replace grid segments where three or more adjacent rings are broken or damaged.

For Open-Celled Plastic Grids filled with aggregate

- Accumulated debris and litter removal as needed.
- Maintenance is required to prevent clogging of the pervious surface.
- Occasional weed suppression may be required.
- Periodic replenishing and/or raking of displaced gravel may be required.
- Inspect surface gravels once a year. When inspections show accumulation of sediment and debris on top of gravel or slow infiltration, remove and replace top few inches of gravel.

For Open-Celled Plastic Grids planted with turf

- For open-celled grids filled with turf, mechanical aeration of must be avoided, as this can damage the plastic material.

See maintenance requirements for TC-62(e) Porous Turf.

References

Ferguson, B. 2005. Porous Pavements. Boca Raton, FL: CRC Press.

Hun-Dorris, T. 2005. Advances in Porous Pavements. Stormwater, March/April, volume 6(2). http://www.forester.net/sw_0503_toc.html

Puget Sound Action Team. LID Technical Guidance Manual for the Puget Sound.

Urban Drainage and Flood Control District (UDFCD), 2005. Urban Storm Drainage Criteria Manual, Volume 3 – Best Management Practices.

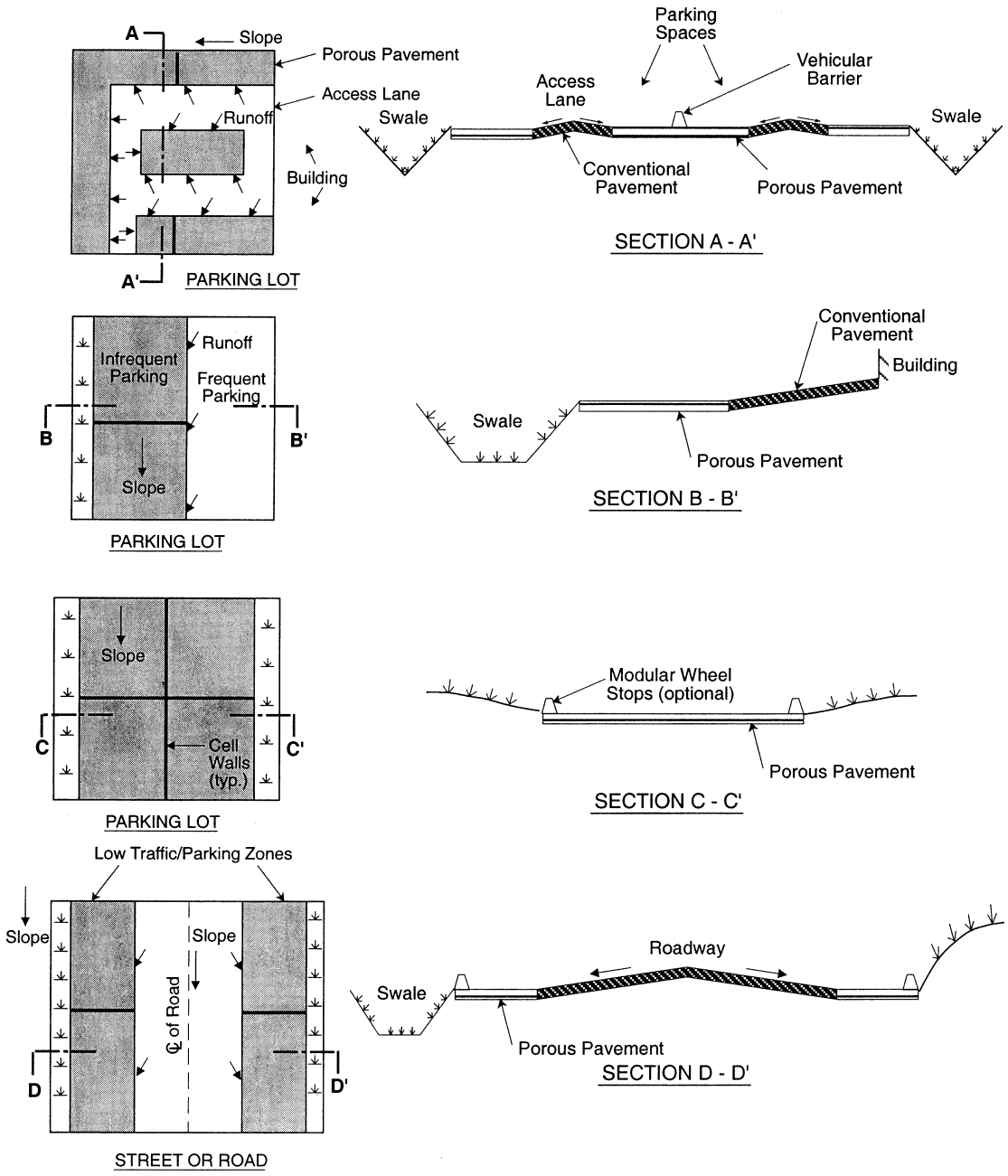


Figure TC-64A. Typical roadway applications for Porous Pavement (modified from UDFCD, 2005).

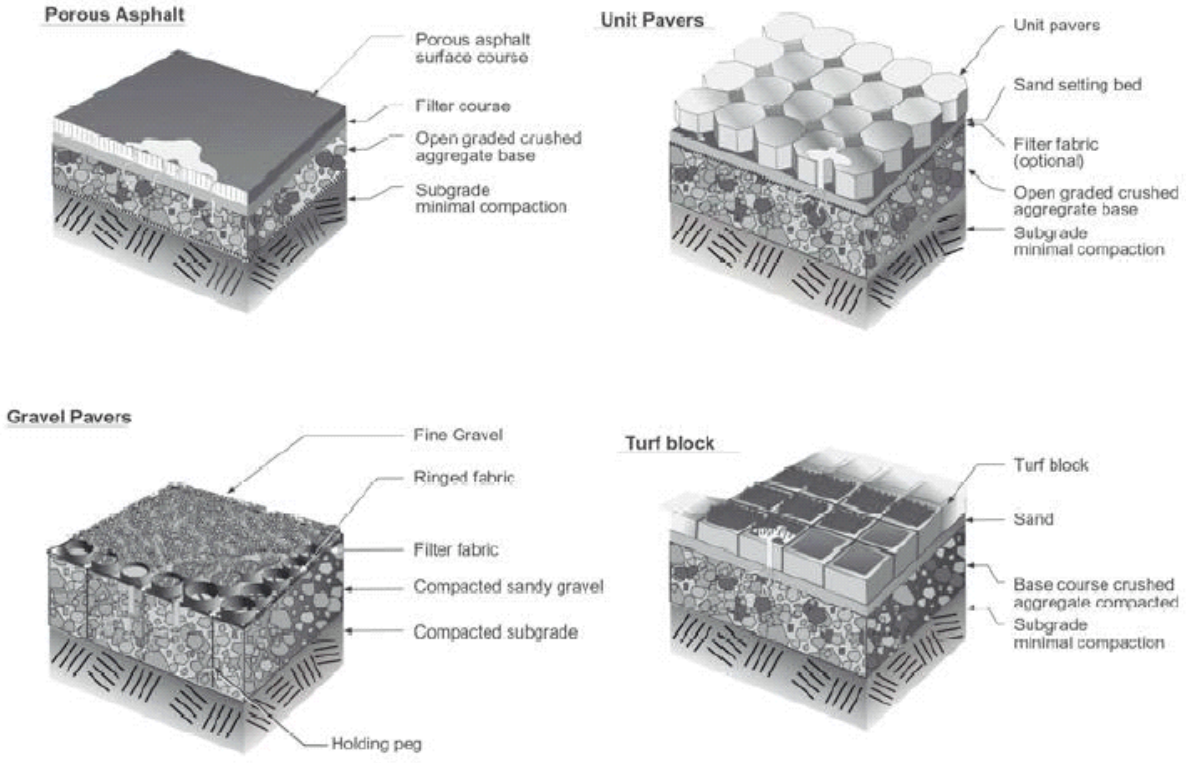


Figure TC-64B. Cross-section of typical porous pavement installation and different types of porous pavement (from Sacramento, 2000).

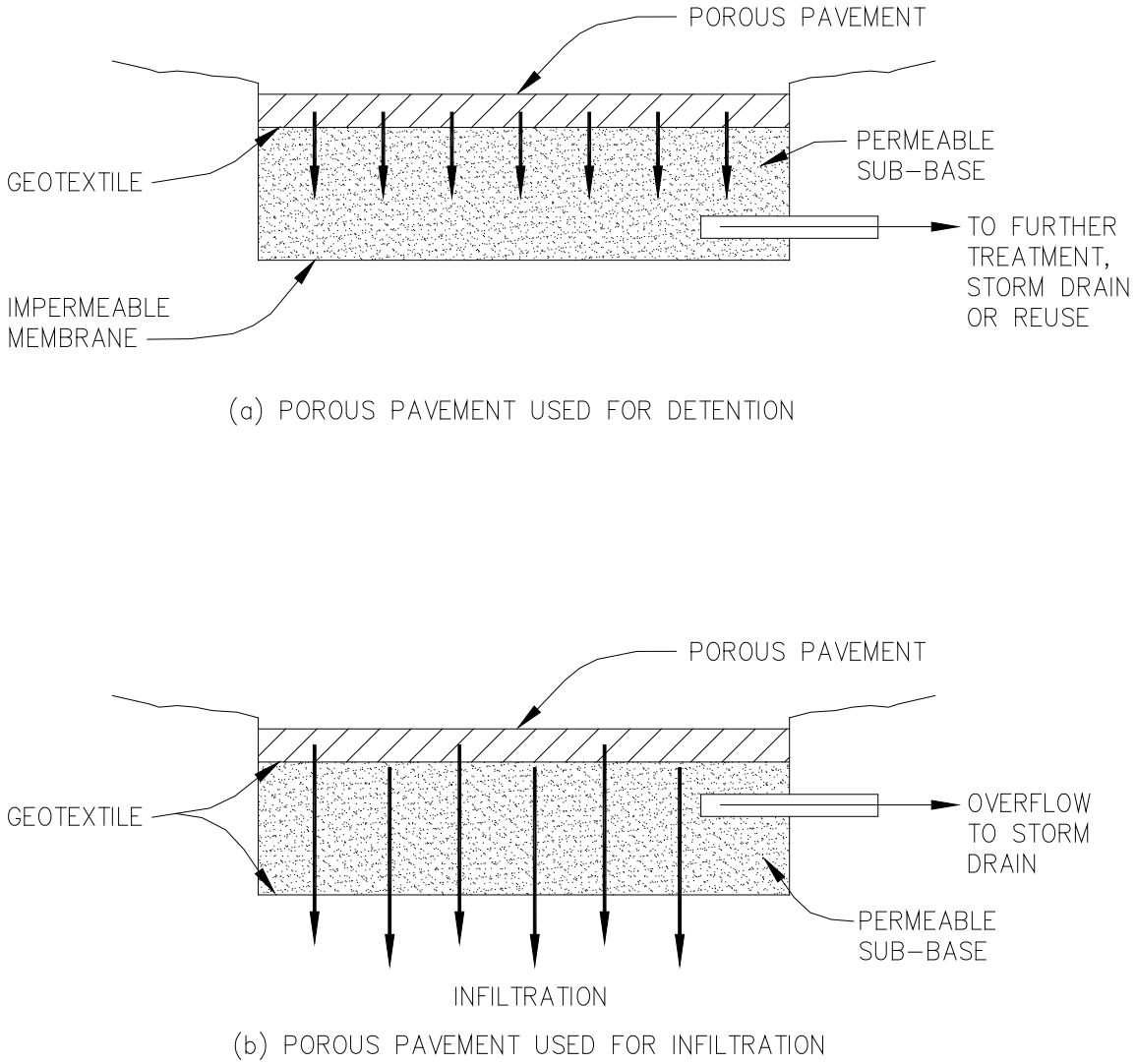


Figure TC-64C. Typical porous pavement and drainage pipe configurations for a) filtering and detaining stormwater runoff and b) filtering and infiltrating stormwater runoff (modified from CASQA, 2003).

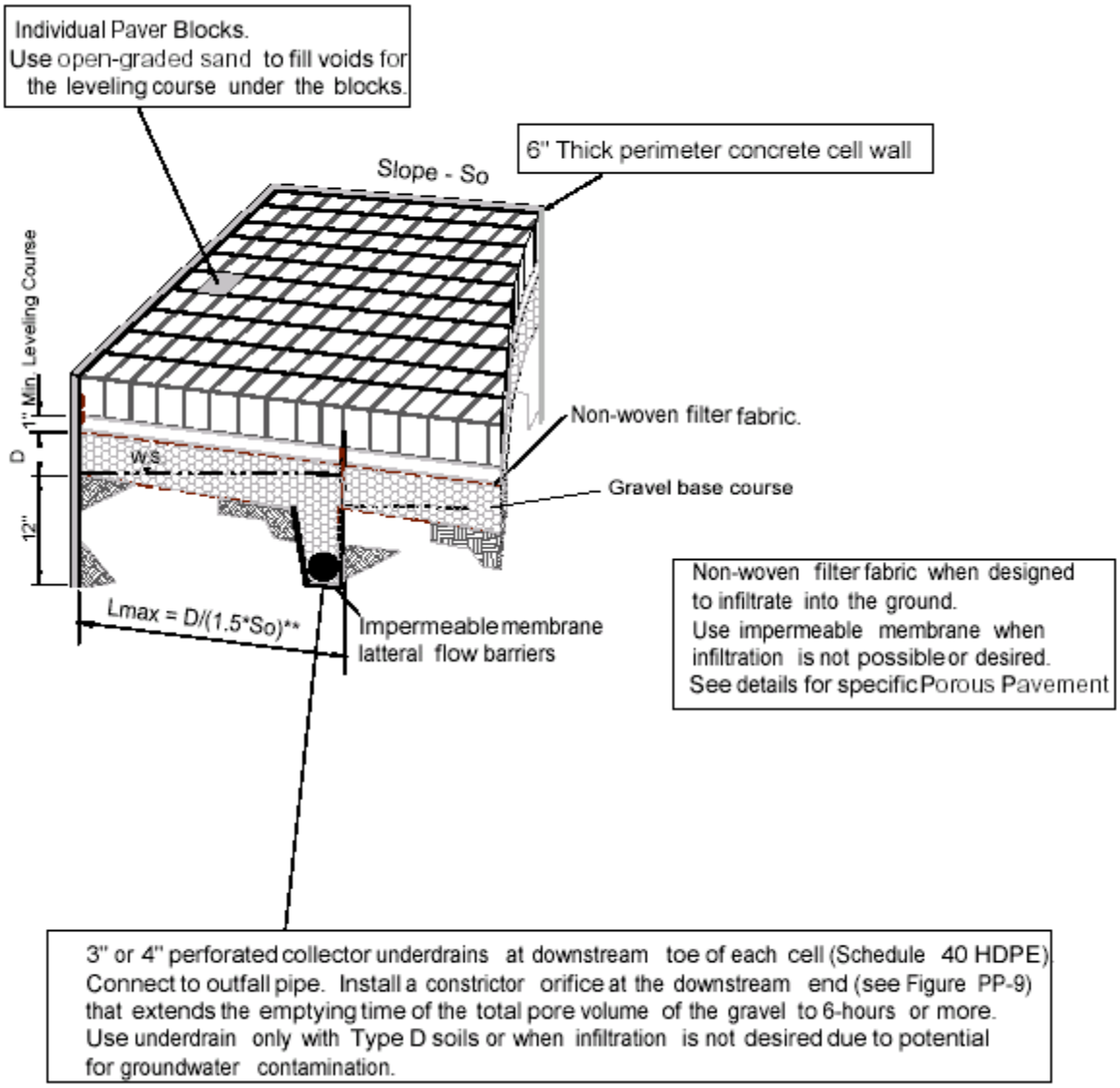
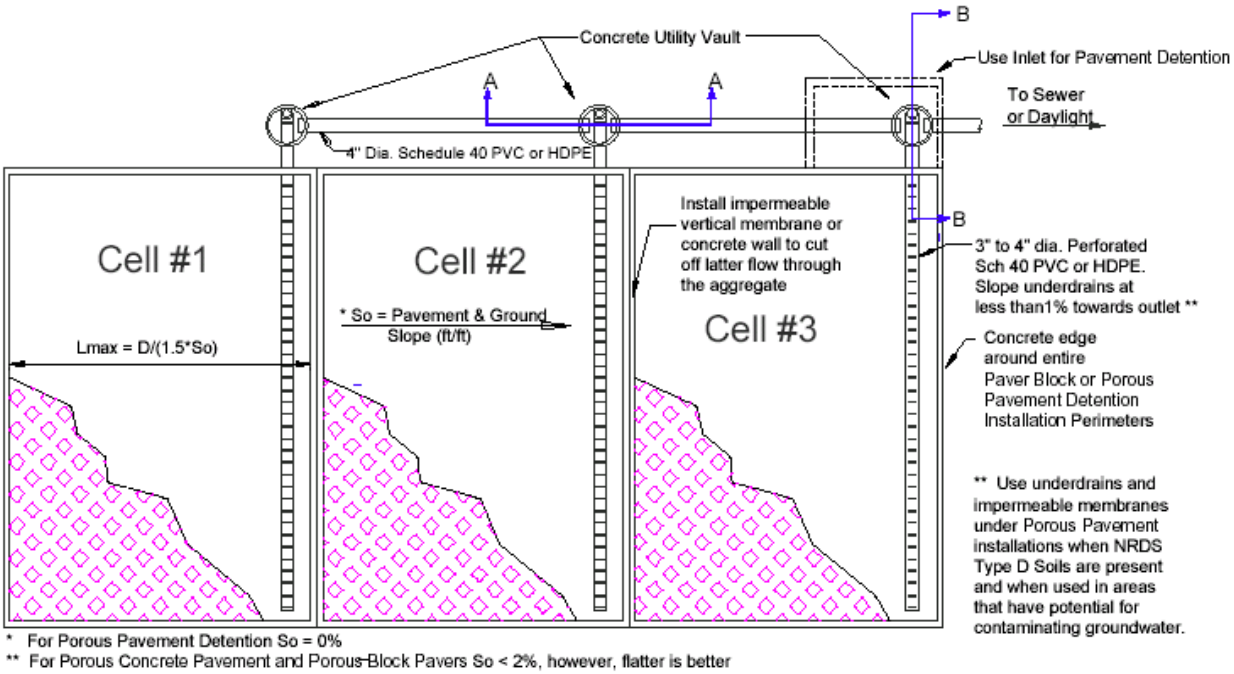
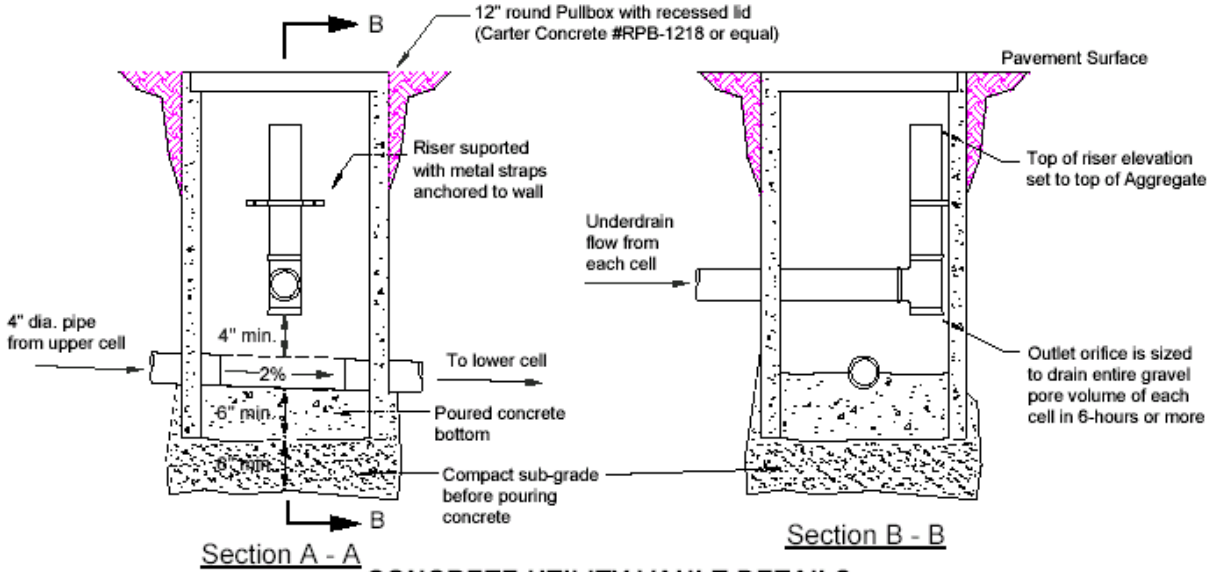


Figure TC-64D. View of a paver block installation showing perimeter wall and contained cells. (modified from UDFCD 2005).



PLAN VIEW



CONCRETE UTILITY VAULT DETAILS

Figure TC-64E. Layout for underdrain system for porous pavement installations. (Modified from UDFCD 2005

6.9 Manufactured (Proprietary) Treatment Controls

Manufactured or proprietary treatment controls are commercially available stormwater treatment devices that are designed and distributed by private companies. They are often prefabricated and available in a number of sizes depending on the flow rate or volume to be treated. They are also typically designed and sized based on criteria determined by the manufacturer, which often differs from the sizing criteria required by municipalities such as those in the Truckee Meadows. Whenever possible, manufactured treatment controls applied in the Truckee Meadows should be sized based on the WQ_F or WQ_V criteria for public domain treatment controls presented in **Section 6.3** of this Manual. Alternative sizing criteria may be acceptable if the manufacturer provides performance data that demonstrates acceptable pollutant removal rates.

Manufactured treatment controls can be applied in a wide variety of urban settings, but are often most useful where space is limited. Therefore, they can be particularly applicable to retrofit situations. The science and technology of stormwater quality improvement is evolving and new and innovative structural controls continue to be developed. This is particularly true with manufactured treatment controls. The manufactured treatment controls that are currently available can be broadly grouped into the following categories:

- MTC-10 Hydrodynamic Separators
- MTC-20 Wet Vaults
- MTC-30 Catch Basin Inserts
- MTC-40 Modular Wetlands
- MTC-50 Media Filtration Systems
- MTC-60 Landscape Filtration Systems

Advancements in manufactured treatment controls have allowed for the application of multiple treatment approaches within a single unit. Thus, some manufactured treatment controls may be referenced under multiple categories.

Note: The manufactured or proprietary treatment controls discussed in this manual are provided only as examples of the types of devices that are currently commercially available. The companies and devices noted do not indicate an endorsement by Truckee Meadows Stormwater Permit Coordinating Committee, the City of Reno, the City of Sparks, Washoe County or the Nevada Department of Transportation.

MTC-10 HYDRODYNAMIC SEPARATORS

Description

Hydrodynamic separators (e.g., vortex separators or swirl concentrators) are round gravity separators that are increasingly used for stormwater treatment. They are designed to remove trash, debris, and some amount of sediment, oil, and grease from urban runoff. They consist of flow-through structures that have a settling or separation unit to remove sediment and other pollutants. The energy of stormwater flowing into a hydrodynamic separator is utilized to create centrifugal forces that allow suspended sediment and attached pollutants to move to the center of the device and settle to the bottom. Hydrodynamic separators are best suited for heavy particulates (which settle) or floatables (which can be captured), rather than dissolved solids and pollutants that do not settle.

Applications

Hydrodynamic separators are available in many sizes and are easily added to a new or existing storm drain system. They may achieve a pollution reduction performance similar to wet vaults, but in a smaller space. Their versatility makes them a good option for stormwater "hotspots" such as near industrial sites where higher concentrations of pollutants are more likely.

Performance Data

Performance claims differ depending on the manufacturer and the type of separator. However, in general hydrodynamic separators are capable of removing 90% of all particles with a specific gravity of 2.65 (glacial sand) down to 150 microns (CASQA, 2003). They can also effectively capture floatable trash and debris and oil and grease. Proper design and maintenance is necessary for maximum performance.

Limitations

- Will not significantly remove dissolved pollutants or fine sediments.
- Typically not designed with significant detention storage.
- Units with standing water potentially face problems with mosquito breeding.
- Non-steady flows of stormwater decrease the efficiency that is estimated from testing under constant flow.

Siting Criteria

- Hydrodynamic separators can be installed anywhere a standard manhole can be installed. They can be retrofit into many locations including existing manholes.
- The size of the drainage area that can be served is directly related to the capacities of the largest models.
- Individual units can be placed in parallel to provide treatment for larger flows.

Design and Construction Criteria

- Hydrodynamic separators are often sized based upon the manufacturers design criteria, which can vary significantly. The sizing requirements of hydrodynamic separators should be based on the water quality flow criteria outlined in **Section 6.3**.

Alternative sizing criteria may be acceptable if performance data demonstrate acceptable pollutant removal rates.

- Hydrodynamic separators are frequently designed to accommodate a treatment flow rate and a bypass flow rate. The designer must be certain that treatment design event WQ_F matches the stated treatment flow rate, while the maximum hydraulic capacity usually indicates the peak flow rate that can pass through the unit, bypassing much of the treatment.
- If an off-line facility, the design peak flow should be equal to the treatment flow rate.
- Head loss differs by product and by model but is generally about one foot or less.
- Native soils must provide adequate bearing strength.
- Cost is dependent on the flow rate to be treated, site constraints, source control implementation, and any other treatment technologies that are being implemented.
- Eliminate access openings for adult mosquitoes.
- For detailed design guidance and specifications, contact the manufacturer.

Inspection and Maintenance Requirements

- For most sites, hydrodynamic separators are cleaned annually.
- Hydrodynamic separators should be inspected at least twice a year, depending on manufacturer recommendations.
- A dipstick can be used to measure accumulated sediment level.
- Hydrodynamic separators should be cleaned when collected sediments reach capacities outlined by the manufacturer.
- Cleaning can be accomplished with a sump vac or a vacuum truck.
- Proper disposal of trash, debris, sediment, oil and grease is required.

References and Sources of Additional Information

California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook, New Development and Redevelopment. https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook

Minton, G.R., 2002. Stormwater Treatment, Biological, Chemical & Engineering Principles, Resource Planning Associates, Seattle, Washington.

Manufacturers

- AquaShield Aqua-Swirl™
  http://www.aquashieldinc.com/--aqua-swirl.html
- Contech CDS®
  http://www.conteches.com/products/stormwater-management/treatment/cds.aspx
- Contech Vortechs®

http://www.conteches.com/products/stormwater-management/treatment/vortechs.aspx

- Contech VortSentry® HS
  http://www.conteches.com/products/stormwater-management/treatment/vortsentry-hs.aspx
- Hydro International Downstream Defender®
  http://www.hydro-int.com/us/products/downstream-defender
- Hydro International First Defense®
  http://www.hydro-int.com/us/products/first-defenseKristar FloGard Dual-Vortex®
  http://www.kristar.com/index.php/hydrodynamic-separators/flogard-dual-vortex

MTC-20 WET VAULTS

Description

Wet vaults are subterranean structures designed to dissipate the energy of stormwater runoff with baffles and chambers and promote the settling of particulate stormwater pollutants. They have a permanent pool of water, generally 3 to 5 feet deep. They may also have a constricted outlet that causes a temporary rise in the water level of the pool during storm events. The temporary additional volume of stormwater generally drains within 12 to 48 hours after the end of each storm event.

Applications

Wet vaults are typically used for commercial, industrial, or roadway projects where space constraints limit the use of other treatment controls.

Performance Data

The targeted constituents of wet vaults are sediment, nutrients, trash, metals, oil and grease, and organics.

Limitations

- Can be considerably more expensive than many other BMPs. However, the added cost may be offset by the value of continued use of the land surface.
- Wet vaults are believed to be ineffective in removing dissolved pollutants such as soluble phosphorus or metals such as copper and wet vaults may actually export dissolved nutrients if maintenance is neglected and accumulated organic matter (e.g., leaves) decomposes in the units.
- As sediment fills the storage chamber of wet vaults, treatment efficiencies decline.
- Maintenance of wet vaults can require special equipment and may be subject to OSHA confined space entry requirements.
- Wet vaults typically do not support biological activity to increase stormwater treatment.
- Accumulated sediment and stagnant conditions may cause noxious gases to form and accumulate in the vault if regular maintenance is neglected.
- Standing water may create a mosquito-breeding habitat.

Siting Criteria

There are no unique siting criteria. The size of the drainage area that can be served by a manufactured wet vault is directly related to the capacities of the specific models and individual site constraints.

Design and Construction Criteria

- Depending on the particular unit, it should be sized to convey the WQ_F or detain the WQ_V as outlined in **Section 6.3**. Alternative sizing criteria may be acceptable if performance data are available, that demonstrate acceptable pollutant removal rates.

- Cost dependent on the volume to be treated, site constraints, and any source or treatment controls used within the drainage area.
- Native soils must provide adequate bearing strength.
- Eliminate access openings for adult mosquitoes.
- For detailed design guidance and specifications, contact the manufacturer.

Inspection and Maintenance Requirements

- Recommended cleaning rates differ depending on the manufacturer and the land uses of the drainage area being treated. However, for most sites wet vaults should be cleaned annually.
- Wet vaults should be inspected twice a year.
- A dipstick can be used to measure sediment level.
- Cleaning can be accomplished with a sump vac or a vacuum truck.
- Proper disposal of trapped sediment and oil and grease is required.
- Internal wet vault maintenance or repairs may be subject to OSHA confined space entry requirements.

References and Sources of Additional Information

California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook, New Development and Redevelopment. https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook

Idaho Department of Environmental Quality, 2005. Catalog of Stormwater Best Management Practices: For Idaho Cities and Counties. BMP #17 – Wet Vault/Tank. https://www.deq.idaho.gov/media/622263-Stormwater.pdf

Minton, G.R., 2002. Stormwater Treatment, Biological, Chemical & Engineering Principles, Resource Planning Associates, Seattle, Washington.

Manufacturers

- Baysaver Technologies BaySeparator
  http://www.baysaver.com/products/BaySeparators/index.html#
- Imbrium Systems Inc., Stormceptor®
  http://www.stormceptor.com/en/products/brochures.html
- Jensen Stormwater Systems StormVault®
  http://www.jensenstormwater.com/stormvault
- Suntree Technologies Inc. Nutrient Separating Baffle Box®
  http://www.suntreetech.com/Products/Nutrient+Separating+Baffle+Box/default.aspx

MTC-30 CATCH BASIN INSERTS

Description

Catch basin inserts (a.k.a. drain inserts) are manufactured filters placed in drop inlets to help remove sediment and debris from stormwater runoff. They are used to increase a catch basin's efficiency at removing trash, debris and sediment and some oil and grease, organics, and metals. There are many varieties of catch basin inserts; however, they typically fall into one of three main types: trays, boxes or socks. The tray insert option consists of a series of trays, with the top tray serving as an initial sediment trap. Underlying trays often contain filters composed of a variety of different types of media including polypropylene, porous polymers, treated cellulose, and activated carbon. The box option is typically constructed of plastic or wire mesh with filtering medium that fits directly into the box within the catch basin. Hydrocarbons are removed as the stormwater passes through the adsorbent filters while trash, debris and sediment remains in the box as the stormwater exits. Both tray and box type catch basin inserts typically provide overflow features and reportedly do not reduce the original hydraulic capacity of the catch basin. The sock option uses filter fabric (usually polypropylene) to remove pollutants from vertical drop inlets. The fabric is attached either to a frame or directly to the catch basin grate. Each of these options provides very little volume; therefore frequent sediment removal and maintenance is required. Some models allow for sediment removal with a vacuum truck while others require physically removing the insert for cleaning.

Applications

Catch basin inserts are typically used for retrofit applications. They can also be used as a pretreatment device for other manufactured treatment controls. They do not require additional space, can be easily accessed for inspection and maintenance, and do not encourage the breeding of mosquitoes.

Performance Data

A 2005 study evaluated the removal efficiency of TSS and total petroleum hydrocarbons (TPH) by catch basin inserts. Results of this study indicated 11 to 42% reduction in TSS and a removal rate for TPH ranging from 10 to 19%. Other studies have demonstrated considerable variability in field results of removal efficiencies. A Caltrans study of highway BMP retrofits suggested that the catch basin inserts performed poorly compared to other BMP types. This study concluded that catch basin inserts are best applied for the removal of gross solids.

Limitations

- Typically require maintenance several times per year.
- May reduce the hydraulic capacity of a catch basin, particularly when full of debris.
- Performance is likely significantly less than other available treatment systems such as ponds and vaults.
- Usually not suitable for large areas or areas with trash or leaves that can plug the insert.
- Studies have found that a variety of inserts showed little removal of TSS, partially due to scouring and re-suspension from relatively small storm events.

- Some options require extensive maintenance to prevent buildup of sediment while others allow sediment removal with a vacuum system.
- The relative low cost of inserts may tend to favor the use of these systems over other, more effective treatment controls. However, the initial cost savings may be offset by the number of units required, the costs associated with frequent maintenance, and replacement requirements due to shorter structural life spans.

Siting Criteria

- Can be installed in new or existing catch basins.
- Drainage area for each catch basin insert should be less than 10 acres.

Design and Construction Criteria

- Refer to manufacturer's guidelines; there are many options to choose from depending on individual site needs.
- Installation should be done in a manner that ensures that runoff enters the unit and does not leak around the perimeter. Leakage between the frame of the insert and the grate of the catch basin can easily occur with vertical drop inlets.
- For detailed design guidance and specifications, contact the manufacturer.

Inspection and Maintenance Requirements

- Inspect several times during the first year to establish cleaning frequencies.
- At a minimum, inserts should be cleaned or replaced once or twice per year.
- Removal of sediment in catch basins may require a vactor truck.
- Many brands of inserts can be serviced in ten minutes or less.

References and Sources of Additional Information

California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook, New Development and Redevelopment. https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook

USEPA, NPDES. Post-Construction Stormwater Management in New Development & Redevelopment. Catch Basin/Catch Basin Insert. http://cfpub.epa.gov/npdes/stormwater/menuofbmps/index.cfm?action=browse&Rbutton=detail&bmp=77&minmeasure=5

Walch, M, Walters, D., Frost, W., DiNicola, P. and Gneo R, Evaluation of the Performance of Four Catch Basin Inserts in Delaware Urban Applications, StormCon 2004, Palm Desert, CA, http://deldot.gov/stormwater/pdfs/StormCon04_Walch.pdf

Morgan, RA, Edwards, FG, Brye, KR, Burian SJ. 2005, An evaluation of the urban stormwater pollutant removal efficiency of catch basin inserts. Water Environ Res. 2005 Sep-Oct;77(5):500-10.

Manufacturers

- Abtech Industries Ultra-Urban Filters
  http://www.abtechindustries.com/solutions/stormwater-management/stormwater-management-solutions/products-and-systems/storm-drain-inserts/ultra-urban-filters
- AquaSheild Aqua-Guardian
  http://www.aquashieldinc.com/--aqua-guardian.html
- BioClean Environmental Services, Inc.
  http://www.biocleanenvironmental.com/
- Contech Triton Catch Basin Inserts
  http://www.conteches.com/products/stormwater-management/treatment/triton-catch-basin-inserts.aspx
- EcoSense International Stormwater Filtration System
  http://www.ecosenseint.com/Stormwater_Filtration_Systems.htm
- Fabco StormBasin
  http://www.fabco-industries.com/stormwater-products-page/decentralized-treatment/stormbasin.html
- Kristar FloGard+Plus Catch Basin Insert Filter®
  http://www.kristar.com/index.php/drain-inlet-filtration/flogard-plus-catch
- Suntree Technologies Inc. Grate Inlet Skimmer Box™
  http://www.suntreetech.com/Products/default.aspx
- UltraTech International, Inc. Ultra-Hydrokleen®
  http://www.spillcontainment.com/hydrokleen

MTC-40 MODULAR WETLANDS

Description

Modular wetlands, or manufactured wetlands provide water quality treatment through routing of subsurface flows of stormwater through gravel and wetland vegetation root systems allowing for microbial utilization and plant uptake of nutrients and dissolved pollutants. Pretreatment with an upstream treatment control can be added to remove litter, debris and coarse sediment loads. Supplemental media including activated carbon, iron wool and zeolite can also be added to increase pollutant removal efficiency. Modular wetlands are reportedly effective at removing dissolved and suspended solids, nutrients, pesticides, heavy metals and bacteria from urban runoff.

Applications

Can be used to treat runoff from parking lots, buildings, roadways, and residential properties where discharge into a sensitive water body is a concern. Pollutant removal and treatment efficiency improves as contact time increases. Some models are equipped with a spill contamination feature that can capture an upstream release and lessen the spill impact on the environment.

Performance Data

High removal efficiency of TSS, nutrients, pesticides, total metals, petroleum hydrocarbons, and microbiological materials can be expected.

Limitations

- Typically limited to drainage areas less than one acre.
- Larger drainage areas require numerous units to treat runoff and may take up valuable land surface space.
- Requires a perennial water source to maintain wetland vegetation.
- May create a mosquito breeding habitat if water ponds above the wetland surface. If no standing water is present in the modular wetland, the opportunity for mosquito breeding is greatly reduced.
- If litter, debris and coarse sediment loads are not removed with an upstream pretreatment device, clogging of the device may occur.
- Wetland vegetation requires annual maintenance.

Siting Criteria

- Depending on the design, modular wetlands may require significant land surface footprint.
- Can be used to treat runoff from highways, parking lots, airports, marinas, and commercial, industrial, and residential areas.

Design and Construction Criteria

- Modular wetland should be sized to capture and treat the WQV as outlined in **Section 6.3**. However, alternative sizing criteria may be acceptable if performance data are available that demonstrates acceptable pollutant removal rates.
- Excavation depth of over 5 ft. is typical.
- For detailed design guidance and specifications, contact the manufacturer.

Inspection and Maintenance Requirements

- Inspect periodically and remove any invasive wetland plant species.
- Inspect periodically to prevent water ponding standing longer than 7 days.
- Wetland vegetation should be harvested once a year, during mid-summer, before plants transfer phosphorus and metals from aboveground foliage to subsurface roots.
- Annual inspection and measurement of sediment accumulation.
- A vacuum truck or a septic tank service truck can be used for sediment removal.

References and Sources of Additional Information

California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook, New Development and Redevelopment. https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook

Minton, G.R., 2002. Stormwater Treatment, Biological, Chemical & Engineering Principles, Resource Planning Associates, Seattle, Washington.

State of California - Department of Transportation, 2008. Caltrans Treatment BMP Technology Report. p. B-285.

Manufacturers

- StormTreat Systems http://www.stormtreat.com/
- Modular Wetlands http://www.modularwetlands.com/

MTC-50 MEDIA FILTRATION SYSTEMS

Description

Manufactured media filters are typically subsurface BMPs consisting of two chambers that include a pretreatment settling basin and a basin with a sand filter or an absorptive filter media. Large particles and floatables are typically removed in the first chamber while finer grained particles and other pollutants are removed by the filtering media in the second chamber. Overflow weirs are typically incorporated to allow higher flows from larger storm events to bypass the device and flow directly into the storm drain system.

Applications

Manufactured media filters are typically used for commercial, industrial or roadway projects where space constraints limit the use of other treatment controls.

Performance Data

Manufactured media filters can be expected to have similar pollutant removal efficiencies to public domain media filters (TC-60 and 61). Removal of dissolved constituents depends on the type of media used in the device. Filters with perlite and filter fabric are not effective at removal of dissolved constituents, whereas filters with zeolites, activated carbon, compost and peat are.

Limitations

- Media filters may have reduced pollutant removal efficiencies at higher flow rates.
- Use in drainage areas with high sediment loads can lead to premature clogging.
- Filter replacement may require confined space entry.
- Standing waters in the device may provide mosquito habitat.

Siting Criteria

- Can be placed under roadways, parking lots, sidewalks or landscaped areas and can treat drainage areas of up to 5 acres (depending on the manufacturer and model).
- Issues of buoyancy must be considered in areas with high groundwater tables.
- In areas where high sedimentation may be an issue, consider a pre-treatment device.

Design and Construction Criteria

- Media filtration systems should be sized to capture and treat the WQV as outlined in **Section 6.3**. However, alternative sizing criteria may be acceptable if performance data are available, that demonstrates acceptable pollutant removal rates.
- May be used on sites with impermeable soils since the runoff filters through filter media, not native soils.
- The main factors that influence removal rates are the storage volume, filter media, and detention time.
- For detailed design guidance and specifications, contact the manufacturer.

Inspection and Maintenance Requirements

- Inspect several times during the first year to establish loading and cleaning frequencies.
- Media filtration systems are typically cleaned once a year.
- May require confined space entry for maintenance.

References and Sources of Additional Information

California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook, New Development and Redevelopment. https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook

Manufacturers

- AquaShield Aqua-Filter http://www.aquashieldinc.com/--aqua-filter.html
- Baysaver BayFilter http://www.baysaver.com/products/BayFilter/index.html
- Contech Stormwater Management Stormfilter® http://www.conteches.com/products/stormwater-management/treatment/stormwater-management-stormfilter.aspx
- Contech Jellyfish® Filter Manhole http://www.imbriumsystems.com/en/products/manhole.html
- EcoSense International Stormwater Filtration System http://www.ecosenseint.com/Stormwater_Filtration_Systems.htm
- Fabco StormSafe http://www.fabco-industries.com/stormwater-products-page/centralized-treatment/stormsafe.html
- Kristar FloGard® Perk Filter™ http://www.kristar.com/index.php/media-filtration/flogard-perk-filter

MTC-60 LANDSCAPE FILTRATION SYSTEMS

Description

Landscape filtration, or manufactured biofiltration systems consist of subsurface structures that filter stormwater runoff and irrigate turf or landscaped vegetation. Filtered outflow can be stored for future use, allowed to infiltrate into the soil or discharged to the conventional storm drain system. The soil media and vegetation root system have the capability to remove suspended and dissolved solids, nutrients, bacteria and organics from stormwater runoff. Pretreatment can be applied to remove litter, debris and coarse sediment loads that may cause clogging. Overflow or bypass structures may be required to protect against flooding from larger events or backup if clogging occurs.

Applications

Landscape filtration systems can be used to treat runoff from buildings, roadways, parking lots, service stations, garages and storage yards. Self-contained landscape filtration systems are preferred over infiltration practices when potential contamination of groundwater is a concern. In addition, this treatment control can be applied where native soils cannot treat runoff adequately or where the ground water table is high. Some systems can be configured to store runoff to be used as a source for subsurface irrigation. Subsurface application of irrigation water uses capillary action to deliver water to plants, reducing evaporation, improving nutrient uptake, and optimizing the use of water resources.

Performance Data

Landscape filtration systems can be expected to have high removal efficiencies for sediment, nutrients, petroleum hydrocarbons and fecal coliform.

Limitations

- May become clogged with debris and particulates over time.
- May require frequent maintenance in areas with high pollutant loads.

Siting Criteria

- Suitable for relatively small drainage areas from one to five acres.
- Can be installed in parkways, along roadways upstream of catch basin inlets, in medians and in vegetated areas between roadways and sidewalks.

Design and Construction Criteria

- At a minimum, should be sized to capture and treat the WQ_V as outlined in **Section 6.3.2**. However, alternative sizing criteria may be acceptable if performance data are available, that demonstrates acceptable pollutant removal rates.
- The porosity of the filter media must be considered when sizing.
- May be used on sites with impermeable soils since the runoff filters through soil media, rather than native soils.
- Refer to the manufacturer's specifications for additional design and construction criteria.

Inspection and Maintenance Requirements

- Inspect several times during the first year to establish cleaning frequencies.
- At a minimum, landscape filtration systems should be cleaned once a year.

References and Sources of Additional Information

California Stormwater Quality Association (CASQA), 2003. California Stormwater BMP Handbook, New Development and Redevelopment. https://www.casqa.org/resources/bmp-handbooks/new-development-redevelopment-bmp-handbook

Manufacturers

- AquaShield Bio-Filter™ http://www.aquashieldinc.com/--bio-filter.html
- Contech UrbanGreen™ BioFilter http://www.conteches.com/products/stormwater-management/treatment/urbangreen-biofilter.aspx
- Evaporative Control Systems, Inc. EPIC system http://www.ecs-green.com/
- Filterra™ Stormwater Bioretention Filtration System http://www.filterra.com/
- Kristar Bio-Mod® Modular Bioretention System http://www.kristar.com/index.php/low-impact-development-lid/bio-mod-modular-bioretention-system
- StormTree Stormwater Filtration Systems http://storm-tree.com/

Glossary

Anti-Seep Collar: An impermeable diaphragm, usually of sheet metal or concrete, constructed within the zone of saturation along the conduit of a principal spillway or outlet, installed to prevent piping or seepage along the conduit.

Aquatic Bench: A 10 to 15 foot wide bench which is located around the inside perimeter of a permanent pool and is normally vegetated with aquatic plants; the goal is to provide pollutant removal and enhance safety in areas using storm water pond storm water practices.

Baffles: Guides, grids, grating or similar devices placed in a pond to deflect or regulate flow and create a longer flow path.

Berm: A shelf that breaks the continuity of a slope; a linear embankment or dike.

Best Available Technology Economically Achievable (BAT): Technology-based standard established by the CWA as the most appropriate means available on a national basis for controlling the direct discharge of pollutants to waters of the United States.

Best Management Practices (BMPs): Schedules of activities, prohibitions of practices, maintenance procedures, structural devices and other management practices to prevent or reduce the discharge of pollutants to waters of the United States.

Biochemical Oxygen Demand (BOD): A measurement of the amount of oxygen utilized by the decomposition of organic material, over a specified period (usually 5 days) in a water sample.

Biofilters: Grass depression areas such as engineered channels or swales that are used to collect and filter urban storm water.

Bioretention: A water quality practice that utilizes landscaping and soils to treat urban runoff by collecting it in shallow depressions, before filtering through a fabricated planting soil media.

Buffer: An area adjacent to a shoreline, wetland or stream where development is restricted or prohibited.

Check Dam: A small dam constructed in a swale or other small watercourse to decrease the stream flow velocity (by reducing the channel gradient), minimize channel scour, and promote deposition of sediment.

Clean Water Act (CWA): Formerly known as the Federal Water Pollution Act. Legislation, which provides statutory authority for both NPDES pretreatment and storm water programs.

Detention: The temporary storage of storm runoff in a storm water practice with the goals of controlling peak discharge rates and providing gravity settling of pollutants.

Detention Structure: A structure constructed for the purpose of temporary storage of stream flow or surface runoff and gradual release of stored water at controlled rates.

Discharge: The direct or indirect entry of storm water or non-storm water into the storm drain system or a receiving water body. This term can also reference the pollutants being discharged from an activity or operation into storm water and/or non-storm water.

Drainage Area: An area that contributes all precipitation falling within its boundaries to a single common or outflow point.

Energy Dissipater: A designed device such as an apron of riprap or a concrete structure placed at the end of a water transmitting apparatus such as pipe, paved ditch or paved chute for reducing the velocity, energy and turbulence of the discharged water.

Erosion: Detachment and movement of soil or rock fragments by water, wind, ice or gravity.

Extended Detention: A storm water design feature that provides for the gradual release of a volume of water over a 12 to 48 hour interval in order to increase settling of urban pollutants and protect downstream channels from frequent storm events.

Filter Media: The sand, soil, or other organic material in a filtration device used to provide a permeable surface for pollutant and sediment removal.

Filter Strips: A vegetated area that treats sheetflow and/or interflow by removing sediment and other pollutants. The area may be grass-covered, forested or of mixed vegetative cover.

Fines (Soil): Generally refers to the silt and clay size particles in soil.

General Permit: An NPDES permit issued under 40 CFR 122.28 that authorizes a category of discharges under the CWA within a geographical area. A general permit is not specifically tailored for an individual discharger.

Hazardous Substance: Any substance, other than oil, which, when discharged in any quantities into waters of the U.S., presents an imminent and substantial danger to the public health or welfare, including but not limited to fish, shellfish, wildlife, shorelines and beaches (Section 311 of the CWA); identified by EPA as the pollutants listed under 40 CFR Part 116.

Heavy Metals: Metallic elements with high atomic weights (e.g. mercury, chromium, cadmium, arsenic, and lead) that can damage living things at low concentrations and tend to accumulate in the food chain.

Illicit Connections: Illegal and/or unauthorized connections that result in untreated wastewater discharges into storm drainage systems and receiving waters.

Illicit Discharge: Any discharge to a municipal separate storm sewer system that is not composed entirely of storm water, except for discharges allowed under an NPDES permit or waters used for certain emergency situations.

Impervious: The characteristic of a material, which prevents the infiltration or passage of liquid through it. This may apply to roads, streets, driveways, parking lots, rooftops, patios and sidewalks.

Infiltration Rate: The rate at which water percolates into the subsoil measured in inches per hour.

In-Line: A storm water management system designed to manage storm water in its original stream or drainage channel.

Manufactured (proprietary) treatment controls: Patented devices that are engineered, constructed and distributed by private companies.

Municipal Separate Storm Sewer System (MS4): A conveyance or system of conveyances (including roads with drainage systems, municipal streets, catch basins, curbs, gutters, ditches, man-made channels, or storm drains) owned and operated by a state, county, city, town, district, association, or other public body (created by or pursuant to state law) having jurisdiction over the disposal of sewage, industrial wastes, storm water, or other wastes, that discharges to waters of the United States. [40 CFR 122.26(b)(8)].

Municipal Storm water Permit: An NPDES permit issued to municipalities to regulate discharges from municipal separate storm sewers for compliance with EPA established water quality standards and/or to specify specific storm water control strategies.

National Pollutant Discharge Elimination System (NPDES): The national program for issuing, modifying, revoking and reissuing, terminating, monitoring and enforcing permits, and imposing and enforcing pretreatment requirements, under Sections 307, 318, 402, and 405 of the CWA.

Non-Point Source Pollution: Unlike pollution from industrial and sewage treatment plants, non-point source (NPS) pollution comes from many diffuse sources. NPS pollution is caused by rainfall or snowmelt moving over the ground that picks up and transports natural and human-made pollutants, finally depositing them into lakes, rivers, wetlands, coastal waters, and underground sources of drinking water. Common non-point sources are agriculture, forestry, urban, mining, construction, dams, channels, land disposal, saltwater intrusion, and city streets.

Non-Storm Water Discharges: Flows or discharges that are not entirely composed of storm water. These may include but are not limited to uncontaminated groundwater, natural springs, car washing, air conditioner condensate, and hydrant flushing water.

Non-Structural Storm Water Practices (or BMPs): Management practices and measures designed to reduce pollutant levels in storm water, which do not require extensive construction efforts, and promote pollutant reduction by eliminating the pollutant source.

Off-Line: A storm water management system designed to manage a storm event by diverting a percentage of storm water events from a stream or storm drainage system.

One Hundred Year Storm: A precipitation event, which occurs on average once every 100 years or statistically has a 1% chance on average of occurring in a given year.

Open Space: A portion of a development site, which is permanently set aside for public or private use and will not be developed with homes. The space may be used for passive or active recreation, or may be reserved to protect or buffer natural areas.

Ordinance: A law, a statute, a decree enacted by a municipal body, such as a city council or county commission. Ordinances often govern matters not already covered by state or federal laws (such as local zoning, safety and building regulations), but may also be used to require stricter standards in local communities than those imposed by state or federal law.

Organic Filter: A filtering practice that uses an organic medium such as peat or compost in the filter bed to filter storm water runoff.

Outfall: The point where water discharges from a conduit, pipe, or drain to a stream, river, lake or another waterbody.

Outlet: The point at which water discharges from a structure such as a basin, a trench or a concrete structure to another structure or a pipe or channel.

Overflow Chamber: A design feature of some on-line storm water treatment practices that captures larger flows than are not treated by the practice, and passes them to the storm drain system.

Peak Discharge (Flow Rate): The maximum instantaneous rate of flow during a storm, usually in reference to a specific design storm event.

Perennial Stream: A stream channel that has running water throughout the year.

Permeability: The rate of water movement through the soil column under saturated conditions.

Pervious: A property of a material that allows for the passage of liquid through it.

Point Source: Any discernible, confined, and discrete conveyance or container, including but not limited to, any pipe, ditch, channel, tunnel, conduit, well, or tank from which pollutants are or may be discharged. This term does not include return flows from irrigated agriculture or agricultural storm water runoff.

Pollutant: Dredged spoil, solid waste, incinerator residue, filter backwash, sewage, garbage, sewage sludge, munitions, chemical wastes, biological materials, radioactive materials, heat, wrecked or discarded equipment, rock, sand, dirt, and industrial, municipal, and agricultural waste discharged into water [40 CFR 122.2].

Porosity: Ratio of pore volume to total solids volume.

Porous Pavement: Permeable pavement surface with an underlying stone reservoir to store temporarily surface runoff before it infiltrates into the subsoil. It can be used to replace asphalt and concrete and can be used for driveways, parking lots and walkways.

Pretreatment: Techniques employed in storm water practices to provide storage or filtering to help trap coarse materials before they enter the system.

Public domain treatment controls: Devices/facilities that can be designed by an engineer and have been implemented and tested by numerous communities throughout the nation.

Rain Barrel: A temporary storage device connected to a roof downspout, typically including a hose attachment to allow for reuse of rooftop runoff.

Rational Method: Used to determine peak flow rates for drainage areas of 100 acres or less, and 25 acres or less where the composite runoff coefficient is 0.50 or less.

Recharge Rate: The annual amount of rainfall that contributes to groundwater.

Redevelopment: Land-disturbing activity that results in the addition or replacement of impervious surface area on an already developed site. This may include the expansion of a building footprint, changes that are not part of routine maintenance, change to or an addition of a structure, and any related land disturbing activities.

Retention: The amount of precipitation on a drainage area that does not escape as runoff. It is the difference between total precipitation and total runoff. It also refers to the amount of storm water that is retained in a treatment control and is not slowly released to the storm drain system.

Retrofit: The installation of a new storm water practice or the improvement of an existing one in a previously developed area.

Riparian: The land area that borders a stream or river and which directly affects and is affected by the water quality. This land area often coincides with the maximum water surface elevation of the 100-year storm.

Riser: A vertical pipe that extends from the bottom of a storm water treatment control that houses discharge control devices such as weirs, orifices or multiple perforations.

Runoff: That part of precipitation, snow melt, irrigation or wash water that runs off the land into the storm drain system, streams or other surface-waters.

Run-on: The flow of storm water from an upgradient area onto an area where potential pollutants may exist.

Sanitary Sewer: A pipe or conduit (sewer) intended to carry wastewater or water-borne wastes from homes, businesses, and industries to the publicly owned treatment works (POTW) facility.

Secondary Containment: A containment that is external and separate from the primary containment (concrete dike, wall, barrier, berm, bin, drum, or tank).

Sediment: Solid particulate material, both mineral and organic, that can be transported from its site of origin by air, water, gravity, or ice.

Sedimentation Chamber: A section of a storm water treatment control that provides for the settling out of relatively large sediment particles from suspension in storm water.

Setbacks: The minimum distance requirements for location of a structural storm water practice in relation to roads, wells, septic fields, other structures.

Sheet Flow: Water, usually storm runoff, flowing in a thin layer over the ground surface prior to the development of channelized flow.

Side Slopes: The slope of the sides of a channel, dam or embankment. It is customary to name the horizontal distance first, as 3H:1V, meaning a horizontal distance of 3 feet to 1 foot vertical.

Source controls: Measures and practices that emphasize reducing or eliminating pollutants in storm water runoff at their source by reducing runoff and potential pollutant exposure to rainfall and runoff.

Spillway: An open or closed channel, or both, used to convey safely excess water from a basin, pond or reservoir over a dam or embankment.

Stilling Basin: An open structure or excavation at the foot of an outfall, conduit, chute, drop, or spillway to reduce the energy of the descending stream of water.

Storm Water = Stormwater: Rain and snow melt runoff and drainage associated with precipitation events [40 CFR 122.26(b)(13)].

Storm Water Hot Spots: Land-uses or activities that generate highly contaminated runoff. Examples include fueling stations and airport de-icing facilities.

Storm Water Management: The process of collecting, conveying, storing, treating, and disposing of storm water to ensure control of the magnitude and frequency of runoff to minimize the hazards associated with flooding and the impact on water quality caused by manmade changes to the land.

Storm Water Pollution Prevention Plan (SWPPP): A written document that describes the activities required to control the discharge of pollutants in storm water and non-storm water runoff. It is intended to facilitate a process whereby the operator evaluates potential pollutant sources at the site and selects and implements appropriate BMPs.

Stream Buffers: Zones of variable width, which are located along both sides of a stream and are designed to provide a protective natural area along a stream corridor.

Structural Treatment Controls: Devices that are constructed to provide temporary storage and treatment of storm water runoff and non-storm water flows. They use physical, biological and/or chemical processes to remove pollutants that have already affected storm water runoff and non-storm water flows.

Toe (of slope): Where the slope stops or levels out. Bottom of the slope.

Total Maximum Daily Load (TMDL): A tool for establishing the allowable loadings of a given pollutant in a surface water resource to meet predetermined water quality standards.

Total Suspended Solids (TSS): A measure of the filterable solids present in a water sample, as determined by the method specified in 40 CFR Part 136.

Trash Rack: Grill, grate or other device at the intake of a channel, pipe, drain or spillway

for preventing oversized debris from entering the structure.

Ultra-Urban: A region dominated by highly developed areas in which very little pervious surface exists.

Variance: A special allowance granted to a developer, which permits the use of designs different from the requirements of the current code.

Water Quality Standard: A law or regulation that consists of the beneficial use or uses of a waterbody, the numeric and narrative water quality criteria that are necessary to protect the use or uses of that particular waterbody, and an anti-degradation statement.

Water Quality Flow Rate (WQ_F): The flow rate representing frequently occurring rainfall/runoff events determined using the Rational Method for the 2-year storm event and the drainage area connected to the BMP.

Water Quality Volume (WQ_V): The storage volume required to capture and treat 90% of the average annual storm water runoff events.

Watershed: All the land area that contributes runoff to a particular point along a waterway.

Sources:

The City of Reno Municipal Code, Section 12.16.820 Definitions.

The Storm Water Manager's Resource Center, Glossary, http://www.stormwatercenter.net/

The U.S. Environmental Protection Agency, NPDES Glossary
http://cfpub.epa.gov/npdes/glossary.cfm

The U.S. Environmental Protection Agency, Terms of the Environment
http://www.epa.gov/OCEPAterms/nterms.html

Appendix A

History

Storm Water Quality Management Program Milestones

The Truckee Meadows Storm Water Quality Management Program (SWMP) is made up of nine required elements; intergovernmental coordination, monitoring, public outreach, illicit discharge and detection, industrial, municipal operations, construction, land use, and structural controls. The focus here is on the element for land use and structural controls; however, other elements may be referenced because of the relevance to timing and implementation of the entire program. A tremendous amount of regional funds and time was expended to ready this community for the implementation of Structural Controls and Low Impact Development (LID) for stormwater quality. Significant milestones for the regional Truckee Meadows program and its guidance manuals follow:

1990's: Beginning in 1990, the first National Pollutant Discharge Elimination System (NPDES) permit for stormwater was issued by Nevada Division of Environmental Protection (NDEP) to the Truckee Meadows as a Phase 1 community. The Cities of Reno and Sparks, Washoe County, and the Nevada Department of Transportation (NDOT) were named as Co-Permittees. An Interlocal Agreement was established for the implementation of the permit. The agreement created the Truckee Meadows Storm Water Permit Coordinating Committee (SWPCC) with a representative from each Co-Permittee. The City of Reno was established as the lead agency to provide a coordinator, clerical and legal support. Early in the decade there was monitoring of stormwater conducted on several sub-watershed catchments to characterize pollutants from different types of land use. Based upon the NPDES permit, construction sites 5 acres and greater required a permit from NDEP. The Truckee Meadows SWPCC drafted a construction site best management practices (BMP) manual. As the decade went on, there was little regulatory push and priority on the stormwater implementation and interest declined.

2000: In January, the NDEP issued a revised permit to the Co-Permittees. The permit more explicitly required the development of a Storm Water Quality Management Program (SWMP) to address each of nine the required elements. The SWPCC representatives recognized this would be a $500,000 undertaking and went to the Washoe County Regional Water Planning Commission (RWPC) to be considered for funding assistance. RWPC recognized the regional implications of the stormwater program and agreed to fund $250,000 of the SWMP development. The balance was shared equally between the Co-Permittees. The SWPCC selected Kennedy/Jenks Consultants (KJC), to assist in the development of the SWMP.

2001: In December, the City of Reno had hired a new Senior Engineer who was designated the Storm Water Quality Coordinator. Concurrently, the SWMP document with its schedule of implementation was accepted by the SWPCC.

Within the SWMP, the element for the structural program for new development and significant redevelopment was broken into key components and schedule for implementation: policies and procedures (2002/03), ordinance revision (2002-04), drainage manual revision (2002-04), database tracking (2003-05), complaint reporting (2004/05) and public education on Best Management Practices (BMPs) as well as training for staff, project designers and developers (2003/05) all with the formal program beginning in 2005/06. "Low Impact Development" was identified as the preferred terminology to address post construction stormwater quality for new development and redevelopment.

2002: In January, the U.S. Environmental Protection Agency (USEPA) conducted an audit of the Truckee Meadows regional SWMP. The result of the audit was a push for the NDEP and the SWPCC to be more proactive in the implementation of the stormwater NPDES permit. The USEPA expressed that the Truckee Meadows, a Phase 1 community, should have already had many of the elements of the program underway, particularly a program for construction inspection. The USEPA was also critical of the timeline as it had been laid out in the SWMP saying that it was not aggressive enough and that implementation needed to be within the term of the permit due to expire in 2005.

Presentations were made to the RWPC, Reno City Council, Sparks City Council, and the Washoe County Board of Commissioners on the status of the program and the implications of the Storm Water Quality Management audit conducted by USEPA. Most significant was the requirement that the program elements for Construction and Industrial stormwater inspections be accelerated to be in place by July 2003, to coincide with the implementation of the Clean Water Act NPDES Storm Water Quality Phase 2 permit. Phase 2 lowered the threshold of construction sites requiring a permit from NDEP and a Storm Water Quality Pollution Prevention Plan (SWPPP) from 5 acres down to 1 acre. The RWPC authorized additional funding to the program so the Co-Permittees could accelerate the development of guidance manuals for construction site BMPs and Structural Controls for Post Construction.

The SWPCC jointly developed a website www.TMstormwater.com for the regional program. For convenience, it has been hosted on the City of Reno website and server. The independent web address is intended to show autonomy from the City.

2003: During the winter and spring**,** the SWPCC completed The Truckee Meadows Construction Site Best Management Practices Handbook and the construction inspection program structure was developed. Draft ordinances for construction and industrial implementation of the inspection program were developed. The SWPCC conducted several outreach workshops to reach the construction community through the American Society of Civil Engineers (ASCE), the Builders Association of Northern Nevada (BANN), the Associated General Contractors (AGC) and others.

The City of Reno amended its municipal code to address both industrial and construction site discharge. Since the City of Reno did not have any inspectors, a fee structure was adopted to support the hiring of two stormwater inspectors. The City of Sparks and Washoe County cross-trained existing construction inspectors and began construction inspections as well. Washoe County customized the ordinance language, and adopted it as well.

The SWPCC held an initial public workshop to reach out to the engineering, development and construction community on the committee's development of the Truckee Meadows Structural Controls Design Manual. Later, a second public workshop was held to present the final Structural Controls Design Manual, which was also known as the Guidance on Source and Treatment Controls for Storm Water Quality Management.

Concurrently, there was an effort to develop a Truckee Meadows Regional Watershed Plan. The RWPC as well as the 319(h) grant program provided funding from NDEP. Along with the plan development, there was a fundamental assessment of the tributaries to the Truckee River. There was a recommendation that a committee be formed to implement the Watershed Plan. However, since of the Watershed Plan goals overlapped with the Stormwater program the conclusion was to incorporate watershed management as it relates to water quality into the purview of the SWPCC.

The remaining grant funding was directed to an effort towards a watershed coordinator (KJC were selected to address the coordinator scope of work) and development of a Low Impact Development Manual.

2004: The RWPC accepted the final Truckee Meadows Structural Controls Design Manual. The Structural Controls program implementation was not clearly defined by the USEPA or NDEP, so much of the interpretation was left up to the community. The public meetings and manual development prompted numerous questions:

- What is a practical threshold to impose structural controls for new development and redevelopment?
- What should be involved in the permitting, application and design approval process and how should the structural controls be tracked, inspected and maintained?

To answer these questions fairly, it was the consensus of the SWPCC that the use of a Professional Advisory Group (PAG) was warranted. The Co-Permittees requested and were granted full funding from the RWPC for the facilitation of this group.

In April, participants for the PAG were solicited from various groups in the community. The selected members held their first meeting in May 2004. They met again in June and August. In September, the SWPCC gave the RWPC an update regarding the progress of the PAG and the development of the Low Impact Development Manual.

One of the recommendations from the PAG was to develop a standard design template to aid in simplifying implementation of the Storm Water Quality Management practices and Low Impact Development. The SWPCC agreed and the project was funded in part by the RWPC, while the balance was shared equally between the Cities of Reno and Sparks, and by Washoe County.

With the anticipation of the 2005 permit issuance and NDOT being permitted independently, there was a need to amend the Interlocal Agreement. The amended agreement included three other significant changes:

1. The Storm Water Permit Coordinating Committee representation increased from one to two members from each Co-Permittee.
2. The City of Sparks and Washoe County must contribute to the salaries of the City of Reno staff designated as the Stormwater Coordinator and secretary to the Committee.
3. The Committee must expand its purview to include watershed management.

The amended agreement regarding the NPDES implementation was approved by the Cities of Reno and Sparks and by Washoe County, dated June 22, 2004.

In October, the NDEP issued a new draft NPDES permit for the Truckee Meadows Co-Permittees to review. The PAG met to review the draft with the SWPCC and commented.

2005: In January, the NDEP issued a new 5-year NPDES permit. One new requirement of the permit was for the SWPCC to update the SWMP by January 2006. The PAG met once more in February and in May the SWPCC accepted from K/J Technical Memorandum LU 2.3.C, Final Recommended Policies and Procedures for Structural Controls and Low Impact Development (LID) in the Truckee Meadows.

The Truckee River Fund granted the City of Reno funding for the inclusion of tree box filters as an

LID demonstration feature into the Virginia Street Improvement Project. The intent was to treat the first flush of stormwater off of the street and sidewalk and potentially improve stormwater quality in an ultra-urban setting.

A formal subcommittee of the SWPCC regarding ordinance development for LID was established with representation from each of the Permittees. The subcommittee presented to BANN after a number of public meetings on LID design guidance and draft ordinances. BANN was invited to participate in the review of draft ordinances and discussion of local codes and issues.

To develop the LID implementation approach, the committee conducted a series of public meetings and workshops to discuss the following factors:

- LID programs and practices in other communities;
- The regulatory framework for structural controls and LID;
- The development of regional policies and procedures for structural controls and LID practices;
- The preferred format of the LID Handbook;
- The concurrent development of a watershed assessment program and an assessment of problem road crossings and culverts in the Truckee Meadows;
- Concurrent public education and outreach activities with the University of Nevada Cooperative Extension;
- The development of maintenance and vector control policies with the District Health Department; and,
- Comments and concerns of the general public.

2006: In January, the Truckee Meadows Storm Water Quality Management Program Annual Report displayed the updated schedule for the implementation of the program. The implementation and enactment of ordinances for Structural Controls was planned to take place during fiscal years 2005-06 and 2006-07. In February, the SWPCC gave a presentation to the BANN regarding the SWMP and Construction Site BMPs. In April, staff from the Cities of Reno and Sparks and Washoe County conducted beta testing of the new Standard Design Guidance worksheets for LID and structural controls.

2007: The Regional Water Planning Commission was eliminated when Chapter 531, Statutes of Nevada created a new regional water entity in Washoe County named the Western Regional Water Commission (WRWC). The new law effective April 1, 2008, also created the Northern Nevada Water Planning Commission (NNWPC).

The NNWPC is a technical advisory group that reports to the WRWC. The NNWPC is responsible for developing a Comprehensive Regional Water Management Plan and recommending it to the WRWC for adoption. This Commission continued its interest and support of the Truckee Meadows Storm Water Quality Management Program.

In an on-going effort to implement the SWMP, the City of Reno staff presented to the City of Reno Planning Commission the concepts of LID and structural controls for post construction stormwater quality. The Commission requested that staff initiate the ordinance development. In April, staff gave the same presentation to the Truckee Meadows Branch of the American Public Works Association (APWA).

An update of the Structural Controls Design Manual provided additional information on the water quality of the Truckee River and significantly updated design guidance and information on public domain and manufactured structural treatment controls. The April 2007 update of the manual included a series of Design Guidance Worksheets for structural treatment controls and LID practices. The worksheets utilized Excel spreadsheets with write-protected design criteria from the manual to provide a tool to assist with the consistent design and review of proposed structural treatment controls and LID practices in the Truckee Meadows. The Design Guidance Worksheets are intended to be used by designers and submitted to agency staff to expedite the plan review process.

In August, the NNWPC accepted the final Low Impact Development Handbook. The Commission was advised that the City of Reno would be moving forward with developing code for Post Construction Storm Water Quality Management and Low Impact Development. The SWPCC adopted the final LID Manual at their August 23, 2007 meeting.

An outreach presentation was made in 2007 to the *Interim Western Regional Water Commission Staff Working Group* on the Truckee Meadows SWMP in which implementing the Structural Controls for Storm Water Quality was discussed, and the adoption of codes and ordinances was identified as a milestone. In September 2007, staff from City of Reno, City of Sparks and Washoe County provided training on the implementation of Structural Controls for Post Construction in a workshop sponsored by the ASCE and APWA. The components of the City of Reno draft ordinance were presented. In November, the presentations and training continued when staff was involved in the *Lorman Education Services class - Current Issues in Storm Water Regulation in Nevada,* and a *University of Nevada Cooperative Extension class - Harvesting Water in the Landscape: Implementing Low Impact Development*. The training class specifically addressed Structural Controls for Post Construction Storm Water Quality and the City of Reno draft ordinance scheduled to go to the City of Reno Planning Commission in December. Filterra at the AGC office hosted another free seminar on LID.

In December, the BANN requested that a committee be formed with representatives from the City of Reno and BANN to review the draft ordinance for Post Construction Storm Water Quality. This postponed taking the ordinance to the Planning Commission.

2008: In January, the BANN/Reno Committee initiated meetings to discuss the draft ordinance. The SWPCC was provided with a status update of Reno's draft ordinance and their discussions with the BANN/Reno Committee. In July, the BANN/Reno Committee concluded their review of the draft ordinance. The BANN representatives offered suggestions for the development of a Pass/Fail Checklist. The City agreed to update the City of Reno Public Works Design Manual for consistency with the draft ordinance.

In September, with the anticipation of the City of Reno ordinance moving forward in the winter, another training class in LID design and use of the design guidance worksheets was held with

ASCE. In preparation, two practice training sessions were scheduled with committee representatives, other staff and BANN representatives, to provide input into the training formats on the use of the Design Guidance Worksheets. Many of the newer committee members and staff were not familiar with on-line worksheets as tools. The Pass/Fail Checklist was introduced to all in attendance.

NDEP representatives conducted an audit of the Truckee Meadows Storm Water Quality Management Program. NDEP staff met with each entity to evaluate how they were administering the program and issued separate letters to each of the entities with regard to the findings. NDEP determined that all three Permittees continued to meet the terms of its MS4 permit.

One of the sections within the audit findings letter was "**Low-Impact Development".** The letter sent to the City of Reno stated, "*Reno will steer post-construction facilities to use LID, where feasible. A LID Manual has been developed for the Truckee Meadows area and is available to the public. Reno has adopted an ordinance for post-construction controls with an emphasis on LID. Some builders have expressed concerns about the design with checklists, prompting a community based review of the worksheets and checklists. The LID ordinance will be presented simultaneously to the Washoe County Board of County Commissioners (WCBCC) and the Reno City Council for their approval, estimated in January 2009. Reno installed four tree box filters as an urban LID pilot project and found there were some problems with the installation and design and watering schedule. There will be challenges as LID becomes more prevalent in the Truckee Meadows, simply in the retooling of construction, maintenance and monitoring. Reno will also try to obtain grant money to do more LID pilot projects in downtown Reno*."

2009: An update of the City of Reno's Public Works Design Manual was initiated to support LID and other structural controls consistent to the ordinances. A presentation was made to the NNWPC regarding the Construction Site BMP Field Guide and other stormwater program elements. The Commission was specifically briefed on the status of implementation of Structural Controls/LID.

In November, the first public workshop on the City of Reno's Public Works Design Manual was held at the AGC offices, and in December, two public workshops were held to receive comments on the City of Reno's Public Works Design Manual. Chapter X was added to the Public Works Design Manual specifically for Post Construction Structural Controls. An amended version of the manual and a table of comments with corresponding sections were posted on the City of Reno website to enable final comments and rebuttal.

The City of Reno Planning Commission approved the amendments to Reno Municipal Code to include Post Construction Storm Water Quality. The Reno City Council subsequently approved the ordinance.

2009-2012: Due to the recession, there was very little new development. Staff within each jurisdiction was cut. If there was a silver lining, it gave the plan reviewer time to become acquainted with the worksheets.

2012: The Standard Design Guidance Worksheets were updated and version 1.04 posted to the TMStormwater.com site.

2013 - 2014: Washoe County and City of Sparks developed ordinances similar to Reno's for

Structural Controls for New Development and Redevelopment.

The LID Handbook was developed with the intention to complement the Truckee Meadows Structural Controls Design Manual. However, it seemed one would get used but not the other. Consequently, the SWPCC decided to merge the two regional manuals into one manual for regional planning and design guidance.

Local design engineers, architects, landscape professionals and contractors should use this current version, the 2015 Truckee Meadows Structural Controls Design & LID Manual.

Appendix B

NEMO Fact Sheets

Protecting water quality through community planning

Nonpoint Education for Municipal Officials

www.unce.unr.edu/nemo

Fact Sheet FS-09-25

Low Impact Development in Northern Nevada: Bioretention

By Susan Donaldson, Water Quality Education Specialist
UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Low Impact Development (LID) is a sustainable strategy for handling stormwater that uses techniques that aim to mimic the way water behaved on the site before development occurred. LID uses a variety of design and pollution-prevention techniques, including bioretention, to compensate for impacts such as increases in runoff flow rate and volume and water-quality impairment. One of the most recognized and widely applied sustainable stormwater management techniques is called bioretention.

Benefits of Bioretention

- **IMPROVES** water quality
- **REDUCES** post-development stormwater volumes and offsite flows
- **INCREASES** groundwater recharge
- **COSTS LESS** to design, install and maintain than conventional stormwater technologies
- **PROVIDES** attractive landscaping
- **ENHANCES** wildlife habitat

How do bioretention features work?

Bioretention is the practice of routing stormwater to landscaped depressions filled with porous soil and covered with a thin layer of mulch. Unlike typical landscape designs that focus on raised planters or islands, these features store water in gentle depressions. Plants, including grasses, shrubs and small trees, are grown in the bioretention feature. The plants promote evapotranspiration, maintain soil porosity, encourage biological activity and absorb some pollutants. When located over silt- or clay-rich soils with slow infiltration rates, bioretention features typically require perforated drainage pipes called underdrains to facilitate proper drainage.

Chris Conway

This residential rain garden captures and filters runoff water.

Runoff from an impervious area, such as a parking lot or roof, is directed into a bioretention area. The flow can be contained within a planter box located at ground level or be diverted into a larger landscaping feature. The water infiltrates through the plant/mulch/soil environment, providing pollutant treatment. Infiltration rates must be tested prior to installation to ensure water does not remain ponded in the feature for longer than a few days to discourage mosquitoes and other vermin. Supplemental irrigation is needed for most bioretention features in northern Nevada to ensure plant survival during extended dry weather periods.

Bioretention features are designed to retain the stormwater runoff volume produced by the most frequently occurring

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LID is used because it is:

EFFECTIVE in reducing and treating urban runoff;

ECONOMICAL, when less infrastructure is required for LID practices than for traditional stormwater features;

SIMPLE!
Most LID features are not highly engineered, expensive or elaborate;

FLEXIBLE and customized for each site;

USEFUL in achieving multiple objectives: stormwater management, landscape beautification, habitat improvement, open space connectivity, etc.; and

DESIRABLE, because it adds value when the landscape features used to achieve LID goals are also aesthetically pleasing. This can increase property values.

rainfall or runoff events. This is determined from records of storm events in the area. For larger storms, most large bioretention features are designed so that any overflow of stormwater runoff is diverted to a conventional stormwater conveyance system, such as a storm drain. Even though the bioretention feature may not be able to retain all the stormwater from these large events, some settling and filtering of the stormwater occurs before it overflows to the conventional storm drain system.

Where can bioretention be used?

Bioretention features can be constructed on individual sites, within a new development, or even retrofitted into an existing landscape. This technique can be as simple as directing the downspout of gutters to a landscaped garden bed or rain garden instead of the driveway or street. In a commercial setting, bioretention can be incorporated into parking lot islands and perimeters, street median strips, driveway perimeters, the centers of cul-de-sacs and virtually anywhere landscaping is planned, including planter boxes located next to buildings.

While they should be planned in advance, bioretention areas are one of the last features to be installed within a new development. To prevent clogging and provide pretreatment, include grass buffer strips or swales leading into the feature. Consider existing vegetation and drainage patterns and the location of existing or proposed underground utilities, including septic or sewer systems, water lines and storm drain pipes, when designing the system. These systems are most cost-effective when applied to areas with minimal slope, well-draining soils and low sediment loads, which helps to discourage clogging. Mark areas that will incorporate bioretention into native soils before work begins to avoid soil compaction during construction. Vehicular traffic other than what is specifically necessary to construct the facility should not be allowed within 10 feet of planned bioretention areas.

If proposed to be located in"hotspot" drainage areas near gas stations or other businesses that have high potential pollutant loads, or areas with known soil and/or groundwater contamination, bioretention features must be designed as flow-through planters that do not allow infiltration into underlying soils. Flow-through bioretention facilities are designed to temporarily store stormwater within an impermeable container, such as a concrete box or a liner. These facilities collect filtered stormwater in perforated underdrain pipes located at the bottom of the impermeable container and drain to an approved discharge point, such as a ditch or storm drain.

Where an approved discharge point is available, flow-through bioretention facilities can also be used in areas that have poorly draining soils, where the water table is within 6 feet of the ground surface, next to

Do rain gardens actually work to improve water quality?

The pollutant removal effectiveness of bioretention basins has been the focus of several studies. The publication, "Design Guidelines for Stormwater Bioretention Facilities," University of Wisconsin-Madison (2006), lists the following typical pollutant-removal rates for these facilities.

Pollutant	Removal Rate
Total phosphorus	80%
Metals (copper, zinc, lead)	>90%
Total Kjeldahl nitrogen	65-75%
Total suspended solids	90%
Ammonium	60-80%
Organics	90%
Bacteria	90%

buildings, on steep slopes, or at sites with other constraints that prevent infiltration of stormwater into underlying soils.

How are bioretention features maintained?

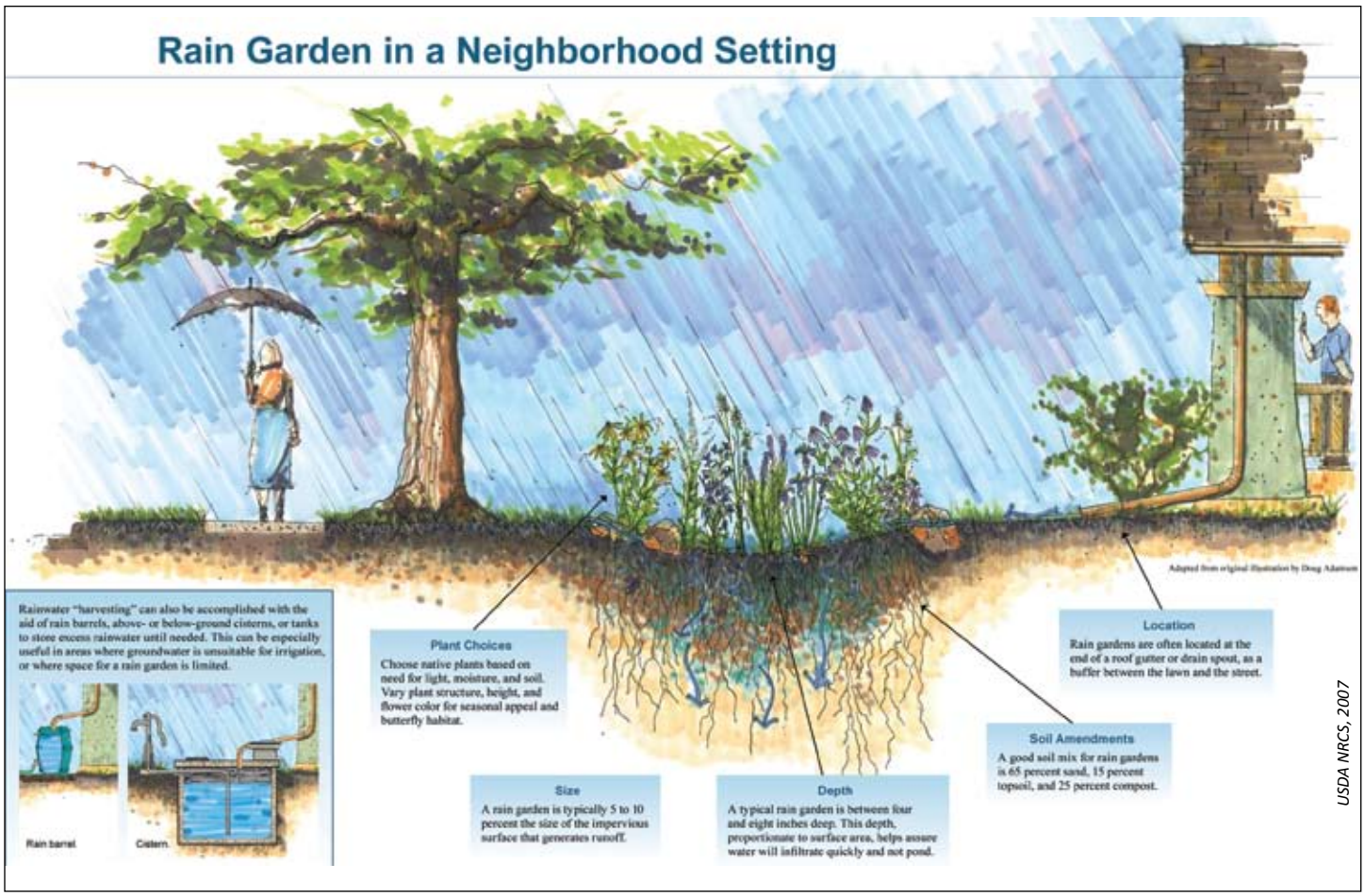
Maintenance needs include typical landscape maintenance tasks, such as pruning, mowing, adjusting and monitoring irrigation systems, hand weeding, trash collection and replacement of dead plants. The mulch layer should be removed if it is reducing the water storage volume, and the surface soils should be excavated if clogging has occurred. Minimize the need for fertilization by selecting well-adapted or native plants. In most cases, native plants will be best adapted to the local climate, better able to withstand pests, require less maintenance and provide habitat for wildlife. Select plants that are able to withstand submergence for a few days during extended storm periods. See FS-09-28, LID in Northern Nevada: Plant Materials, for suggestions.

In addition to routine landscape maintenance, be sure to inspect bioretention areas regularly for accumulated sediment, damage and standing water. Check cells 48 hours after a rainstorm to ensure they have completely drained. Each month, inspect and repair eroded areas. Remulch bare areas as needed. If a bioretention area has failed, it can be excavated and rebuilt at the same site if infiltration rates are sufficient or underdrains are constructed.

Rain gardens

One of the most common bioretention designs for capturing runoff in a landscaped area is called a rain garden. The rain garden is depressed below adjacent impervious surfaces, such as concrete driveways or paved roadways. The water drains into the garden, where it gradually infiltrates into the soil bed. Pollutants are removed by a variety of processes, including adsorption, filtration, volatilization, ion exchange and decomposition.

"Rain gardens are more than just depressions in the ground containing plants. They must be carefully designed to capture the appropriate volume of stormwater runoff, drain quickly, avoid erosion and blend with the landscape. The design should include a safe overflow area, such as a storm drain, ditch or open space area, in case stormwater exceeds the capacity of the rain garden."



USDA NRCS, 2007

For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

LID: An Introduction, FS-09-22

Soil Considerations, FS-09-23

Rainwater Harvesting, FS-09-24

Bioretention, FS-09-25

Vegetated Swales and Buffers, FS-09-26

Green Roofs, FS-09-27

Plant Materials, FS-09-28

Porous Pavement, FS-09-29

Roadway and Parking Lot Design, FS-09-30

Maintenance, FS-09-31

Rain gardens are used nationwide as a technique for cleaning up stormwater. In northern Nevada, they are also useful in conserving water for landscape use, which may become even more important as water costs rise. In addition to filtering runoff pollution and conserving water, rain gardens have many benefits. They create habitat for birds and butterflies, enhance sidewalk appeal, add interest to the landscape and reduce high-water-use turf areas. In addition, where native soils drain well, they recharge groundwater.

Rain gardens are more than just depressions in the ground containing plants. They must be carefully designed to capture the appropriate volume of stormwater runoff, drain quickly, avoid erosion and blend with the landscape. The design should include a safe overflow area, such as a storm drain, ditch or open space area, in case stormwater exceeds the capacity of the rain garden.

After identifying an appropriate location to which runoff from roofs or pavement can be diverted, design the rain garden to capture and contain the water-quantity volume from the site - generally the first half-inch of runoff from the contributing drainage area. Typically, the soil surface should be depressed 6 to 12 inches to create space for water to temporarily pond. Excavate soil from the basin to make space for the soil mix, fill the hole with water, and observe how fast the water soaks in. Refer to FS-09-23, LID in Northern Nevada: Soil Considerations, for small-scale testing methods, or consult the Truckee Meadows Structural Controls Design Manual for approved methods. Rates should be greater than one-half inch per hour. If native soil infiltration rates are slower, place an underdrain surrounded by clean drain rock at the bottom of the basin to drain the system and prevent extended ponding. Connect the underdrain to a ditch or part of the storm drain system. Place a 4-inch layer of pea gravel in the bottom of the excavated basin to maintain drainage into the underlying native soils. Avoid using filter fabric in the bottom of the basin and around the underdrain, as it tends to clog with time, requiring complete excavation and replacement of the rain garden.

Next, construct a berm around the edge of the rain garden, using the soil that was excavated to make the depression. If the site slopes, the berm should be highest at the down-slope side. Do not attempt to construct a rain garden on steep slopes of 20 percent or greater.

The recommended soil replacement mix is 50 to 60 percent clean sand, 20 to 30 percent topsoil and 10 to 20 percent certified organic or pesticide-residue-free compost, thoroughly mixed and approximately 30 inches deep. If the existing soils are well-draining sands, loamy sands, sandy loams or loams, the percentage of sand and topsoil in the soil replacement mix can be reduced. Complete removal and replacement is often needed when existing soils are silts or clays. Leaf compost is a preferred type of amendment because the nutrient content in the leaves is

Rain Garden Design Tips

- Don't build a rain garden within 10 feet of building foundations.
- Keep rain gardens at least 100 feet away from septic system leachfields and water wells.
- Don't make the depressed area in the rain garden so deep that a tripping hazard might occur. Most are 6 to 8 inches deep.
- Redirect rooftop runoff using underground piping, a vegetated swale or channel, or a gutter extender. Don't let the runoff flow across bare soil, as erosion and clogging of the rain garden may occur due to excessive sediments in the runoff water.
- To avoid damaging tree roots, don't excavate an extensive rain garden under large trees.
- Avoid rain gardens in areas where the seasonally high groundwater table is within 6 feet of the ground surface, to guard against potential groundwater contamination.
- Don't build rain gardens in areas with slopes greater than 20 percent.

typically minimal during the fall when leaves drop. This reduces leaching of nutrients out of the system. Do not use compost that includes animal or food wastes.

Plant the berm or use landscape fabric and mulch to stabilize the soil and reduce weed problems. Design an irrigation system for regular watering from May through October and between rainfall events. Drip systems are ideal for rain gardens. Select plants that will survive stresses such as periodic inundation or very dry periods, and avoid species that are invasive. Consider a mix of perennial flowering plants, shrubs and ornamental grasses, or consult LID in Northern Nevada: Plant Materials, FS-09-28.

Mulch the soil surface after installing plants. Mulching helps conserve water and decreases the potential for soil erosion from the garden. It also helps suppress weeds.

Maintenance is similar to that for any landscape bed. Monitor irrigation to make sure plants are not stressed. From May through October, monitor to ensure standing water does not persist for seven or more consecutive days to avoid mosquito breeding. Complete drainage within 48 hours is preferable. Replace mulch as needed to keep the soil surface covered. Inspect trees and shrubs for pests or diseases, and treat as needed or replace. Prune and weed when appropriate. Remove litter and debris on a regular basis.

Tree box filters

In more urban or developed settings where space is limited, tree box filters can be used to add bioretention while providing landscape aesthetics. Filter boxes are mini-bioretention systems that provide landscaping benefits without requiring a high degree of maintenance. Tree box filters can be designed as flow-through planters with underdrains that do not allow infiltration into underlying soils, or they can be

Susan Donaldson

Tree filter box under construction on Virginia Street in Reno, Nevada., near the Truckee River. Runoff from the street enters the box through the curb cut.

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

Additional information about bioretention can be found at:

- Bioretention.com, An Online Reference for Designers, www.bioretention.com/
- Bioretention at North Carolina State University, www.bae.ncsu.edu/topic/bioretention
- Low Impact Development (LID) Urban Design Tools, www.lid-stormwater.net
- Prince George's County, Maryland, Bioretention Manual, www.co.pg.md.us/Government/AgencyIndex/DER/ESG/Bioretention/bioretention.asp
- Stormwater Manager's Resource Center, www. stormwatercenter.net

designed with drainage holes that allow infiltration.

As with all landscape features, tree box filters require routine maintenance. Check the curb cut inlet areas and the surface of the soil inside the box several times a year to make sure they are free of trash and debris, there is no standing water, and the filter box continues to function as designed.

National NEMO Network

Susan Donaldson

A completed tree filter box in downtown Reno (above).

Rain garden designs for parking lots (at left and below).

National NEMO Network

References:

- Atchison, D., K. Potter and L. Severson, 2006, Design Guidelines for Stormwater Bioretention Facilities, University of Wisconsin-Madison Water Resources Institute, Madison, WI.
- USDA-NRCS, 2007, Rain Gardens, Montana NRCS, 06/07/MT.

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

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Fact Sheet FS-09-27

Low Impact Development in Northern Nevada: Green Roofs

By **Susan Donaldson,** Water Quality Education Specialist

UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Green roofs are one type of Low Impact Development (LID) technique. LID is a sustainable approach to stormwater management that minimizes impacts on waterways by controlling rainfall and runoff close to the source. Also referred to as vegetated roofs, ecoroofs, roof gardens and living roofs, green roofs have been used for hundreds of years as a way of keeping houses cool in the summer and warm in the winter.

Benefits of Green Roofs

- **ABSORB** rainfall
- **REDUCE** urban runoff at the source
- **IMPROVE** runoff quality
- **REDUCE** the urban heat island effect
- **ADD** green, natural landscapes and wildlife habitat to dense urban areas
- **PROVIDE** building insulation
- **REDUCE** noise pollution
- **INCREASE** roof lifespan

Connecticut NEMO Program

The use of green roofs is growing in the West. In addition to absorbing rainfall and snowmelt, they provide a number of other benefits. During the heat of summer, the surface temperature of a vegetated rooftop can be cooler than the air temperature, significantly reducing the urban "heat island" effect of conventional roofs. Green roofs also provide excellent insulation and can reduce indoor heating and cooling costs. They help filter air pollutants, provide increased wildlife habitat and urban green space, and are visually attractive.

How does a green roof work?

A typical green roof consists of several inches of lightweight soil or other growth medium planted with specially selected vegetation, placed over a drainage layer and a waterproof membrane.

Green roofs help to decrease the amount of stormwater that runs off roofs by absorbing water like sponges. An average of 63 percent of the rainfall volume of most rainstorms can be retained in 2 to 6 inches of growth medium. The plants take up and transpire rainwater and help process pollutants such as nutrients. In addition to stormwater-management benefits, green roofs also help decrease energy costs by providing thermal mass and evaporational cooling. The layer of soil and plants is more resistant than conventional roofing materials to the damaging effects of ultraviolet light and temperature extremes, helping to prolong the life of the roof.

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For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

LID: An Introduction, FS-09-22

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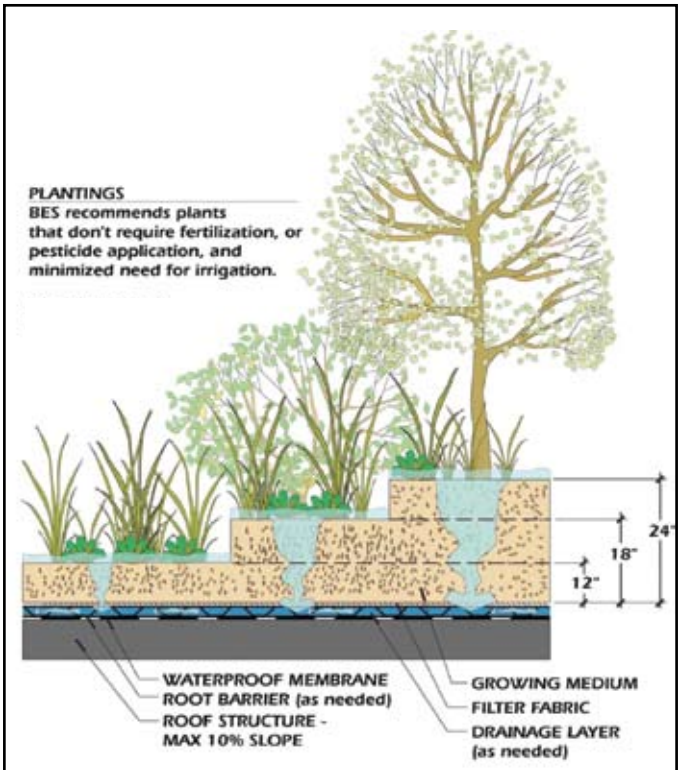
Roadway and Parking Lot Design, FS-09-30

Maintenance, FS-09-31

Types of green roofs

There are two structural types of green roofs: extensive and intensive. **Extensive green roofs** are typically installed on roofs with slopes of less than 25 percent. They are relatively lightweight and are planted with hardy, drought-tolerant plants such as sedums, succulents or hardy perennials. This keeps irrigation needs and costs relatively low, although some irrigation will be needed during initial plant establishment and occasionally during hot and dry periods. It is important to monitor plant health and adjust irrigation accordingly. Extensive roofs generally incorporate about 2 to 6 inches of lightweight growth media. The media must be low in organic matter content to avoid settling, leaching of nutrients and rapid plant growth.

Extensive green roofs are low-maintenance and usually do not provide public access. Depending on the age and type of the structure, roof reinforcement to handle the extra weight of an extensive green roof may not be needed, making them potentially suitable for retrofit projects. Consult an architect and/or structural engineer whenever considering the retrofit of a green roof onto an existing roof.



Elements of an intensive green roof.

Portland Bureau of Environmental Services (BES)

Intensive green roofs typically include 12 inches or more of soil or growth medium and may incorporate lawns or trees. They require extra structural support, as they are designed to create usable outdoor garden spaces. Some hospitals and other public facilities add green roofs as forms of healing or nature gardens. They can retain more stormwater and provide more insulation and energy efficiency than extensive roofs. However, the cost is higher for intensive roofs, as there are additional structural and irrigation requirements. The addition of a waterproof membrane, a drainage layer, growth medium and plants adds weight to the roof. On average, each square foot of green roof, when saturated during a storm, will add 10 to 25 pounds. The load can be incorporated when designing new buildings, but may require additional measures when retrofitting onto existing buildings.

To reduce the potential for structural problems and leaks, hire experienced engineers and contractors to design and install extensive and intensive green roofs.

Chris Conway

This building in Portland, Oregon, has both extensive (left) and intensive (right) green roofs.

Are green roofs expensive?

The initial costs for engineering and installing a green roof average about $10 to $15 per square foot for new construction, and $15 to $25 per square foot for re-roofing, which is considerably higher than the cost of a conventional roof. However, if correctly engineered and constructed, green roofs can provide long-term savings resulting from reduced energy costs and roof replacement costs. The lifespan of a green roof can be as much as twice as long as a conventional roof because green roofs are more resistant to UV light and temperature fluctuations.

The growth medium should be lightweight and relatively low in organic matter to prevent excess nutrients from leaching out of the medium and into the runoff. Lightweight materials such as pumice are often added to the growing medium to reduce the need for structural improvements to address increased weight loads.

Before selecting plants for a green roof, determine the roof area's average high and low temperatures, as well as expected temperature extremes. In addition, determine the roof's exposure to sunlight and wind, and its average annual precipitation. Roof slope and orientation will influence both the amount and intensity of sunlight reaching the surface and the exposure to prevailing winds. These factors affect soil moisture content and plant survivability. Vents from heating and air conditioning units can result in added soil moisture losses, and their locations should be considered when designing the landscaping.

Susan Donaldson

An extensive green roof planted with sedums.

Other factors include the rate of plant establishment and longevity, how densely the plants will grow, and resistance to disease and pests. Ideally, green roof plants should be long-lived, low-maintenance, able to tolerate shallow soils, self-sustaining without fertilizers or pesticides, and require minimum summer irrigation. Avoid deeply rooted species.

Plant materials for northern Nevada must tolerate wide swings in temperatures and high winds. In most cases, due to prolonged dry periods, irrigation will be needed to keep the plants alive. Avoid highly flammable plants such as annual grasses. Aesthetic appeal is also important, as many plants have dormant periods during which they do not appear green. Many plants used for green roofs appear red, orange, yellow or other colors

Portland Bureau of Environmental Services

An extensive green roof on the Portland Building in Portland, Oregon. The plants chosen offer a variety of colors.

Maintenance

Like a conventional roof, a green roof requires periodic care for optimal performance.

- Inspect the green roof on a regular basis for leaks and proper drainage. Current technology for waterproofing is greatly improved, and low-cost electronic grids can be installed under the membrane to locate leaks.
- If used, monitor the irrigation system and adjust to plant water demands. Cycle irrigation on and off to avoid runoff. Irrigation may also be needed to decrease wildfire risk during the dry season.
- Keep drainage pipes and other drainage features clear of debris.
- Remove or mow dead plant material and weeds.
- Add mulch periodically.
- Replace vegetation as needed.

LID is used because it is:

EFFECTIVE in reducing and treating urban runoff;

ECONOMICAL, when less infrastructure is required for LID practices than for traditional stormwater features;

SIMPLE!
Most LID features are not highly engineered, expensive or elaborate;

FLEXIBLE and customized for each site;

USEFUL in achieving multiple objectives: stormwater management, landscape beautification, habitat improvement, open space connectivity, etc.; and

DESIRABLE, because it adds value when the landscape features used to achieve LID goals are also aesthetically pleasing. This can increase property values.

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

at various times of the year.

Plants for extensive green roofs should be low-growing, drought-tolerant species that spread or reseed naturally and create a thick layer on the roof. Some of the more common plants used in extensive green roofs include sedums, succulents and hardy perennials. Conventional turf-type grasses should not be used due to the amount of irrigation and maintenance needed. Plants for intensive green roofs (i.e. roof gardens) include a wide variety of trees, shrubs, herbs, succulents and grasses.

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

Additional information about green roofs can be found at:

- Green Roofs for Healthy Cities, www.greenroofs.org
- Michigan State University, Department of Horticulture, Green Roof Research Project, www.hrt.msu.edu/greenroof/
- Portland Bureau of Environmental Services, EcoRoof, www.portlandonline.com/bes/index.cfm?c=44422&
- Urban Design Tools, Low Impact Development, Green Roofs, www.lid-stormwater.net/greenroofs_home.htm
- U. S. Environmental Protection Agency, Heat Island Mitigations, Green Roofs, www.epa.gov/hiri/strategies/greenroofs.html

Susan Donaldson

This green roof in San Francisco provides a way to capture and infiltrate rain water, reduce stormwater runoff and augment valuable green space.

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Fact Sheet FS-09-22

Low Impact Development in Northern Nevada: An Introduction

By Susan Donaldson, Water Quality Education Specialist
Melody Hefner, Water Quality Program Assistant
UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

While we don't get a lot of precipitation in northern Nevada, when it rains or when snow melts, there is often enough water to result in flow from roads, driveways, sidewalks and other impervious surfaces into the storm drain system. In addition, activities such as landscape irrigation with sprinklers, washing your car in the driveway or washing off your sidewalk often produce runoff that drains into the storm drain system.

Traditional storm drain systems are designed and constructed to convey water safely off the road to avoid flooding and traffic problems. They typically consist of a connected system of impervious concrete curbs and gutters, catch basins and underground pipes. Unfortunately, they generally are not designed to also improve runoff water quality. The water flowing off roads and other impervious surfaces picks up any pollutants, such as oil drips, trash, road sand and salts, and metals from automobile brakes. These pollutants are then carried with the stormwater and delivered, without treatment, into nearby water bodies such as the Truckee River.

As our communities grow, the total amount of impervious surface increases. This means that there is less open land available to absorb, store and treat stormwater. At the same time, we are increasingly challenged to maintain or improve water quality in local creeks and rivers so that we can continue to enjoy high-quality drinking water and opportunities to swim, fish and enjoy our waterways.

A strategy called Low Impact Development (LID) was developed to allow us to continue to grow while avoiding additional problems from polluted runoff. LID practices can also be used to treat runoff from existing developed areas.

Susan Donaldson

Bare slopes and impervious surfaces can result in muddy runoff that can damage rivers and streams being fed by stormwater.

Benefits of LID

- **REDUCES** and **CLEANSES** urban runoff
- **CONSERVES** water and open space
- **PROTECTS** waterways
- **AIDS** in groundwater recharge
- **REDUCES** traditional storm drain infrastructure

What Is Low Impact Development?

Low Impact Development, or LID, is a sustainable approach to stormwater management that minimizes impacts on waterways. LID can be integrated into "Green Design" or "Smart Growth" or similar approaches to community design. It is a flexible, site-specific, customized approach that uses

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LID is used because it is:

EFFECTIVE in reducing and treating urban runoff;

ECONOMICAL, when less infrastructure is required for LID practices than for traditional stormwater features;

SIMPLE!
Most LID features are not highly engineered, expensive or elaborate;

FLEXIBLE and customized for each site;

USEFUL in achieving multiple objectives: stormwater management, landscape beautification, habitat improvement, open space connectivity, etc.; and

DESIRABLE, because it adds value when the landscape features used to achieve LID goals are also aesthetically pleasing. This can increase property values.

a variety of site-design and pollution-prevention techniques to compensate for the impacts of land development on site hydrology and water quality.

How does LID work?

LID attempts to mimic the way rainfall, snowmelt and stormwater runoff soaked into the ground before a site was developed. Instead of conveying stormwater directly into underground pipes, it is diverted onto open-space areas, into depressed landscaping, or into other LID features, where it infiltrates. Pollutants are broken down in the soil by bacteria or taken up in plants, providing a system of natural pollutant processing. Runoff decreases when water is stored in the soil pores. Some of the water will evaporate, be used by vegetation, or infiltrate and recharge groundwater in areas where favorable site conditions exist. These effects are maximized where the site is underlain by sandy soils.

There are a number of basic practices associated with LID, from better site design to incorporating open space and cluster development, to specific technologies. All the practices attempt to achieve the following:

■ Mimic predevelopment site hydrology

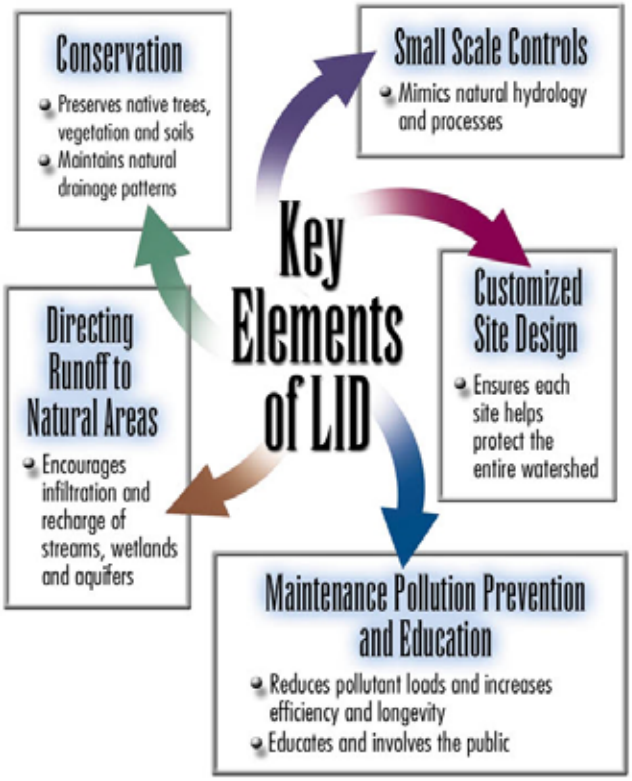
LID attempts to reduce runoff by finding ways to infiltrate stormwater onsite, much as it did prior to development. The harvested water soaks into the ground, helping to irrigate landscaping and replenish groundwater supplies. Some of the water evaporates. This results in less runoff and fewer pollutants in stormwater, as compared with traditional site-development practices.

■ Minimize disturbance to the site

Nevada's soils are easily erodible and rely on ground cover, leaf canopy and plant roots to retard erosion. The effects of soil disturbance and loss of native vegetation from grading activities during construction can last for a long time, unless revegetation is successful. Erosion of the ground surface contributes sediment to stormwater runoff. Sediment can be a source of excess nutrients and may also contain toxic chemicals and pathogens deposited from site activities. Minimizing site disturbance can minimize new inputs of these nonpoint sources of pollution.

■ Reduce impervious cover

Impervious cover, as noted previously, is any surface that prevents or limits the amount of water that soaks into underlying soils. Impervious surfaces include roads, driveways, sidewalks, parking lots, roofs and compacted soils. Reducing the amount of impervious surfaces when possible allows more area for onsite stormwater infiltration. There are many ways to reduce impervious cover. Instead of traditional concrete, consider permeable asphalt or concrete pavement, pavers or gravel. Minimize street



Source: Puget Sound Action Team

Susan Donaldson

Algae blooms can result from inputs of runoff contaminated with nutrients.

widths where appropriate, allowing for emergency access. Consider installing sidewalks on one side of the road, rather than on both sides.

■ **Minimize connected impervious cover**

This LID practice seeks to interrupt the flow of stormwater runoff by disconnecting the associated impervious surfaces. This may be as simple as directing flow from driveways onto lawns, where the runoff will slow down and some will infiltrate. Pollutants will be deposited and processed naturally. Stormwater can also be captured in rain barrels or cisterns or directed via roof gutter downspouts to the vegetated areas of the yard, where the landscaping will benefit from the added water. On a larger scale, impervious cover can be disconnected by using turf areas, native landscaping or swales.

■ **Control stormwater as close to the source as possible**

By decreasing flow across impervious surfaces, fewer pollutants are transported into the storm drain system. Small-scale LID practices capture, store and treat stormwater onsite.

Literature-Reported Percent Removal Efficiency For Various Pollutants

LID Practice	Total Suspended Solids	Total Phosphorous	Total Nitrogen
Bioretention	75-90%	70-80%	65-80%
Porous Pavement	70-90%	40-55%	10-20%
Vegetated Buffers	10-74%	0-10%	0-15%
Vegetated Swales	60-95%	5-45%	15-65%

The table above presents a summary of the literature-reported range of pollutant removal efficiencies for various LID practices. The range of removal efficiencies reflects differences in designs, variable stormwater pollutant concentrations and underlying soil properties. Source: Truckee Meadows Structural Controls Design Manual, April 2007 update.

What are common LID practices?

A wide suite of different LID practices are available that can be customized to each site. Some focus on improved site design, such as open space and cluster development designs. Others are specific features that reduce and treat runoff, including bioretention features such as rain gardens and filter boxes or permeable pavements. The benefits of each practice vary, in terms of both the amount of pollutant reduction that can be expected, and the effects on peak flow volumes, volume reduction and water conservation. The table on page 6 summarizes the general benefits of various LID practices.

How much does LID cost?

LID can be very cost-effective when compared to traditional development practices, particularly where soils are appropriate for infiltration. When incorporated at the planning stage, LID can reduce the cost of grading and stormwater management facilities. Additional savings can occur if road widths are minimized, alternatives to curb and gutter designs are used and other innovative design techniques are applied. In some cases, when large-scale detention basins can be eliminated, additional lots are freed for development. Lot values have increased in a number of developments that incorporated LID, due to the aesthetic value of additional open space.

Terri Svetich

Low Impact Development practices help protect the clarity and ecological health of our waterways.

■ **Preserve and restore natural landscape features**

Preserving natural features, such as trees, vegetated stream buffers, native plants and natural drainage channels, helps to reduce the potential for erosion and nonpoint pollution. Where natural features cannot be preserved, recreating or incorporating landscape and drainage features that mimic natural features can help reduce runoff and process nonpoint source pollutants.

■ **Facilitate detention and infiltration of stormwater**

Detaining stormwater runoff to allow infiltration to occur can be accomplished using rain gardens and other bioretention features, vegetated swales, lawn buffers or infiltration basins. Each of these landscaping features has different benefits and design requirements, but if designed correctly, all will reduce nonpoint source pollution and erosion and improve infiltration.

■ **Distribute small-scale practices throughout the landscape**

Rather than creating one large detention basin within a development, which takes a great deal of space and is often aesthetically undesirable, small-scale practices such as rain gardens or other bioretention features can be incorporated into the landscaping of each dwelling. These multifunctional landscapes will improve water quality without loss of developable land.

Why do we need LID?

Waterways in northern Nevada watersheds are subject to regulatory limits on certain nonpoint source pollutants, including nitrogen, phosphorus, total dissolved solids and other substances. LID is one strategy that helps to decrease the amounts of these pollutants delivered to local waterways by retaining stormwater onsite, where pollutant processing can occur.

The addition of large areas of manmade impervious surfaces and the use of traditional stormwater management systems have also resulted in major changes in the volume and rate of stormwater runoff. The traditional storm drain system concentrates flows and delivers them quickly to adjacent waterways. Because the opportunity to infiltrate stormwater and store it onsite is reduced, not only do storm flows reach waterways earlier, but the volume of flow is also increased. This can result in increased erosion and flooding in areas that previously were outside the natural floodplain.

Detention and retention basins can be used to help decrease peak flows, but they typically do not infiltrate stormwater or process pollutants.

Detention, Retention or Infiltration: What's the Difference?

Master Plans, Low Impact Development practices and Stormwater Management Manuals encourage increasing the ***detention, retention and infiltration*** of stormwater runoff. While all three terms are often used interchangeably, they are distinct practices that are used for different purposes.

Detention ***is the temporary storage and controlled release of stormwater to reduce peak flows from developed sites.*** Stormwater is detained. Most commonly, a **detention basin** is constructed within a development or at an offsite location. They are generally large and serve several homes or entire developments. Water flows into the basin through a large opening such as a storm drain pipe. Water exits the basin through a smaller opening, which slows the flow and reduces peak flows from the site. The peak flow rates leaving the site should be comparable to those that occurred during storm events before development took place. While not generally a design feature, some infiltration may occur through the basin floor. Some settling of suspended particles and debris will also occur.

Chris Conway

Detention basins collect and slowly release stormwater.

Most often, detention basins are designed so that they will empty within 24 to 48 hours after a storm has occurred. They are not practical or aesthetically pleasing on individual sites or within the home landscape. Also, detention basins typically do not reduce the increased volume of stormwater produced by manmade impervious surfaces.

Retention ***is the permanent storage of a portion of the stormwater produced by a developed site to allow infiltration, evaporation and/or uptake of the water by surrounding vegetation.*** Stormwater is retained. Retention generally occurs in a **closed basin or depression** of some kind. While there is no outlet from the retention basin for routine flows, an overflow structure must be designed to safely bypass stormwater flows from large storm events. To allow infiltration and prevent the long-term ponding of water, retention basins generally must be engineered to provide sufficient drainage. This may involve removal of the existing soil and subsoil and replacement with gravel, sand and/or mulch. Care must be taken not to compact the imported engineered soils.

Most municipalities have limits on the length of time that water can remain in a retention basin after a single event. These requirements are intended to reduce or prevent the breeding of mosquitoes or other vermin. Retention basins can be constructed on a very small scale and are well-suited for individual home landscapes. They can also be retrofit into existing landscapes. Small-scale retention features that incorporate plant materials are also considered to be LID bioretention areas. Rain gardens are one common type of bioretention area.

Infiltration ***is the entry of stormwater into the soil profile.*** Stormwater is infiltrated. Under normal predevelopment conditions, infiltration occurs at varying rates depending on the type of soil and vegetation present at the site. Some infiltration of stormwater may occur in traditional earthen detention and retention basins.

However, infiltration is often limited in these basins due to compaction of the soil during construction. Large infiltration features, such as **infiltration trenches or infiltration basins**, are generally engineered to improve the natural infiltration. If they become clogged with silt and debris, the infiltration rate will decline. The plant roots in bioretention areas provide pathways for water to infiltrate, which helps decrease the rate of clogging.

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

LID: An Introduction, FS-09-22
Soil Considerations, FS-09-23
Rainwater Harvesting, FS-09-24
Bioretention, FS-09-25
Vegetated Swales and Buffers, FS-09-26
Green Roofs, FS-09-27
Plant Materials, FS-09-28
Porous Pavement, FS-09-29
Roadway and Parking Lot Design, FS-09-30
Maintenance, FS-09-31

For more information about LID, see:

- Low Impact Development Center, Inc., *www.lowimpactdevelopment.org*
- National Institute of Building Sciences Whole Building Design Guide, Low Impact Development Technologies, *www.wbdg.org/resources/lidtech.php*
- Urban Design Tools, Low Impact Development, *www.lid-stormwater.net/background.htm*
- U.S. Environmental Protection Agency Polluted Runoff (Nonpoint Source Pollution), Low Impact Development (LID), *www.epa.gov/nps/lid/*

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

Benefits of LID Practices

Type of LID practice	Peak flow control	Volume reduction	Water quality improvement	For more information
Bioretention				
Rain garden	✔	✔	✔	FS-09-25
Tree box filter	✔	✔	✔	FS-09-25
Stormwater planter	✔	✔	✔	FS-09-25
Vegetated swale	✔	✔	✔	FS-09-26
Vegetated buffer	✔	✔	✔	FS-09-26
Green roof	✔	✔		FS-09-27
Porous pavement				
Porous concrete, asphalt	✔	✔	✔	FS-09-29
Permeable pavers	✔	✔	✔	FS-09-29
Rainwater harvesting				
Rain barrels, cisterns	✔	✔		FS-09-24
Site design				
Narrow road design	✔	✔		FS-09-30
Downspout routed[1]	✔	✔		FS-09-24
Tree planting	✔	✔		FS-09-25, FS-09-28

[1]*When downspout is routed to landscaping*

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Fact Sheet FS-09-31

Low Impact Development in Northern Nevada: Maintenance

By Susan Donaldson, Water Quality Education Specialist

UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Low Impact Development (LID) is a sustainable approach to stormwater management that minimizes impacts on waterways by treating and infiltrating runoff from rainfall, snowmelt and overirrigation close to its source. As is the case with conventional storm drain infrastructure, regular maintenance is required to keep LID facilities working as designed.

Regular maintenance is needed to:

- Convey flows and prevent flooding
- Process pollutants
- Provide adequate emergency vehicle access
- Avoid expensive or excessive repairs
- Meet community expectations for appearance and aesthetics
- Protect public health

Communities often grapple with many questions about maintenance activities, and maintenance concerns can sometimes become barriers to LID implementation. The following considerations will help in developing general LID maintenance plans. For more information on maintenance activities for specific LID features, see the other fact sheets in this series.

Where is the facility located?

In order for small, decentralized stormwater infiltration facilities to continue to capture and treat runoff, they must be documented and locations recorded so property owners cannot remove them from service. Many communities record locations using global positioning system (GPS) units and plot them on

Questions to Answer When Developing LID Maintenance Plans:

- **WHERE** is the facility located?
- **WHO** is responsible for inspections and maintenance?
- **HOW OFTEN** should the facility be checked and maintained?
- **WHAT** maintenance is required?
- **HOW DIFFICULT** is the maintenance to perform?
- What will it **COST?**
- **WHO** is responsible for recordkeeping and reporting?

National NEMO Network

National NEMO Network

This rain garden is no longer functioning correctly and may not have been properly installed. The inlet has eroded and sediment has clogged the infiltration area. Routine maintenance is essential to repair this type of damage as quickly as possible.

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For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

LID: An Introduction, FS-09-22

Soil Considerations, FS-09-23

Rainwater Harvesting, FS-09-24

Bioretention, FS-09-25

Vegetated Swales and Buffers, FS-09-26

Green Roofs, FS-09-27

Plant Materials, FS-09-28

Porous Pavement, FS-09-29

Roadway and Parking Lot Design, FS-09-30

Maintenance, FS-09-31

Typical Seasonal Maintenance Tasks for a Vegetated LID Practice*

Year	Spring	Summer	Fall	Winter
1	Install practice, plant vegetation, and install irrigation system (if needed).	Control weeds and remove sediment, debris and trash as needed.	Control weeds and remove sediment, debris and trash as needed.	Inspect for erosion and sedimentation after storm events. Repair as needed.
2-4	Inspect structures, embankments, inlets and outlets. Check for signs of erosion and repair as needed. Adjust irrigation system and replace mulch as needed.	Control weeds and remove sediment, debris and trash as needed. Check for standing water or mosquitoes.	Control weeds and remove debris and sediment as needed. Check for standing water or mosquitoes.	Inspect structures, embankments, inlets and outlets. Check for signs of erosion and repair as needed.
5-10	As above, plus replace plants as needed.	As above.	As above.	As above.

**Vegetated LID practices include bioretention systems, vegetated swales and buffers.*

geographic information system (GIS) maps. This allows jurisdictions to track maintenance needs and readily identify and notify property owners of their responsibilities.

Who is responsible for inspections and maintenance?

While it is tempting to place responsibilities for maintenance on homeowners or homeowners' associations (HOAs), it is probably not realistic. Homeowners can maintain small, simple facilities such as rain gardens on their properties if they are provided with specific instructions, but generally lack the ability and tools to perform more complex maintenance. Most HOAs lack the training, experience and staff necessary to provide high-quality maintenance. In most cases, some level of responsibility for inspection and maintenance will fall on private contractors or city/county/state jurisdictions.

If homeowners are expected to play a role in inspections and maintenance, they must be provided with sufficient education and appropriate checklists or other materials.

How often should the facility be checked?

Periodic monitoring is inexpensive when compared to the cost of renovating a failed facility. Frequency varies with the type of facility and the design specifications. More frequent inspections will be needed in areas where a lot of upstream erosion and sediment transport is occurring.

All facilities should be monitored a minimum of once a year, as well as following storm events that exceed the capacity of the facility. Any facility that incorporates irrigation should be checked at the beginning of the irrigation season to ensure the system is operating correctly, and periodically during the growing season to adjust irrigation to seasonal plant needs.

How often should the facility be maintained?

Each type of stormwater treatment facility will require maintenance specific to its design. Signs that maintenance of LID practices is needed include the following:

- Water has ponded for longer than 48 to 72 hours after a rainfall event (for infiltration facilities, including porous pavement).
- Insects become a problem.
- Vegetation is overgrown, dead, missing, wilting or damaged.
- Invasive weeds are present.
- Erosion is visible.
- Sediment has accumulated.
- Trash is present.
- Vandalism has occurred, or there has been improper use by the public or animals.
- The mulch layer is too thin.
- The overflow structure is clogged or damaged.

What maintenance is required?

Maintenance needs vary by the type of facility. Some common activities include:

- Vegetation management, such as mowing, pruning, replanting and weed control
- Sediment removal
- Trash removal
- Clearing of curb cuts
- Pest control, including insects and rodents
- Replacement of mulch
- Repair of eroded areas
- Repair or retrofit of irrigation systems
- Unclogging overflow pipes or structures and underdrains
- Sweeping and suction cleaning of porous pavement

Melody Hefner

Routine maintenance of this parking lot inlet consists of sediment and trash removal.

Consult the individual fact sheets in this series for more information on the maintenance needs for specific facilities.

Melody Hefner

This parking lot island requires some minor maintenance in the form of weed removal.

How difficult is the maintenance to perform?

Complexity can vary widely, but most routine maintenance of LID practices can be performed without special training or equipment. A survey of Minnesota Municipal Public Works Managers found that most maintenance tasks were minimal and simple and rarely required a professional (Kang et al., 2008). Porous pavement was one exception, since routine sweeping and vacuuming with specialized equipment is necessary to prevent sediment from clogging pores.

What will it cost?

Costs can be highly variable, and depend upon the specific type of facility, its size, the volume of stormwater and sediment that can be retained in the facility, how easy it is to access the facility for maintenance, and disposal methods for sediment and debris. If available, onsite disposal is typically the most cost-effective.

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

Use caution when stockpiling removed sediment to ensure it does not wash or blow onto pavement or into storm drains. If loading and hauling are required, maintenance costs will increase significantly.

Some estimates suggest that annual maintenance costs may vary from $100 per acre for routine simple landscape maintenance such as mowing, to $500 or more for debris or sediment removal. (Northern Virginia Regional Commission, 2007). Nonroutine or infrequent maintenance costs should be considered and included in budgets.

Who is responsible for recordkeeping and reporting?

Keeping records helps document ongoing performance of the facility, typical maintenance needs, and routine costs. Records should be submitted by the entity performing the maintenance to whoever has stormwater oversight, such as the local utility company, the county or the homeowner's association, or via a report provided to the contracting entity by the private maintenance contractor.

John Bilotta

Routine maintenance of porous pavement includes vacuum sweeping at least twice a year.

John Bilotta

Additional information about maintenance of stormwater facilities can be found at:

- Low Impact Development Center, Inc., www.lowimpactdevelopment.org
- Maintenance of Low Impact Development Facilities, http://www.psparchives.com/publications/our_work/stormwater/lid/D_
- Portland, Oregon Stormwater Management Manual, Chapter 3.0, Operations and Maintenance, Revised September 2004, www.portlandonline.com/bes/index.cfm?c=35122&a=55800

References:

- Kang, J-H, P.T. Weiss, J.S. Gulliver and B.C. Wilson, 2008, Maintenance of Stormwater BMPs, Stormwater Magazine, November/December 2008, www.stormh2o.com/november-december-2008/bmp-maintenance-cost.aspx
- Northern Virginia Regional Commission, 2007, Maintaining Stormwater Systems, www.novaregion.org/index.aspx?nid=25

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

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Fact Sheet FS-09-28

Low Impact Development in Northern Nevada: Plant Materials

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UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Low Impact Development (LID) is a sustainable approach to stormwater management that minimizes impacts on waterways. When designing LID practices, proper plant selection is essential to ensure plants are suited to soils, climates and microsites. In addition to improving the appearance of properties and LID features, plants also aid in stabilizing soil, minimizing erosion, providing windbreaks, shade and both food and cover for wildlife.

Most LID practices or features are designed to detain, retain and/or infiltrate stormwater runoff. Detention or retention times will depend on the size of the LID feature, the size of the stormwater collection area feeding into the feature, and the infiltration rate of the soil. These three factors determine the level and duration of moisture in the LID feature, and are important factors to consider when selecting plants.

This publication lists trees, shrubs, grasses and flowering plants that are well-suited to northern Nevada and may be useful in various LID features.

Follow these tips when using the plant list:

- Assess soil characteristics, including soil texture and salinity, to help determine the type of LID feature that will work best and the plants that will grow best at a given site. Few plants grow well in all types of soil.
- Some plants can survive periodic flooding or temporary inundation, while others require well-drained soils to flourish. Consider these characteristics carefully when selecting plants for biorention features. Plants that can survive in saturated soils are good choices for the

Susan Donaldson

This LID feature includes a number of ornamental grasses and flowering plants and shrubs, including butterfly bush, autumn joy sedum, tickseed coreopsis and cotoneaster.

Benefits of Proper Plant Selection

- **FILTER** and infiltrate stormwater runoff
- **REDUCE** erosion
- **STABILIZE** slopes
- **MINIMIZE** inputs of fertilizer and pesticides
- **IMPROVE** aesthetics

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lower portions of a bioretention feature. Plants requiring well-drained soils are better choices for the upper slopes or upland areas of biorention features.

- Many of the plants listed are native to Nevada, while some are introduced species. Both types are adapted to our dry climate.
- When planning the LID feature, consider the mature size of the plant materials. The list provides estimates of the mature size and form of individual plants. For purposes of this publication, a tree is defined as more than 10 feet tall with one main stem, and a shrub is less than 10 feet tall with one or more stems.
- As the trees or shrubs planted in the biorention area begin to grow, smaller plants may be shaded. Shade tolerance is an important consideration in multi-storied plantings.
- Irrigation is an added expense many property owners wish to avoid. Some plants are more drought-tolerant than are others. Very few plants will grow without additional water in our area, at least during establishment. Irrigation systems should be included in the design.
- If your soil has a high salt content, consider planting salt-tolerant species. A soil test will provide you with information about the salinity levels in your soil.
- Wind tolerance is important if the bioretention feature is subject to high winds or if the LID feature will also serve as a wind break.

Trees, shrubs and grasses useful in LID projects

Al Schneider, www.swcoloradowildflowers.com

Jana Vanderhaar

Susan Donaldson

Sheri Hagwood,USDA-NRCS

Susan Donaldson

Ed Smith

A wide variety of plants are useful in LID projects:

1 Black hawthorn grows to 15 feet and provides good browse for wildlife;

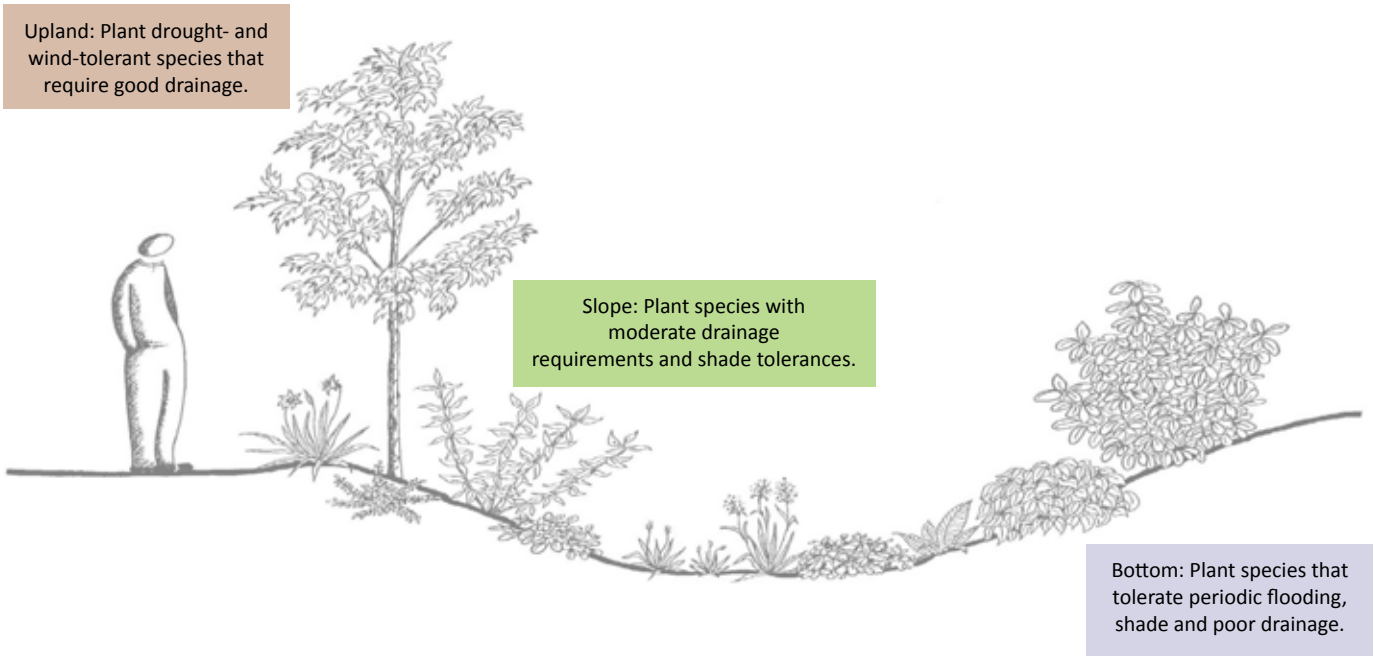
2 Penstemon, which is highly adapted to medium and coarse soils;

3 Bitterbrush, which is highly adapted to medium-textured soils as well as coarse-textured soils;

4 Squirreltail grass, which is a bunchgrass that competes with cheatgrass;

5 Potentilla, also known as shrubby cinquefoil, a bush that is suitable for swales, rain gardens and green roofs;

6 Barberry, a 3- to 6-foot shrub that adds a lot of color and is adapted to coarse-textured soil.



- Some of the plants that grow best in northern Nevada can become invasive or weedy. Avoid their use when possible, particularly on sites where they have proven to be invasive in the past.
- Commercial availability of seed, container or bareroot stock can be a limiting factor. Check with your local nursery, retail outlet or online during the planning phase to determine if the plant material you want is available.

Jana Vanderhaar

Baltic rush is native to Nevada. It can grow to 2 feet tall and works well in vegetated swales, biorentention cells and rain gardens.

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

For a description of Low Impact Development practices, consult the following Fact Sheets in this series:

LID: An Introduction, FS-09-22
Soil Considerations, FS-09-23
Rainwater Harvesting, FS-09-24
Bioretention, FS-09-25
Vegetated Swales and Buffers, FS-09-26
Green Roofs, FS-09-27
Plant Materials, FS-09-28
Porous Pavement, FS-09-29
Roadway and Parking Lot Design, FS-09-30
Maintenance, FS-09-31

Plants for Bioretention A

Susan Donaldson

Botanical Name	Common Name	Native status N = Native, I=Introduced	Location in feature U=Upland, S=Slope, B=Bottom	Height/form ′ = feet, ″ = inches	Annual water requirement (inches)	LID Feature Suitability: Vegetated swales and larger-scale features	LID Feature Suitability: Bioretention cells, rain gardens, smaller-scale features	LID Feature Suitability: Green roofs	Soils: Adapted to clay or fine-textured soils	Soils: Adapted to medium-textured soils
TREES										
Acer grandidentatum	Bigtooth maple	N	U,S	10-30’ tree	16-30	X	X		H	H
Acer negundo	Boxelder	N	S,B	18-60’ tree	15-75	X	X		H	M
Alnus incana subspecies *tenuifolia*	Thinleaf alder	N	S,B	6-15’ shrub/tree	10-20	X	X		H	M
Calocedrus decurrens	Incense cedar	N	U,S	50-125’ tree	20-80	X			H	H
Catalpa speciosa	Northern catalpa	I	U,S,B	20-60’ tree	20-80	X	X		L	H
Celtis occidentalis	Common hackberry	I	U,S,B	26-60’ tree	14-60	X	X		M	H
Cercis orbiculata	Western redbud, California redbud	N	U,S	7-20’ tree/shrub		X	X		L	H
Cercocarpus ledifolius	Curl-leaf mountain mahogany	N	U,S	12-20’ tree	10-45	X	X		L	M
Crataegus douglasii	Black hawthorn	N	S,B	to 15’ tree	16-260	X	X		H	H
Gleditsia triacanthos	Honeylocust	N	U,S,B	35-75’ tree	20-70	X	X		H	H
Malus hybrids	Flowering crab apple, crab apple	I	U,S	6-25’ tree	30-60	X	X		M	H
Picea pungens	Colorado spruce, blue spruce	N	U,S	30-60’ tree	20-45	X	X		L	H
Populus tremuloides	Quaking aspen	N	U,S	20-65’ tree	7-60	X	X		H	H
Prunus americana	American plum	N	U,S	to 24’ shrub/tree	16-40	X	X		L	H
Prunus emarginata	Bitter cherry	N	U,S	2-6.5’ tree	16-32	X	X		L	L
Salix amygdaloides	Peachleaf willow	N	S,B	45-60’ shrub/tree	24-60		X		L	H
Sambucus nigra subspecies *cerulea*	Blue elderberry	N	U,S	6-20’ shrub/tree	10-60	X	X		L	H
Sambucus racemosa	Red elderberry	N	S,B	10-20’ shrub/tree	24-60	X	X		L	H
SHRUBS										
Amelanchier alnifolia	Saskatoon serviceberry, Western serviceberry	N	S,B	3-15’ shrub/tree	12-140	X	X		H	H
Artemisia species	Sagebrush	N	U,S	1.5-5’ shrub	16-20	X	X	X	L	H
Atriplex canescens	Fourwing saltbush	N	U,S	1-4’ shrub	5-18	X	X	X	M	H
Atriplex confertifolia	Shadscale, shadscale saltbush	N	U,S	1-3’ shrub	4-12	X	X	X	H	H
Atriplex lentiformis	Big saltbush, quailbush	N	U,S	to 10’ shrub	4-20	X	X	X	L	H
Berberis species	Barberry	I	U,S	3-6’ shrub	30-60	X	X	X	M	H

reas in Northern Nevada

KEY:
H - high, highly;
M - moderate, moderately;
L - low, poor, poorly

	Water			Tolerances				Other			
Adapted to coarse-textured soils	Tolerance for prolonged saturation	Tolerance of periodic flooding	Drainage requirement	Drought	Salinity	Wind	Shade	Potential to be weedy or invasive	Commercial availability	Additional Notes	Data Sources
H	L	L	M/H	L	L	M	M	L	M	Good fall color	11
M	H	H	M	H	M	L	M	M	H	Birds, small mammals eat seeds; attracts boxelder bugs; suckers; brittle limbs	3,5,6,9,11
M	M	H	L	L	L	L	M	M	H	Forms thicket; has invasive roots; good in high water table areas	2,3,5,9,11
H	L	L	M	H	L	H	L	L	H	Tolerates summer heat and poor soil; good screen or windbreak for large area	5,8
H	L	L	H	M	L	L	L	L	H	Good wildlife food & cover; huge leaves, showy flowers; likes deep, moist soil	3,8,11
H	L	M	L	H	L	H	H	L	H	Good for wildlife; good in urban setting; deep roots; tolerates air pollution	3,8,11
H	L	M	H	H	L	L	L	L	H	Plants do well in moderate- to low-fertility soils	11
H	L	L	H	H	L	L	M	L	M	Prefers deep, rocky soils; evergreen	5,6
M	M	H	M	L	L	M	M	M	M	Has thorns; forms thicket; good wildlife browse	5,9,11
L	L	H	H	H	M	H	L	L	H	Hardy & fast-growing; thorns; used in urban stress areas, such as parking lots	3,8,11
H	L	L	H	M	L	M	M	L	H	Good wildlife food value; pruning required; characteristics vary by variety	3,8,11
H	L	L	M	M	L	H	M	L	H	Good wildlife cover; needle color interesting in landscape; long-lived	3,8,11
M	M	H	M	L/M	L/M	M	L	H	H	High water use; best at higher elev.; short-lived; can be invasive; wildlife food & habitat	
H	M	M	H	L	L	H	L	L	H	Good for bird nesting, food & cover; good for erosion control	3,11
H	L	L	M	M	L	L	L	L	M	Red bark; bitter red fruit	5,6,11
H	M	H	L	L	L	H	L	H	M	Woody; easy to establish	2,9,11
H	L	M	H	M	L	L	M	L	M	Good food & cover for birds	3,5,6,9,11
L	L	M	M	M	M	L	M	L	H	Big game browse; wildlife eat fruit; fruit toxic to humans without preparation	3,5,6,9,11
H	L	L	M	L	L	H	M	L	H	Forms a thicket; has edible fruit	3,5,6,11
M	L	L	M	H	M	M	L	M	H	Characteristics vary by species	5,8,11
H	L	L	M	H	H	M	L	L	M	High boron tolerance	5,7,11
H	L	L	L	H	H	L	L	L	M	Calcium-tolerant; good winter forage for wildlife	7,11
L	M	L	L	H	H	L	L	L	M	Tolerant of alkaline soil; good to 7 degrees F	7,11
H	L	L	M	L	L	M	L	L	H	Attractive color in landscape; has thorns	8,11

Plants for Bioretention A

David Allen

Botanical Name	Common Name	Native status N = Native, I=Introduced	Location in feature U=Upland, S=Slope, B=Bottom	Height/form ' = feet, " = inches	Annual water requirement (inches)	LID Feature Suitability: Vegetated swales and larger-scale features	LID Feature Suitability: Bioretention cells, rain gardens, smaller-scale features	LID Feature Suitability: Green roofs	Soils: Adapted to clay or fine-textured soils	Soils: Adapted to medium-textured soils
SHRUBS (continued)										
Buddleja species	Butterflybush	I	U,S	6-12' shrub		X	X		L	H
Caragana arborescens	Siberian peashrub	I	U,S	to 12' shrub	12-55	X	X		H	H
Chrysothamnus nauseosus, Ericameria nauseosa	Rabbitbrush, rubber rabbitbrush	N	U,S	to 4' shrub	6-20	X	X	X	H	H
Cornus sericea subspecies *sericea*	Redosier dogwood,red-twig dogwood	N	S,B	3-12' shrub/tree	18-60	X	X		H	H
Cotoneaster species	Cotoneaster	I	U,S	1-9' shrub	14-30	X	X		H	H
Dasiphora fruticosa, Potentilla fruticosa	Shrubby cinquefoil, bush cinquefoil	N	U,S,B	1-2.5' shrub	16-40	X	X	X	L	H
Ephedra viridis	Mormon tea	N	U,S	1-3' shrub	6-12	X		X	L	H
Fallugia paradoxa	Apache plume	N	U,S	2-6' shrub	4-20	X	X	X	L	H
Forestiera pubescens, Forestiera neomexicana	Stretchberry, desert olive, New Mexico privet	N	U,S	to 6' shrub	9-24	X	X		H	H
Forsythia species	Forsythia	I	U,S	3-10' shrub	32-60	X	X	X	H	H
Mahonia repens	Creeping barberry, creeping Oregon grape	N	U,S	1-2' shrub	15-45	X	X	X	L	H
Philadelphus microphyllus	Littleleaf mock orange	N	U,S,B	3-15' shrub	8-12	X	X		L	H
Pinus mugo	Mugo (Mugho) pine	I	U,S	4-10' shrub	35-60	X	X		L	H
Prunus andersonii	Desert peach	N	U,S	3-7' shrub	8-12	X	X	X	M	H
Prunus virginiana	Chokecherry	N	S,B	3-20' shrub/tree	13-65	X	X		L	H
Purshia tridentata	Antelope bitterbrush, bitterbrush	N	U,S	2-6' shrub	8-20	X	X		L	H
Rhus trilobata	Skunkbush sumac	N	U,S	2-6' shrub	8-20	X	X		L	H
Ribes aureum	Golden currant	N	S,B	4-10' shrub	12-20	X	X	X	L	H
Ribes cereum	Wax currant	N	S,B	3' shrub	13-35	X	X		L	H
Rosa woodsii	Woods' rose	N	S,B	3-10' shrub	12-40	X	X		L	H
Shepherdia argentea	Silver buffaloberry	N	U,S,B	3-20' shrub	15-20	X	X		L	H
Spiraea species	Spirea	I	U,S	2-5' shrub	35-60	X	X	X	H	H
Symphoricarpos albus	Common snowberry	N	U,S,B	3-6' shrub	12-45	X	X	X	H	H
Syringa vulgaris	Common lilac	I	U,S	to 20' shrub	30-50	X	X	X	H	H

reas in Northern Nevada

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	Water			Tolerances				Other			
Adapted to coarse-textured soils	Tolerance for prolonged saturation	Tolerance of periodic flooding	Drainage requirement	Drought	Salinity	Wind	Shade	Potential to be weedy or invasive	Commercial availability	Additional Notes	Data Sources
H	L	L	H	L	L	L	L	L	H	Attracts butterflies	8
H	L	L	H	H	M	H	M	L	H	Very tolerant of infertile soils; requires little maintenance	3,8,11
H	L	L	L	H	M	L	L	L	M	Calcium-tolerant; good wildlife cover; pollen may irritate those with allergies	5,7,8,10,11
M	H	H	L	M	L	H	L	L	H	Brilliant red fall color	1,2,5,6,11
H	L	L	L	M	L	H	M	L	H	Adapted to a variety of soil textures	3,8,11
H	L	H	H	L	M	H	L	L	H	Height and flower color dependent on variety; fair nesting cover	3,8,9
H	L	L	H	H	H	L	M	L	M	Calcium-tolerant; intolerant of wet sites and poor drainage	8,11
H	L	L	M	H	M	M	L	H	L	Adds interest in landscape; wildlife browse	6,11
H	L	M	H	M	M	M	L	L	M	Provides browse, fruit and nectar for wildlife	8,11
H	L	L	H	M	L	H	M	L	H	Bright yellow spring flowers; characteristics vary by variety	3,8,11
L	L	L	H	H	L	L/M	H	M	M	Creeping habit; stoloniferous growth; evergreen; berries provide wildlife food	11
H	L	L	L	H	L	L	L	L	H	Big-game browse	3,8,11
H	L	L	L	M	M	M	L	L	H	Interesting shape in landscape; size varies with variety; fair wildlife value	3,8,11
M	L	L	M	H	M	M	L	L	M	Pink flowers in spring; can form thicket	6,11
H	L	M	H	M	M	L	L	H	H	Birds and small mammals eat fruit; can be toxic to wildlife	3,5,6,9,11
H	L	L	L	H	L	H	M	L	M	Provides spring & winter browse & cover for wildlife	7,11
H	L	L	H	M	M	L	M	L	H	Good fall color; slow to establish; birds & small mammals eat fruit	2,3,9,11
L	L	M	L	M	L	L	M	L	H	Wildlife food & cover; alternate host for white pine blister rust	2,3,8,9,11
H	L	L	L	H	L	L	L	L	H	Wildlife food & cover; calcium-tolerant; alternate host for white pine blister rust	3,9,11
H	L	M	L	M	L	H	M	M	H	Suckers and grows vigorously in moist sites; heavily thorned	2,3,5,8,9,11
H	L	M	H	M	H	H	M	H	H	Spreads fast, forms thicket; thorny; wildlife food; can fix atmospheric nitrogen	2,3,6,8,11
H	L	L	L	M	L	M	L/M	L	H	Colorful, dense blooms; many varieties; good nesting, food & cover	3,8,11
H	L	M	L/M	H	M	M	L	L	M	Cover and food for birds & small mammals; browse for wildlife	6,8,11
H	L	L	H	M	M	H	M	L	H	Beautiful flowers; fair nesting cover	3,8,11

Plants for Bioretention A

USDA plants database

Botanical Name	Common Name	Native status N = Native, I=Introduced	Location in feature U=Upland, S=Slope, B=Bottom	Height/form ' = feet, " = inches	Annual water requirement (inches)	LID Feature Suitability: Vegetated swales and larger-scale features	LID Feature Suitability: Bioretention cells, rain gardens, smaller-scale features	LID Feature Suitability: Green roofs	Soils: Adapted to clay or fine-textured soils	Soils: Adapted to medium-textured soils
GRASSES, SEDGES & RUSHES										
Bromus biebersteinii	Meadow brome	I	S,B	2-4'	15-30	X	X	X	H	H
Bromus inermis	Smooth brome	N	S,B	1.5-3'	18-60	X	X	X	H	H
Calamagrostis canadensis	Bluejoint reedgrass, bluejoint	N	S,B	2-3'	14-65	X	X		H	H
Calamagrostis X *acutiflora* (Karl Foerster)	Feather reed grass	I	U,S,B	2-6'			X	X	M	H
Carex species *(aquatilis, nebrascensis, rostrata)*	Sedge	N	S,B	1-2'	10-65, depending on species	X	X		H	H
Distichlis spicata, Distichlis stricta	Saltgrass	N	U,S,B	0.5-1.5'	5-70	X	X	X	H	H
Eleocharis macrostachya, Eleocharis palustris	Common spikerush, pale spikerush	N	S,B	0.5-2.5'	16-60	X	X		H	L
Elymus elymoides	Squirreltail	N	U,S,B	4-18"	5-16	X	X	X	H	H
Elymus trachycaulus, Agropyron trachycaulum	Slender wheatgrass	N	U,S,B	2-2.5'	8-25	X	X	X	H	H
Helictotrichon sempervirens	Blue oat grass	I	U,S,B	2'		X	X	X	M	H
Hesperostipa comata	Needle and thread	N	S,B	1-4'	5-20	X	X	X	M	H
Juncus balticus	Baltic rush	N	S,B	1.5-2'		X	X		H	H
Juncus effusus	Common rush, soft rush	N	U,S	to 6'	18-60	X	X		H	H
Leymus cinereus, Elymus cinereus	Basin wildrye, Great Basin wildrye, giant wildrye	N	U,S	5'	8-20	X	X	X	H	H
Leymus triticoides	Beardless wildrye, creeping wildrye	N	S,B	to 3'	7-60	X	X	X	H	H
Muhlenbergia rigens	Deergrass	N	U,S,B	to 5'	10-18	X	X	X	H	H
Panicum virgatum 'Prairie Sky'	Prairie sky switchgrass	I	U,S,B	5'	12-60	X	X	X	L	H
Pascopyrum smithii	Western wheatgrass	N	U,S,B	0.5-1'	8-36	X	X	X	H	M
Scirpus species, *Schoenoplectus* species	Bulrush, tule	N	S,B	2 to 6'	12-60	X	X		H	H
Spartina pectinata	Prairie cordgrass	I	U,S,B	2-4'	14-35	X	X	X	L	H
Sporobolus airoides	Alkali sacaton	N	U,S,B	2-3.5'	5-13	X	X		L	H

reas in Northern Nevada

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	Water			Tolerances				Other			
Adapted to coarse-textured soils	Tolerance for prolonged saturation	Tolerance of periodic flooding	Drainage requirement	Drought	Salinity	Wind	Shade	Potential to be weedy or invasive	Commercial availability	Additional Notes	Data Sources
H	L	M	M	M	M	H	M	M	H	Sod-forming grass; good soil stabilizer; wildlife food	3,11
L	L	M	M	M	M	H	L	H	H	Sod-forming grass; good soil stabilizer; wildlife food	3,11
L	L	H	L/M	L	L	M	L	H	H	Sod-forming grass; good soil stabilizer; wildlife food & cover; does well in saturated soils	3,10,11
L	H	H	L	H	L	H	L	L/M	H	Bunchgrass; bears sterile seed heads into winter; ornamental; cut to ground in fall or spring; moderate water requirement	1,8
L	H	H	L	L	L	L	L-H	L	H	Heat & shade tolerance varies with species; wildlife food & cover	3,4,11
L	H	H	L	H	H	M	L	H	H	Sod-forming grass	7,11
H	H	H	L	L	L	H	L	M	H	Provides waterfowl food	1,3,11
L	L	L	M	H	L	H	L	L	M	Bunchgrass; competes with cheatgrass	1,11
L	L	M	M	H	H	M	L	M	M	Short-lived bunchgrass; wildlife food & cover	9,11
M	L	L	H	H	L	M	L	L	H	Bunchgrass; arching clump; blue-gray color; moderate water requirement	8
H	L	L	H	H	M	H	L	M	M	Bunchgrass; may hybridize with Indian ricegrass, forming sterile hybrids	11
M	H	H	L	H	H	M	M	L	H	Tolerates wide range of hydrologic conditions; fixes atmospheric nitrogen	3,4,11
H	M	M	L	M	L	H	L	H	H	Fast-spreading	1,11
H	L	M	M	H	H	H	L	L	H	Bunchgrass with deep root system; cannot be mowed below 10 inches tall; likes deep soils; excellent wildlife food & cover	7,11
L	M	H	L	H	H	H	L	L	M	Sod-forming grass; fast-spreading	1,11
H	L	H	H	H	L	H	M	L	H	Bunchgrass	1,11
H	L	M	M	M	M	H	L	M	H	Sod-forming grass; excellent nesting, wildlife food & cover	11
L	L	M	H	H	H	M	L	M	H	Sod-forming grass	3,11
L	H	H	L	M	L-H	M/H	L	L	H	Salinity and pH tolerance varies with species (*acutus, maritimus, pungens*); wildlife food & cover	3,4,11
H	L	H	L	L	L	H	L	M	H	Sod-forming grass; shade-intolerant; calcium-tolerant	3,11
H	L	H	M	H	H	H	L	M	H	Bunchgrass	7,11

Plants for Bioretention A

Susan Donaldson

Botanical Name	Common Name	Native status N = Native, I=Introduced	Location in feature U=Upland, S=Slope, B=Bottom	Height/form ' = feet, " = inches	Annual water requirement (inches)	LID Feature Suitability: Vegetated swales and larger-scale features	LID Feature Suitability: Bioretention cells, rain gardens, smaller-scale features	LID Feature Suitability: Green roofs	Soils: Adapted to clay or fine-textured soils	Soils: Adapted to medium-textured soils
PERENNIAL FORBS AND FLOWERING PLANTS										
Achillea millefolium	Common yarrow	N	U,S	0.5-3'	8-60, depending on variety	X	X	X	L	H
Aster species	Aster	N/I	S,B	2-4'	varies with species	X	X	X	H	H
Coreopsis species	Coreopsis, tickseed	I	U,S	1-3'	20-50	X	X	X	M	H
Echinacea purpurea	Eastern purple coneflower	I	U,S	3'	14-40		X	X	H	H
Eriogonum umbellatum	Sulfur-flower buckwheat, Sulfur flower	N	U,S	1'	8-18	X	X	X	L	H
Gaillardia aristata	Indian blanket flower, common gaillardia	N	U,S	2'	16-30	X	X	X	L	H
Gaillardia X *grandiflora*	Blanket flower	I	U,S	2'	16-30	X	X	X	H	H
Gaura lindheimeri	Gaura, Lindheimer's beeblossom	I	U,S	4'		X	X	X	H	H
Hemerocallis hybrids	Daylilies	N	U,S,B	1-3', varies with variety	28-60	X	X	X	H	H
Iberis sempervirens	Evergreen candytuft	I	U,S	6-10"	32-65		X	X	L	H
Iris germanica	Bearded iris, German iris	I	U,S	0.5-3'		X	X	X	M	H
Kniphofia uvaria	Redhot poker	I	U,S	flower spikes to 4'			X	X	L	H
Lavandula angustifolia	English lavender	I	U,S	1-3'		X	X	X	L	H
Linum lewisii	Lewis flax	N	U,S	1-2.5'	10-20	X		X	L	H
Mimulus species	Monkeyflower	N	U,S,B	1-3'	18-36		X	X	M	H
Penstemon palmeri	Palmer's penstemon	N	U,S	to 5'	6-14	X	X	X	M	H
Penstemon species	Beardtongue	N/I	U,S	1-4'	10-20	X		X	L	H
Rudbeckia hirta	Blackeyed Susan	N	U,S	to 3'	28-65	X	X	X	H	H
Salvia species	Salvia, sage	N	U,S	1-3'	8-14	X	X	X	L	H
Sedum species	Stonecrop	N/I	U,S	1-2'		X	X	X	M	M
Sphaeralcea ambigua	Desert globemallow	N	U,S	1-5'	5-15	X	X	X	M	H
Stachys byzantina	Lamb's ear, woolly hedgenettle	I	U,S	1'		X	X	X	L	H
Tanacetum species	Tansy, painted daisy, pyrethum daisy	I	U,S,B	1-2'		X	X	X	L	H

NOTE: For consistency, much of the information used in this table was derived from the USDA plants database. The authors understand there is great variability

Areas in Northern Nevada

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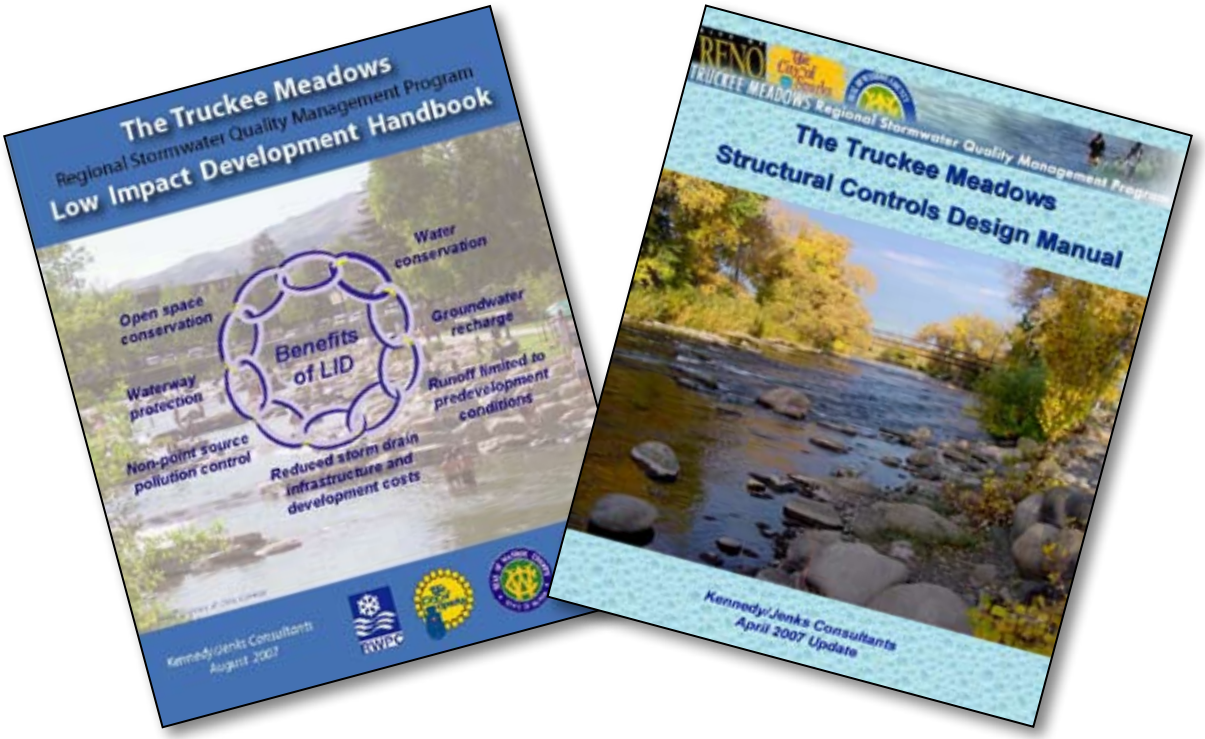
	Water			Tolerances				Other			
Adapted to coarse-textured soils	Tolerance for prolonged saturation	Tolerance of periodic flooding	Drainage requirement	Drought	Salinity	Wind	Shade	Potential to be weedy or invasive	Commercial availability	Additional Notes	Data Sources
L	L	L	H	H	L	H	M	H	H	Many varieties	8,11
L	L	L	H	L	L	L	M	M	H	Fall- or spring-blooming, depending on variety	8,10
H	L	L	M	H	L	L	L	H	H	Some annual species	8,11
H	L	L	H	L	L	L	L	L	H	Grows best at neutral soil pH; attracts insects & birds	8,11
H	L	L	H	H	H	H	L	L	H	Seeds are used as food source for birds & small mammals; excellent for use in dried flower arrangements	7,8,11
H	L	L	L	H	L	L	L	M	H	Orange-yellow flowers	7,11
H	L	L	H	H	L	L	L	L	H	Short-lived	8,11
L	L	M	H	M	L	M	M	M	H	Pink or white flowers; moderate water requirement	8,11
H	L	M	L	M	L	L	M	L	H	Many colors available	8,11
H	L	L	H	M	L	L	M	L	H	Evergreen	5,11
L	L	L	H	H	L	M	M	L	H	Many colors available; divide plants periodically; moderate water requirement	8
H	L	L	M	H	L	H	L	M	H	Attracts birds; moderate water requirement	8
H	L	L	H	M	M	M	L	L	H	Several colors available; moderate water requirement	8
H	L	M	H	L	L	L	L	M	H	Resistant to wildfire	7,11
M	L	M	L	L	L	L	H	L	M	Flower color, height & hardiness vary with species	11
H	L	L	H	H	L	L	L	L	H	Short-lived; fire-resistant	7,11
H	L	L	H	H	L	L	M	L	H	Short-lived; bird & insect nectar source	8,11
L	L	L	M	M	L	L	L	M	H	Naturalized through most of the U.S.; self-seeding	11
H	H	L	M	M	M	L	M	M	H	Best in dry zones; wildlife browse	1,7,8,11
H	L	L	H	H	L	H	L	L	H	Several colors of flowers & foliage available	1,8
H	L	L	H	H	M	M	L	M	M/L	Short-lived; self-seeding	7,11
H	L	M	H	M	M	H	L	H	H	Ground cover; less invasive cultivars available; low water requirement	8,11
H	L	L	H	H	L	M	M	L	H	Moderate water requirement; many species formerly classified as chrysanthemum	8,11

in plant data, depending on the data source. Plant data also vary with soil, location and aspect. The information in this table is meant as a general guide only.



For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

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Fact Sheet FS-09-29

Low Impact Development in Northern Nevada: Porous Pavement

By Susan Donaldson, Water Quality Education Specialist

UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Porous pavement is one method of reducing the extent of impervious surfaces in Low Impact Development (LID) design. LID is a sustainable approach to stormwater management that minimizes impacts on waterways by controlling rainfall, snowmelt and runoff close to its source.

Benefits of Porous Pavement

- **DECREASES** stormwater runoff
- **REDUCES** stormwater peak flows
- **IMPROVES** runoff water quality
- **REDUCES** flooding
- **INCREASES** groundwater recharge
- **ELIMINATES** standing water on pavement
- **DECREASES** pavement ice hazards and reduces need for road salting
- **REDUCES** thermal impacts to waterways

Porous paving systems include porous concrete and asphalt, permeable paver blocks, turf blocks and gravel pavers. They provide a sturdy surface for walking or driving while allowing stormwater to infiltrate through voids in the pavement surface. These systems generally work best in low-traffic areas, although advances in the engineering of porous pavements may make them viable substitutes for all conventional pavement applications in the future.

Porous pavement systems often require some sort of underlying engineered materials, such as sand and gravel, to provide a stable base. These permeable subbase materials also provide space for stormwater detention and, where existing native soils allow, infiltration and groundwater recharge. Porous pavements can also be installed over clay soils, but they may require an underdrain to facilitate drainage.

USDA-NRCS

The porous asphalt on the left rapidly infiltrates water and decreases icy winter road surfaces. The standard impermeable asphalt on the right allows snowmelt to pond and then freeze at night.

Local codes and ordinances can be one of the biggest stumbling blocks to the use of permeable materials in pavement design. In many municipalities, parking lots, driveways and sidewalks are required to be constructed of impermeable concrete or asphalt.

As recognition of the need to better manage stormwater grows, many communities are beginning the process of reviewing and revising their ordinances to allow for more LID features, including porous pavement.

University of Nevada Cooperative Extension

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For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

LID: An Introduction, FS-09-22

Soil Considerations, FS-09-23

Rainwater Harvesting, FS-09-24

Bioretention, FS-09-25

Vegetated Swales and Buffers, FS-09-26

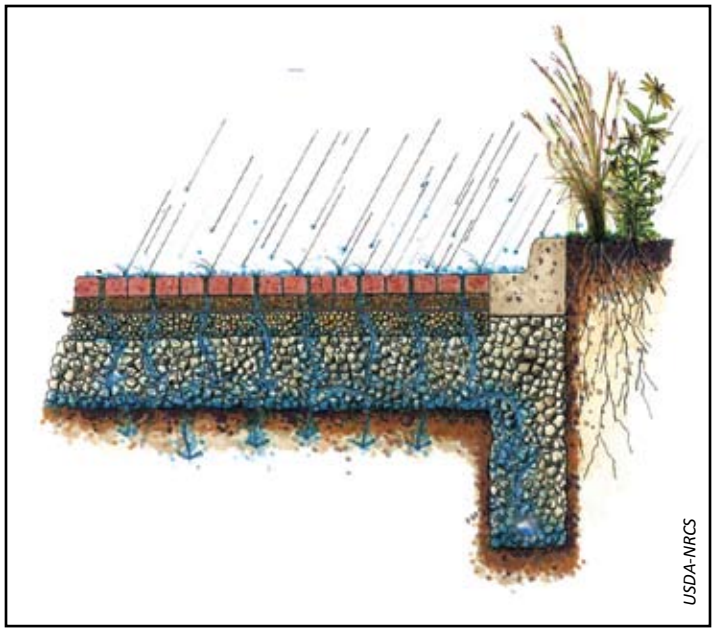
Green Roofs, FS-09-27

Plant Materials, FS-09-28

Porous Pavement, FS-09-29

Roadway and Parking Lot Design, FS-09-30

Maintenance, FS-09-31



Permeable pavements often incorporate layers of sand and gravel or rock that hold and infiltrate runoff into the underlying soils.

Porous concrete and asphalt

These materials appear similar to conventional impervious concrete and asphalt, but differ in the amount of fine material in the mix. Reduced amounts of fine material, sand-sized grains or finer, create void spaces that allow water to pass through the material and into a permeable subbase layer, usually composed of gravel. The sand and gravel in the subbase help to filter out pollutants before the stormwater infiltrates into the underlying soils. Both porous concrete and asphalt must be installed by experienced contractors.

These materials can be used for parking lot stalls, low- to medium-use streets, road shoulders, sidewalks, bike paths, driveways and patios. They have also been used on airport runways and highways, especially in rainy areas where flooding creates problems. When correctly installed, porous asphalt and concrete drain rapidly, reducing runoff, improving stormwater quality, helping to avoid damage from freeze-thaw cycles and improving public safety by reducing ice on pavements.

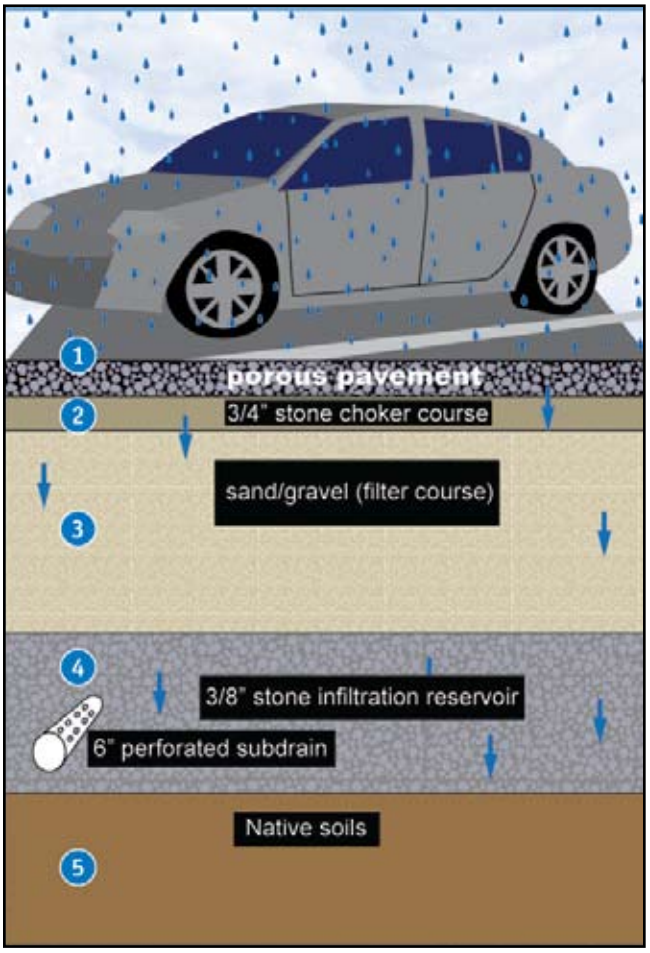
Because porous asphalt looks very similar to standard asphalt, care must be taken to prevent it from being chip-sealed, which will hinder infiltration. Roadway maintenance crews must be notified of the specific locations that should not be chip-sealed.

Permeable pavers

Permeable pavers fall into two main groups: brick or concrete pavers and open-celled grid pavers. Brick or concrete pavers are typically set into a base of leveled sand. An underlying gravel subbase can be added to provide additional stability and stormwater detention. Where underlying soils allow infiltration, such as in native sandy soils, stormwater runoff and snowmelt infiltrate through the pavers and sand to the gravel subbase and continue into the underlying soil. Brick and concrete pavers come in a variety of shapes, sizes and colors and are sometimes designed to interlock. They are attractive and relatively easy to install and can be retrofitted into an existing landscape.

Open-celled unit pavers are typically made of recycled plastic or concrete and are designed as grid networks that are filled with soil, sand or gravel to form a flat

Open-celled unit pavers form the base for this graveled walking trail.



University of New Hampshire Stormwater Center

In areas with poor soils and high groundwater, rain passes through the porous asphalt (1) and choker course (2), and pollutants are filtered out in the filter course (3). Water is stored in the reservoir (4). Any excess water flows out through the subdrain (4) if infiltration into native soils (5) is not possible.

surface. They can be planted with seed or turf. Open-celled unit pavers allow infiltration of stormwater while maintaining a surface that supports vehicles. They work well in overflow parking areas, driveways and sidewalks. Open-celled unit paver systems can also be retrofitted into an existing landscape. The flexibility of the grid pavers makes them appropriate for use on uneven or sloping terrain.

Pavers must be carefully installed to avoid uneven surfaces as they settle. For this reason, pavers may be a poor choice for handicapped parking areas and walkways. Design the subbase layers to bear appropriate loads for the intended use. For example, parking a vehicle requires greater load-bearing capacity than a bicycle path, sidewalk or walkway.

Limitations on the use of porous pavement

All forms of porous pavement work best in fairly flat areas with slopes of less than 5 percent. They are not recommended for areas where the seasonal high groundwater table is less than 3 feet below the bottom of the gravel subbase. They should not be used in areas where highly contaminated runoff may infiltrate the porous pavement, including gas stations and hazardous materials storage or processing facilities, unless an impermeable liner and an underdrain system are included in the design. When installed in areas where road sand is used in the winter or where there are regular inputs of sediment, such as near an eroding slope, clogging may occur.

It is best to install porous asphalt or concrete or permeable pavers at the end of the construction phase or as a retrofit, to minimize exposure to sediment and potential clogging.

Performance in cold climates

Many questions have arisen about the longevity of porous pavement in cold climates. Researchers, including those at the Stormwater Center at the University of New Hampshire, have studied these stormwater treatment systems for several years. They found that a well-drained porous pavement system will have a longer life cycle due to reduced freeze-thaw susceptibility and greater load-bearing capacity than conventional parking lot pavements (Gunderson, 2008).

Because these systems effectively infiltrate snowmelt and keep roads dryer, sand and salt applications can be minimized. Researchers found that winter maintenance of porous asphalt required 25 percent less salt to provide the

Maintenance

Porous pavement should be monitored several times a year as well as after storm events to make sure infiltration is occurring and pores have not been clogged with sand or other sediments.

- Vacuum-type street cleaners should be used at least twice a year on porous road surfaces, driveways and parking stalls.
- Sweep and vacuum pavers on a regular basis with street cleaners that combine suction with sweeping.
- It may be necessary to use flamers or other tools to suppress weeds between pavers.
- Avoid the use of chemical weed killers, which can contaminate water.
- Turf installed in the open cells of grid unit paving systems will require the same type and amount of maintenance as all other turf areas, including irrigation, mowing and weeding. The aggregate layer in open-celled pavers can be replaced as needed if it becomes clogged or contaminated.
- In open-celled unit pavers, grid segments should be replaced when three or more adjacent rings are broken or damaged.

same level (or better) of de-icing and traction (UNHSC, 2007).

Researchers also found that the composition and depth or thickness of the subbase materials made a difference in stormwater storage capacity and treatment efficiency. They added a sand filter layer to the typical layer of coarse rock and achieved increased filtration. The purpose of the subbase is two-fold: to support vehicles and to store and treat water. The subbase should be designed so that water drains rapidly after storms end. When placed over clay or silty soils, an underdrain can be added to facilitate drainage. An impermeable liner can also be included in the design when infiltration is not desired, for example, at locations where native soils are expandable clays, in areas of shallow groundwater, next to building foundations, or where spills of hazardous materials are likely to occur.

A system constructed in Pennsylvania in 1983 as part of the Shared Medical Systems headquarters consisting of a series of porous pavement parking bays connected by conventionally paved roadways continues to function well after 20 years (Adams, 2003). It had not been repaved, despite problems with sinkholes that had caused pavement problems prior to installation of the porous pavement.

John Bilotta

Regular maintenance with vacuum-style street cleaners is needed to keep porous road surfaces functioning.

These systems hold great promise for adding stormwater infiltration into paved surfaces.

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

Additional information about porous pavements can also be found at:

- University of New Hampshire Stormwater Center, www.unh.edu/erg/cstev/
- Stormwater Manager's Resource Center, www.stormwatercenter.net
- Toolbase Services, www.toolbase.org
- U.S. Environmental Protection Agency, Storm Water Technology Fact Sheet, Porous Pavement, www.epa.gov/npdes/pubs/porouspa.pdf
- University of Connecticut NEMO, Planning for Stormwater, Permeable Pavement, www.nemo.uconn.edu/tools/stormwater/pavements.htm
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Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

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Fact Sheet FS-09-24

Low Impact Development in Northern Nevada: Rainwater Harvesting

By Susan Donaldson, Water Quality Education Specialist

UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Rainwater harvesting is the practice of collecting and storing runoff from rooftops for later use on lawns, gardens and other landscaping. Rainwater harvesting is an ancient concept, and has been practiced for thousands of years in Asia, India and the Middle East as a way to supplement water supplies during dry periods.

Before municipal water systems existed, people often relied on rainwater to supplement drinking and irrigation water drawn from rivers or wells.

With the growth of urban centers complete with municipal water and storm drain systems, many of us have forgotten what people knew long ago: rainwater is a high-quality, free source of water that can be used for irrigation with minimal effort. The water is soft, low in salts and dissolved minerals and excellent for leaching desert soils.

What can rain water be used for?

Harvested rainwater can be used for pet and livestock watering, car washing, and sometimes even to supplement nonpotable water uses, such as toilet flushing and evaporative cooling systems. Rainwater should never be used for drinking water purposes unless it has been purified. Because harvested rainwater is not potable, it must be managed to protect both household occupants and the municipal water system from contamination. If used for a purpose such as toilet flushing, proper cross-connection protection, system maintenance and system marking are essential to protect household occupants and prevent contamination of the municipal water system.

While precipitation in the West is generally of good quality, rainfall is infrequent enough that pollutants may have collected on roofs. The first flush of rain may contain dust, debris, bird or other animal droppings. To eliminate these substances, many commercial rainwater-collection systems have devices that divert the first few gallons of runoff onto the ground.

Connecticut NEMO Program

Residential rain barrel.

Stormwater yields from various surfaces

Surface	Percent Yield
Roof	90-95
Paving	90-100
Gravel	25-70
Soil, bare and flat	20-75
Soil, with vegetation	10-60
Flat lawn, sandy	5-10
Flat lawn, clayey	13-17

Source: Harvesting Rainwater for Landscape Use, University of Arizona

Benefits of Rainwater Harvesting

- **SAVES** you money by using "free" water
- **REDUCES** the use of treated drinking water for landscape irrigation
- **IMPROVES** plant health by irrigating with high-quality, salt-free rainwater
- **REDUCES** the potential for moisture damage around your home's foundation
- **KEEPS** water out of the municipal storm drain system
- **REDUCES** dependence on groundwater supplies
- **DECREASES** polluted runoff to rivers and creeks
- **REDUCES** flood flows

University of Nevada Cooperative Extension

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Maintaining your system

Regular maintenance is essential to keep your rainwater harvesting system working correctly. Follow these maintenance tips:

- Keep rain barrels and cisterns free of debris.
- Control and prevent erosion near the overflow outlet.
- Keep gutters and downspouts free of debris.
- Install gutter guards to keep out leaves and other large objects.
- Periodically flush debris from rain barrels and cisterns and decontaminate with bleach.
- Clean and maintain filters.
- Repair leaks promptly.
- Expand berms around landscaping as plants grow.
- Monitor irrigation systems and plant water needs and adjust as needed to maintain a healthy landscape.

Amount of roof water that can be harvested based on annual precipitation

Inches of Rain	Gallons per square foot	Gallons per 1,000 square-foot roof	Gallons per 2,000 square-foot roof
7	4.4	4,400	8,800
9	5.6	5,600	11,200
11	6.8	6,800	13,600

Planning a rainwater harvest system

To determine whether rainwater harvesting will work for you, visualize your property. Where does the water from your roof go when it rains? If you're not sure, observe it during the next rain storm. It's likely that much of the water travels via gutters and downspouts onto paved surfaces and into the storm drain system rather than soaking into the ground. When this occurs, stormwater often picks up pollutants deposited on surfaces, such as oil drips, lawn fertilizer and road salts, and carries them into our surface water bodies, contributing to water pollution.

Rainwater harvesting does not need to be complicated. For example, if your roof has a gutter system, there are a variety of low-cost products available that can be attached to the downspouts to divert the water to your plants. First, determine which areas of your landscape will benefit from additional water. Then determine whether berms should be installed to help retain the water. The existing soils may need to be amended to allow the water to soak into the ground reasonably quickly. Sandy soils infiltrate well, but clay-rich soils have slow infiltration rates and may need amendments such as compost to enhance drainage. See LID in Northern Nevada: Soil Considerations, University of Nevada Cooperative Extension FS-09-23, for more information.

To help plan your rainwater-harvesting system, draw a simple map of your property. The map should identify the location of your house or other buildings, sidewalks and other surfaces that will carry water. This is often referred to as the "catchment," or the area from which runoff is collected. Use arrows to indicate the direction in which water flows across each surface. Show landscaped areas and types of vegetation by their general water needs. The plan will help you decide where and how to direct rainwater, or where to store water should you decide storage is possible.

Should I store rainwater?

In an average year, the Reno area receives about 7.5 inches of precipitation. For a house with a roof area of about 1,500 square feet, if about 90 percent of the water makes it to a storage tank, approximately 6,300 gallons of water could be collected. While this is not enough to supply all our summer irrigation needs, the water could be used to irrigate potted plants or plants that need a bit of extra water.

However, much of our precipitation arrives during the winter months, when the need for landscape irrigation is minimal. Storage is most useful when the water is available at the time of greatest need. In northern Nevada, this occurs during the summer months. However, we do often receive significant amounts of precipitation in the form of summer thunderstorms or spring rains, so a storage system may make sense for you if it fits into your overall goals and needs.

If you do decide to capture and store rainwater, it is important to know how much water will be delivered to your storage tank at one time. Perhaps you are only collecting water from

Storage Volume

Use the following equation to calculate the volume of water in gallons expected from a specific size roof:

V = A x R x 0.90 x 7.5 gallons/ft3 where:

V = volume expected from specific size of roof
A = the surface area of the roof, in square feet
R = rainfall depth, in feet (convert inches to feet by dividing by 12)
0.90 = a factor to allow for losses to evaporation, etc.
7.5 = a factor to convert cubic feet to gallons
This will help you choose the correct volume for the rain barrel.

Susan Donaldson

This cistern collects water from the roof of the restroom facility. The water can be used to flush the toilets.

one side of your 1,500-square-foot roof. When we receive a 1-inch rainfall, 750-square-feet of roof will provide about 420 gallons of water. However, small barrels generally only hold about 55 gallons. Be sure to include an overflow mechanism and a plan for the excess water when using them. It's also a good idea to install a "Roof Washer" or "First Flush" component. These commercially available devices trap or divert the first few gallons of runoff from the roof and channel the dirty water away from the barrel or cistern. Plan to divert about 10 gallons per 100 square feet of roof area.

Rain barrels

There are many commercial barrels available. A quick search of the Internet will reveal a wide variety of shapes, sizes and appearances. You can also construct your own rain barrel using a 55-gallon plastic drum. Make a hole at the top of the barrel for the gutter downspout and place a screen over it to exclude debris and insects. Next, install a spigot to which a hose can be attached. Place the spigot a few inches above the bottom of the barrel so that any debris will remain at the bottom of the barrel until you clean out the tank. Barrels that are open to the atmosphere can become breeding grounds for mosquitoes, and should be avoided. Make sure to seal the lid and any gaps connecting the gutter downspout to the lid. It's also important to have a tamper-proof design that won't attract curious children.

Since the water will flow from the barrel under the force of gravity, place it on cinder blocks or a platform elevated at least 15 inches above the ground. If you would like to capture more rainwater, consider linking two or more barrels together, or placing a barrel at each downspout from your roof. Always design an overflow pipe to allow excess water to safely flow away from the house without causing erosion.

Cisterns

Cisterns are water tanks used to collect and store larger volumes of rainwater, usually from roofs. In the past, they were commonly used to supplement water supplies in areas where rainfall was infrequent. Some communities around the world still rely on them as a source of water. Check with your county for any regulations or restrictions on the use of cisterns.

The tank volume depends

For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

LID: An Introduction, FS-09-22

Soil Considerations, FS-09-23

Rainwater Harvesting, FS-09-24

Bioretention, FS-09-25

Vegetated Swales and Buffers, FS-09-26

Green Roofs, FS-09-27

Plant Materials, FS-09-28

Porous Pavement, FS-09-29

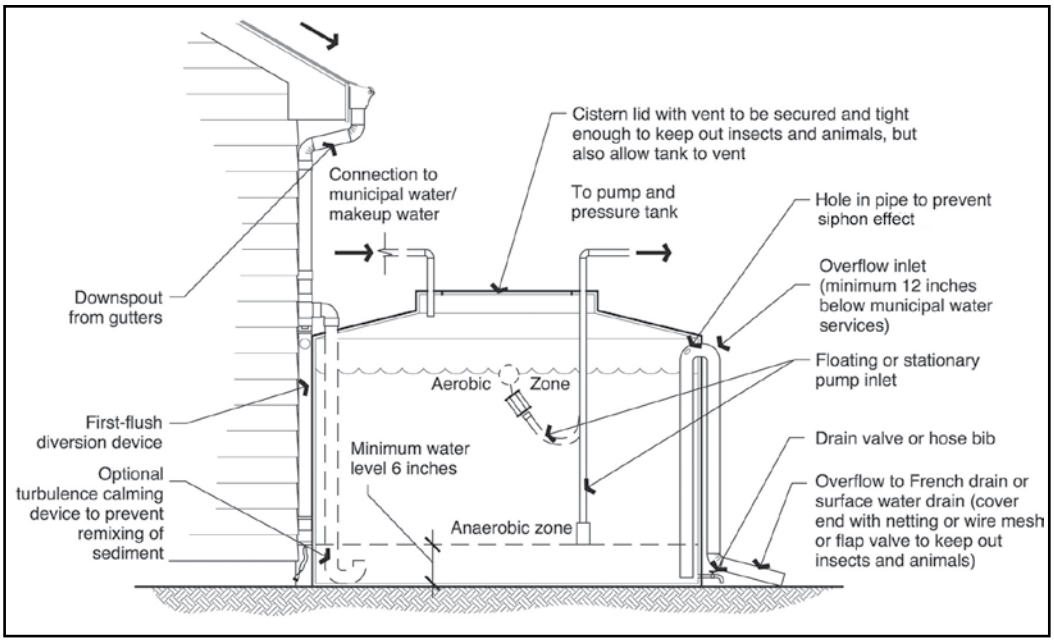
Roadway and Parking Lot Design, FS-09-30

Maintenance, FS-09-31

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

Additional information about rainwater harvesting can be found at:

- Forgotten Rain, Rediscovering Rainwater Harvesting, www.forgottenrain.com
- Harvesting Rainwater for Landscape Use by Patricia Waterfall, http://ag.arizona.edu/pubs/water/az1052/
- Rainwater Harvesting for Drylands and Beyond by Brad Lancaster, www.harvestingrainwater.com/



Forgotten Rain, LLC

Elements of a cistern used for water harvesting.

on roof collection area, the amount of rainfall to be stored, the space available, etc. Some types of roofs are not suitable for water collection, including roofs treated with tar or similar substances. Appropriate materials include tile, concrete or slate shingles, aluminum or plastic.

Cisterns can be made of plastic, metal or concrete. They must be watertight, have smooth interior surfaces and be large enough to capture the desired amount of water. Locate cisterns aboveground or underground, in crawl spaces or other locations. If cisterns are placed below-grade, a pump or other mechanism will be needed to withdraw water. Do not place cisterns near sewage lines or other sources of contamination, and be sure to slope the ground surface away from the cistern to allow adequate drainage. Ground settling can cause cracks in cisterns, so locate them on firm ground away from tree roots. A full cistern can be very heavy, since each gallon of water weighs 8.3 pounds. Remember that aboveground cisterns can be subject to freezing, so winter freeze protection such as insulation or heat tape may be needed.

When determining size, allow for water that will be lost to leaks, evaporate from the roof or be blown away by wind as well as the volume that is diverted by a roof-washing fixture. Some estimates assume a one-tenth to one-third loss. Include an access point to allow for cleaning. The cover should be watertight and locked to avoid contamination or accidents. Screen inlets and outlets to keep mosquitoes and other vermin out of the tank. Include an overflow drain and route the excess water away from buildings and onto areas where the water can soak into the ground.

Regular maintenance is required to keep the water clean. Inspect cisterns regularly and periodically empty and clean them with a dilute chlorine solution consisting of one-fourth cup of 5.25 percent unscented bleach in 10 gallons of water. Flush the tank thoroughly before using it again to remove sediment and chlorine residues.

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

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Fact Sheet FS-09-30

Low Impact Development in Northern Nevada: Roadway and Parking Lot Design

By Susan Donaldson, Water Quality Education Specialist

UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Roadways and parking lots typically comprise about 70 percent of developed impervious surfaces. They provide multiple opportunities to incorporate Low Impact Development (LID) practices that disconnect impervious surfaces and reduce, filter and infiltrate runoff while still providing adequate access and parking. Low Impact Development practices such as bioretention basins in parking lot islands and roadway medians or porous pavement sidewalks can be incorporated into new developments or retrofitted into existing developments.

Opportunities for LID in Streets and Parking Lots

- **REDUCED IMPERVIOUS SURFACES** from decreased street widths and parking stall lengths
- **SHARED OR HOLLYWOOD DRIVEWAYS**
- **ALTERNATIVE DESIGNS** for cul-de-sacs, bioretention islands and medians, roadside swales and bioretention basins, and bioretention curb extensions
- **PERMEABLE PAVEMENT** for sidewalks, alleys, roadway parking and overflow parking areas in parking lots

Low Impact Development is a sustainable approach to stormwater management that minimizes impacts on waterways by treating and infiltrating runoff from rainfall and snowmelt close to its source.

In some cases, the use of LID can result in decreased need for expensive underground stormwater infrastructure, resulting in a net decrease in cost. However, changes to local codes and ordinances are often needed to allow widespread use of LID in roadway and parking lot designs. For example, existing codes that require the use of impermeable asphalt or concrete should be revised to encourage the use of permeable pavement on sidewalks, alleys, roadway parking and overflow parking areas in parking lots.

Roadways

Increasing attention has been focused recently on "Green Streets," or designs that meet multiple needs while capturing, treating and reducing stormwater runoff. Traditional storm drain system designs collect and concentrate flows and pollutants, delivering them to nearby waterways without allowing contact with vegetated areas that can filter and infiltrate runoff. LID designs recognize that stormwater can be a valuable resource.

By mimicking natural hydrology with functional landscaping designs and porous pavements, we can reduce pollution and decrease runoff rate, volume, pollutants and elevated temperatures, while adding aesthetic accents to the landscape.

San Mateo County Sustainable Green Streets and Parking Lots Guidebook

This roadside swale or bioretention basin receives and infiltrates water while providing attractive landscaping. The sidewalk made from porous concrete allows additional infiltration.

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For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

LID: An Introduction, FS-09-22

Soil Considerations, FS-09-23

Rainwater Harvesting, FS-09-24

Bioretention, FS-09-25

Vegetated Swales and Buffers, FS-09-26

Green Roofs, FS-09-27

Plant Materials, FS-09-28

Porous Pavement, FS-09-29

Roadway and Parking Lot Design, FS-09-30

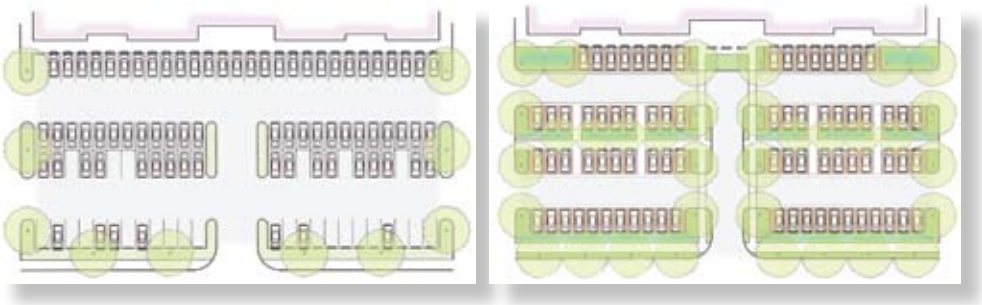
Maintenance, FS-09-31

San Mateo County Sustainable Green Streets and Parking Lots Guidebook

A mid-block curb extension collects stormwater runoff without requiring the removal of existing curb and gutter. Any overflow returns to the street.

Use the following tips to reduce impervious surfaces and increase infiltration of runoff.

- Reduce the width of travel lanes to decrease impervious area. The extra space can be used for bioretention areas, and the narrower widths help slow traffic and reduce runoff.
- Use vegetated swales as alternatives to curbs and gutters. Typical street design standards generally call for curb and gutter to be directly connected to storm drain inlets. This concentrates stormwater and increases its velocity and volume. Instead, eliminate curbs or use curb cuts to route runoff into recessed vegetated roadside swales, where water can soak into the ground.
- Incorporate rain gardens or other bioretention features into roadway medians and the center of cul-de-sacs. Roadways can be sloped toward central bioretention features, and traditional curb and gutter eliminated. A 30-foot island at the center of an 80-foot-diameter cul-de-sac reduces the amount of impervious surface by 15 percent while retaining a 25-foot road width. Curb cuts or rocks can be used to prevent travel into infiltration features.
- Design cul-de-sacs with reduced radii or T-shaped layouts. One-way loops or streets with parking on only one side can also be used to decrease the total amount of impervious surface.
- Reduce the size or number of on-street parking stalls. The extra space can be used for landscaped areas that allow stormwater infiltration. Porous pavement can also be used between parking stalls and for seldom-used parking spaces.
- Require parking on only one side of the street. This design works well in residential neighborhoods where most homes have off-street parking on driveways or in garages.
- Add curb extensions with bioretention basins. These are landcaped areas that extend into the street, as shown in the photo above. Curb extensions are commonly used for traffic calming, but can have added stormwater benefits if designed to allow runoff to drain into recessed landscaped areas. Curb extensions can easily be retrofitted into existing streets, if some on-street parking is removed.



San Mateo County Sustainable Green Streets and Parking Lots Guidebook

At left, a traditional parking lot design with unused spaces. At right, an LID parking lot design, incorporating 15-foot-long parking stalls and 22-foot-wide travel aisles. The LID design does not have as many parking spaces,but allows more landscape space for stormwater bioretention and infiltration and improves pedestrian circulation and safety.

Melody Hefner

Porous pavement was installed in this commercial parking lot.

Parking lots

Parking lots also provide numerous opportunities for bioretention and infiltration of stormwater without losing functionality. Consider the following tips:

- Shorten stall lengths or drive aisle widths. This frees up space for landscape infiltration and can also help improve pedestrian access. Most vehicles will fit within a 15-foot-long parking stall. Parking stall length requirements vary for each municipality. For example, Washoe County code requires 17-foot-long parking stalls.
- Plan for the amount of parking needed on an "average day," rather than for the rare holiday shopping day. Consider opportunities for shared parking with adjacent businesses, particularly for those that are open only during part of the day or evening.
- Incorporate porous paving into the less-used parts of the parking lot. For example, use porous pavement, including grid pavers or porous asphalt or concrete, for outlying parking spaces that are seldom used. This design works best when planned in advance so larger areas of impermeable pavement can be graded to direct runoff to permeable pavement areas. Porous paving can also be incorporated into sidewalks, walkways and medians.
- Place swales at the edges of parking lots or between rows of parking stalls. The swales can incorporate required landscaping while also infiltrating runoff. If site soils are sandy and allow for infiltration, it may be possible to greatly decrease underground infrastructure, such as catch basins and storm drain pipes, providing a cost savings.
- Convert existing landscaping into stormwater facilities. Most parking lots incorporate landscaped islands that are raised and surrounded by curbs. These areas can be redesigned with recessed landscaping to serve as bioretention areas, with no net loss in usable space in the parking lot. Bioretention basins in parking lot islands should use drought-tolerant vegetation to reduce irrigation needs and rock borders or curb stops to control entrance by cars and pedestrians.

Melody Hefner

This parking lot island is designed to receive and infiltrate stormwater runoff from the parking lot. When the water-holding capacity of the island is exceeded, the water runs out the opposite side to a vegetated swale.

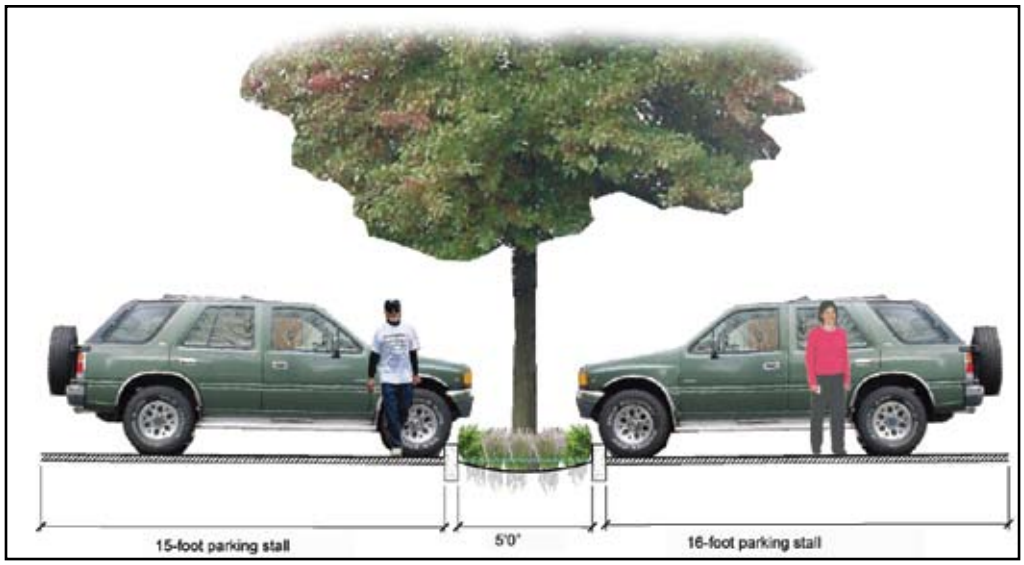
Barriers to implementing LID on roadways and in parking lots

As mentioned earlier, local codes and ordinances can act as barriers to implementing LID. Emergency responders favor wide streets for access. Compromises in street widths can be made to allow infiltration while preserving

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

Reference:

- San Mateo Countywide Water Pollution Prevention Program, 2009, San Mateo County Sustainable Green Streets and Parking Lots Design Guidebook, available at www.flowstobay.org/ms_sustainable_streets.php



San Mateo County Sustainable Green Streets and Parking Lots Guidebook

Place parking lot medians between rows of 15-foot parking stalls. Be sure to allow for pedestrian passage.

emergency vehicle access. Current recommendations call for 24-foot road widths for most low-traffic roads. This width is sufficient for two-way traffic. The National Fire Protection Administration Uniform Fire Code (2003) recommends a minimum unobstructed width of only 20 feet.

LID practices that allow infiltration into underlying soils should not be incorporated into roads or parking lots where the risk from hazardous material spills is high, such as gas stations or chemical suppliers. Other unsuitable sites include areas with high or shallow water tables.

Maintenance workers are often reluctant to approve LID features due to concerns about the type or frequency of maintenance that will be needed. Curb and gutter is seen as a "tidier" solution requiring little maintenance, when in fact, regular cleaning of catch basins and storm drain pipes with specialized equipment is needed, as well as periodic reconstruction of curbs.

LID features such as bioretention basins typically require standard landscaping maintenance while porous pavements require annual street sweeping with vacuum-type street sweepers.

Additional information about LID roadway and parking lot design can be found at:

- Massachusetts Low Impact Development Toolkit, Roadways and Parking Lot Design, Fact Sheet #7, www.mapc.org/regional_planning/LID/PDFs/roadway.pdf
- U.S. Environmental Protection Agency, Managing Wet Weather with Green Infrastructure Municipal Handbook, http://cfpub.epa.gov/npdes/greeninfrastructure/munichandbook.cfm
- Massachusetts Nonpoint Source Pollution Management, Roadway and Parking Lot Design, http://projects.geosyntec.com/NPSManual/Fact%20Sheets/Roadway%20&%20Parking%20Lot%20Design.pdf
- San Mateo Countywide Water Pollution Prevention Program, Sustainable Streets, www.flowstobay.org/ms_sustainable_streets.php

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

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Fact Sheet FS-09-23

Low Impact Development in Northern Nevada: Soil Considerations

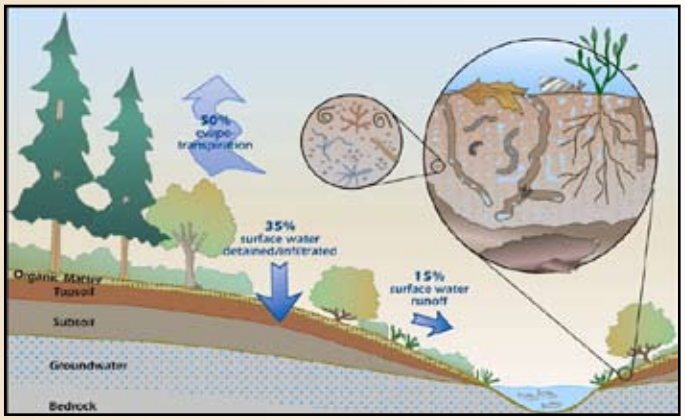
By Susan Donaldson, Water Quality Education Specialist
Melody Hefner, Water Quality Program Assistant
UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Low Impact Development (LID) is a sustainable approach to managing stormwater on developed sites using design techniques that detain, retain, infiltrate, filter and evaporate runoff close to its source. When stormwater infiltration occurs close to the source, the likelihood of soil erosion and increased pollutants in the runoff decreases.

Benefits of Good Soil

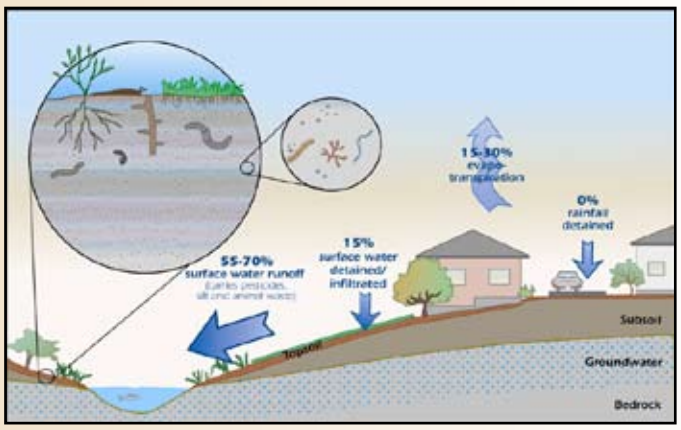
- **INFILTRATES** stormwater
- **PROCESSES** pollutants
- **HOLDS** water and nutrients for plants
- **PROVIDES** pore space for biological activity

The original hydrology of the site, the ability of the site to infiltrate stormwater, and the amount of stormwater that runs off an undeveloped site are dependent on the type of soil present. Site-specific soil properties thus influence the selection of the best method of stormwater treatment for developed sites, as well as the cost.



Washington Organic Recycling Council

Stormwater distribution with ample soil biota (above) is shown on a natural or undeveloped site, while stormwater distribution and depleted soil biota (below) are shown on a developed site.



Washington Organic Recycling Council

How does development affect the amount of stormwater infiltrated into soils?

When rain or snow falls on undisturbed, vegetated soil, about half the precipitation is lost to evapotranspiration, which is the combination of transpiration by plants and direct evaporation (see graphic). Of the other half of the precipitation, about 35

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How does soil compaction affect LID?

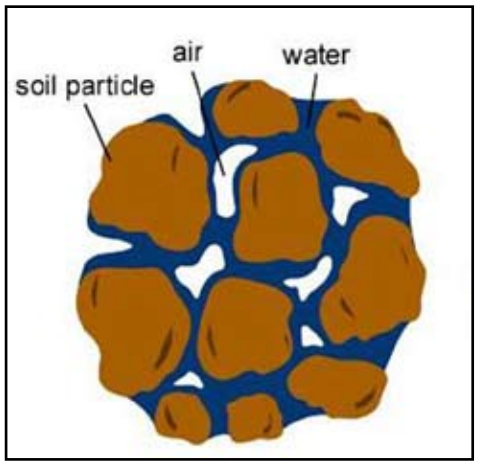
While some increase in pore space occurs naturally through freeze-thaw cycles and other mechanisms, most soil compaction is not easily reversed. The net result is an increase in the amount of runoff from the site, less water storage, less biological processing and more soil erosion. ***Compacted soils are not appropriate for LID.***

percent soaks (infiltrates) into the soil profile and 15 percent runs off. After development occurs, and impervious surfaces such as pavement or buildings cover the soil, this ratio changes dramatically. As much as 55 to 70 percent runs off the site, and as little as 15 percent or less infiltrates.

How are soil properties determined?

The type of native soil that forms at a site is influenced by the original type of rock present on the site; how long weathering has occurred; the local climate; land surface features or topography, including slope; and the actions of plants and animals. These factors influence the chemical, physical and biological properties of a soil. The soil at the surface, called the topsoil, is generally highest in organic matter and most valuable for landscaping.

Determining the best LID practice or practices to implement on a site-by-site basis requires a comprehensive inventory of site conditions. Start by performing an assessment of onsite soil properties and site hydrology, including soil textural analyses and onsite infiltration measurements.



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This soil has about 50 percent pore space. About half of the pore space is filled with air and half with water.

Collect and submit a soil sample for analysis to determine texture, nutrient levels and the type of clay present. If there are significantly different types of soil on the site, collect separate samples from the different areas for analysis.

Maps providing very general information on surface soils in the greater Truckee Meadows area are provided in Appendix A of the Truckee Meadows LID Handbook (available at www.TMstormwater.com). The maps provide very general information on surface soils of the area, and should not be substituted for an onsite assessment of soil properties.

IPMopedia

Use a ruler to measure the rate of infiltration in a pit.

Soil properties: texture, porosity and infiltration

A typical soil in good condition contains about 50 to 60 percent solid material and 40 to 50 percent pore space, or gaps between the particles. In this typical soil, about half of the pore space is filled with water and half with air. The solid materials consist mainly of minerals, and include a small amount of organic material. In Nevada, the organic matter fraction tends to be very small, often under 1 percent. In contrast, in a productive agricultural soil, organic matter may range up to 5 percent. Organic matter helps increase the ability of a soil to adsorb and store water and nutrients.

Soil minerals fall into three main groupings, called sand, silt and clay, based on the size of the particles. Sand grains are the largest particles (0.05 to 2

Infiltration Rates by Soil Type Under Saturated Conditions

Soil Type	Infiltration Rates (inches/hour)	Infiltration Rates (inches/day)
Sand	8.27	198.5
Loamy Sand	2.40	57.6
Sandy Loam	1.02	24.5
Loam	.52	12.46
Silt Loam	.27	6.5
Sandy Clay Loam	.17	4.1
Silt	.10	2.4
Clay Loam	.09	2.2
Silty Clay Loam	.06	1.4
Sandy Clay	.05	1.2
Silty Clay	.04	1.0
Clay	.02	.5

Source: The RETC Code for Quantifying the Hydraulic Factors of Unsaturated Soils, van Genuchten, et al., 1992

millimeters (mm) in diameter), silt grains are intermediate in size (0.002 to 0.05 mm), and clay grains are the smallest (less than 0.002 mm in diameter).

The proportion of sand, silt and clay, called soil texture, affects the porosity and permeability of the soil. Porosity is a measure of the amount of pore space in a soil, and permeability is a measure of how well-connected the pore spaces are to one another. Porosity and permeability affect infiltration rates, or how quickly water is absorbed into the soil. They also affect water-holding capacity, which influences how slowly water drains from the soil. In general, the higher the percentage of silt- and clay-sized particles, the higher the water-holding capacity.

Some Nevada locations have clay-rich soils. Infiltration into these soils is limited by the small grain size of the clay particles and the small pore spaces that remain between the clay grains. Some clay soils swell up when wetted, further reducing the pore space. The ability of clay particles to attract and hold onto water molecules makes the water-holding capacity of these soils high.

Use simple percolation tests to determine infiltration rates. For small-scale projects, dig a pit 1 to 2 feet deep. Fill the pit with water and let it soak in. Then, place a yardstick vertically in the hole and fill the pit again to a measured depth, such as 12 inches. Monitor the rate at which the water level drops and determine the infiltration rate in inches per hour. For larger-scale projects, refer to the infiltration testing methods in the Truckee Meadows Low Impact Development Handbook (www.TMstormwater.com).

LID practices are most effective in soils with infiltration rates of at least one-half inch per hour. Rates of 1 inch per hour are preferred. Amend soils with infiltration rates less than one-half inch per hour with organic material to increase their infiltration rate, or install underdrains to facilitate drainage. The table shows average infiltration rates for different soil types. Sand, loamy sand, sandy loam and loam soil types have infiltration rates appropriate for LID. All other soil types will require soil amendment to increase infiltration rates if they are to be used for LID.

Soil biology

Air-filled pore space is essential to healthy plants and soil organisms. Soils are full of living creatures, such as earthworms, mites and other arthropods, nematodes, and microscopic plants and animals, including bacteria and fungi. Together, the living creatures are called soil biota. The soil biota population increases as the amount of organic material in the soil increases.

Soil biology plays an important role in infiltration, water-holding capacity, pollutant processing, nutrient retention, nutrient cycling and plant growth. The soil biota transform and cycle carbon, nitrogen and other mineral nutrients in plant and animal residues into forms that can be used by plants. Soil bacteria

LID is used because it is:

EFFECTIVE in reducing and treating urban runoff;

ECONOMICAL, when less infrastructure is required for LID practices than for traditional stormwater features;

SIMPLE!
Most LID features are not highly engineered, expensive or elaborate;

FLEXIBLE and customized for each site;

USEFUL in achieving multiple objectives: stormwater management, landscape beautification, habitat improvement, open space connectivity, etc.; and

DESIRABLE, because it adds value when the landscape features used to achieve LID goals are also aesthetically pleasing. This can increase property values.

Water moves rapidly through sandy soils, and slowly through clay soils.

For a description of various Low Impact Development practices, consult the following Fact Sheets in the "Low Impact Development in Northern Nevada" series:

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Rainwater Harvesting, FS-09-24

Bioretention, FS-09-25

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Green Roofs, FS-09-27

Plant Materials, FS-09-28

Porous Pavement, FS-09-29

Roadway and Parking Lot Design, FS-09-30

Maintenance, FS-09-31

have a wide range of abilities to break down pollutants into less harmful components, purifying water as it moves through the soil. Soil compaction reduces pore space. This may affect the habitat available for soil biota. As the number of living organisms in the soil decreases, soil fertility also decreases, limiting plant growth.

Soil compaction

During construction and development, soil is compacted by heavy equipment and vehicular traffic. The effect increases when these disturbances occur on wet soils. Compaction results in a decrease in soil porosity, infiltration rates and the amount of water and oxygen available for plant growth and soil biota. While some increase in pore space occurs naturally through freeze-thaw cycles and other mechanisms, most soil compaction is not easily reversed. The net result is an increase in the amount of runoff from the site, less water storage, less biological processing and more soil erosion. Compacted soils are not appropriate for LID.

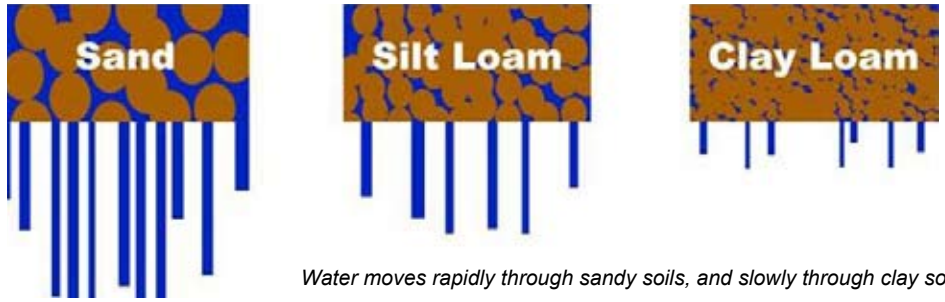
Construction cut and fill practices also result in soil compaction and removal of valuable topsoil. Typically, topsoil is removed, mixed with subsoils and stockpiled prior to excavation for foundations or other earthworks. The hydrology of the site is immediately changed, because topsoil and vegetation are no longer in place to infiltrate, retain or intercept precipitation and hold the soils in place. Rain falling on the site is now much more likely to run off, cause erosion and transport eroded soil particles, other debris and pollutants from the site, unless construction site best management practices (BMPs) have been installed and maintained. To make matters worse, as construction proceeds, heavy equipment further compacts the remaining soil and subsoil.

Once construction activities have been completed, typically a thin layer of imported topsoil is laid down on top of the compacted soil or subsoil and the area is landscaped. Not surprisingly, turf and other ornamental plants installed in these conditions need more water and nutrients to survive, since the compacted subsurface soils restrict root growth and soil moisture retention. Trees planted in holes dug on these sites respond as if they had been planted in plastic pots, with the trees sometimes drowning in their own irrigation water due to lack of drainage through the compacted subsoil. These trees often are unable to maintain a stable root system and may blow over during storms. Landscapes planted in compacted soils often struggle along, requiring extra care and additional inputs of fertilizers or pesticides, before they finally die due to disease and environmental stresses.

Improving compacted soils

The best solution is to avoid soil compaction whenever possible. Prior to construction, assess the site to identify the soils with the highest infiltration capacity. Design developments to protect these soils while placing any impervious surfaces, such as buildings and driveways, on the soils that have lower infiltration rates. Stockpile and replace high-quality topsoil after construction has concluded.

During construction, design and use specified travel paths to

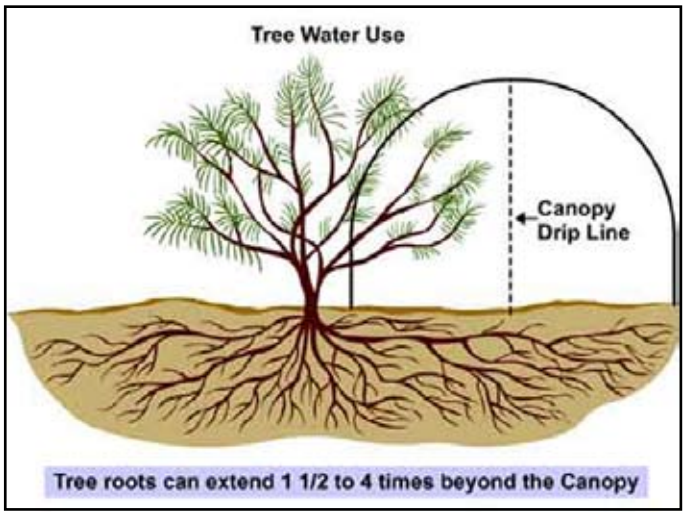


Water moves rapidly through sandy soils, and slowly through clay soils.

limit overall compaction of the site. Restrict heavy equipment to those areas that have soils with the lowest infiltration rates. Protect areas with good infiltration rates, including sandy and loamy soils, to preserve existing infiltration rates and healthy soil biota. Limit removal of vegetation to only what is essential for construction, to reduce the potential for compaction and erosion and preserve the original site hydrology. Flag or fence around existing vegetation that is to be preserved.

After construction, restore compacted soils by ripping and adding organic matter. Any activity on soil should occur when the soil is moist enough that digging will not create dust and dry enough that equipment driving over it does not create ruts. The most common method to reduce compaction is to rip the soil to a depth of 12 inches. In Nevada, call 1-800-227-2600, "Call Before You Dig," prior to ripping to locate all underground gas, water, sewer, septic and utilities. Avoid these areas.

Ripping will provide a temporary increase in soil porosity, but the pore space will decrease over time. To extend the benefits, add organic material to the soil after ripping. Avoid ripping within the drip lines of existing trees to avoid damage to tree roots.



Southern Nevada Water Authority

Preserve the roots within the drip line to avoid damage to the tree.

Adding organic matter to improve soils

Nevada soils are generally deficient in organic matter, and compacted soils will especially benefit from the addition of organic material. Compost, a mixture of decaying organic matter, such as leaves and manure, is often used as a source of organic matter. Amending with compost improves soil structure and water-holding capacity; increases onsite stormwater retention, filtration, pollutant retention, and nutrient-holding capacity; and reduces irrigation water and fertilizer requirements.

When adding organic material or compost to soil, mix one part of compost to two parts of soil. Start by loosening the existing topsoil to a depth of 8 inches. Place 4 inches of compost on the soil and mix or till it. The total depth will then be about 12 inches.

When tilling, use two passes, with the second tilling perpendicular to the first. If enough soil exists, till to a greater depth.

Use caution when selecting the size of the tilling equipment, as heavy tilling equipment will compact the soil further.

On sites with restricted access, buried utilities, or thick vegetation, the addition of 3 to 4 inches of organic mulch on the soil surface will help decrease compaction in the underlying soil with time. However, the process is much slower than direct mixing.

What's the right soil?

Specific LID practices have their own soil requirements. For example, never use uncomposted manure as part of the engineered soil mix of LID practices such as bioretention systems, including landscape detention features, rain gardens, tree box filters and stormwater planters. These systems are designed to capture, concentrate, filter and infiltrate stormwater through engineered soils.

Uncomposted manure typically contains elevated levels of

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

For more information about LID, see:

- Low Impact Development Center, Inc., *www.lowimpactdevelopment.org*
- National Institute of Building Sciences Whole Building Design Guide, Low Impact Development Technologies, *www.wbdg.org/resources/lidtech.php*
- Urban Design Tools, Low Impact Development, *www.lid-stormwater.net/background.htm*
- U.S. Environmental Protection Agency Polluted Runoff (Nonpoint Source Pollution), Low Impact Development (LID), *www.epa.gov/nps/lid/*

Reference:

■ Van Genuchten, M. Th., Leiji, F.J. and Yates, S.R., 1992, The RETC Code for the Hydraulic Functions of Unsaturated Soils, U.S. Environmental Protection Agency Research and Development, EPA/600/S2-91-065.

CSREES

Adding 3-4 inches of organic mulch will help decrease soil compaction and make the soil more capable of filtering stormwater.

ammonia, phosphorus, salts and pathogens, which can leak out and harm a receiving water body. See the other fact sheets in this series for specific recommendations for each LID practice. Whenever possible, determine soil texture, organic matter content and infiltration rate of the native soil present on the site prior to selecting an LID practice.

CSREES

Determine soil texture before applying an LID practice to a site.

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

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Fact Sheet FS-09-26

Low Impact Development in Northern Nevada: Vegetated Swales and Buffers

By Susan Donaldson, Water Quality Education Specialist

UNIVERSITY OF NEVADA COOPERATIVE EXTENSION

Low Impact Development (LID) is a sustainable approach to stormwater management that minimizes impacts on waterways. Vegetated swales and buffer strips are types of LID stormwater treatment systems that use soil and plants to filter pollutants from runoff. They are easy to construct and can be used to treat runoff from parking lots, buildings, roadways and homes. It is important to recognize the difference between a ditch and a swale.

Ditches are excavated channels that are constructed to convey stormwater or irrigation water. Ditches are not constructed to provide water quality benefits.

Swales, sometimes called bioswales, are shallow, gently-sloped vegetated open channels that slow down runoff, filter out stormwater pollutants and allow some infiltration to occur. They can be designed as a form of bioretention (see LID in Northern Nevada: Bioretention, FS-09-25) and can also be used to convey stormwater runoff in place of pipes or ditches.

As water flows along the swale, it is slowed down by the plants and the roughness of the landscaped surface. This allows sediments and pollutants to drop out and be processed by the plants and soil. Some stormwater soaks into the soil and is used by plants, and, depending on existing soil conditions and LID design, some stormwater infiltrates and provides groundwater recharge. Some water continues to flow downhill in the swale, but at a slower rate and sometimes at a lower volume than would flow

Susan Donaldson

This grassy swale in Carson City receives and infiltrates runoff from the parking lot.

Chris Conway

Benefits of Swales and Buffers

- **FILTER** stormwater runoff
- **TRAP** particulate pollutants
- **SLOW** stormwater flows and reduce volumes
- **REDUCE** soil erosion
- **SAVE** money by decreasing irrigation needs, as compared to turf
- **PROVIDE** aesthetic appeal

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Maintenance, FS-09-31

Susan Donaldson

Ditches lack vegetation to help filter pollutants and stabilize soils.

through conventional storm pipes. Vegetated swales are most effective when integrated into the overall site design and can be used to help fulfill new development landscaping requirements.

To provide time for pollutant removal, the minimum length of a swale should be about 100 feet and the channel slope should be between 0.5 and 2.5 percent. If the site has steeper slopes, check dams can be used to maintain a 2.5 percent or less channel slope. With increasing swale length, there is more time to slow the flow of runoff and filter out pollutants. Swales can be designed to incorporate existing natural drainage channels, allowing enhanced recharge, or they can be constructed at the edges of roads, parking lots and developments. Poorly drained soils, such as clays, will require installation of underdrains.

Swales traditionally have been planted with grasses, requiring regular irrigation. If planted with drought-tolerant vegetation, swales will require little to no water once established. In Nevada, swales designed as dry stream channels with rock and native grasses and shrubs are often appropriate, attractive and conserve water in addition to providing urban stormwater treatment.

Buffer strips, sometimes called filter strips or biofilters, are gently sloped areas of vegetation and landscaping installed between or at the edge of impervious surfaces and turf areas. Stormwater runoff from sidewalks, driveways and streets, and irrigation overspray from turf areas is captured and filtered through vegetated buffer strips instead of draining onto the street.

A turf or lawn buffer is an area of vegetation and landscaping located between a lawn and any pavement or cement surface that can be watered without the use of sprinklers. Often, the buffer will be found between the front yard lawn and the sidewalk or street. In many cases, lawn areas have been constructed to drain to the sidewalk or the street. If this is the case, a buffer strip can accomplish two purposes: it will capture overspray and interrupt any runoff from the lawn.

Buffer strips are most effective when planted with drought-tolerant vegetation that requires minimal watering. They should be installed over soils that have adequate infiltration rates (see LID in Northern Nevada: Soil Considerations, FS-09-23) and the slope of the buffer strip soil surface should not exceed 4 percent. The flow entering a buffer strip should not be channelized and concentrated, but should spread out across width of the buffer strip to maximize filtering and infiltration. Flow spreaders, such as gravel-filled trenches, are sometimes necessary to distribute flow evenly across a buffer strip.

The steps to installing a lawn buffer strip in an existing development include rerouting the lawn sprinkler system to the new lawn edge to create space for the buffer. For small areas, consider replacing the entire side lawn, as these small areas are virtually impossible to irrigate with sprinklers without wasting water and creating runoff. Remove the turf, amend the existing soils as necessary to allow infiltration, add a drip system or soaker hoses, install plants, and cover the area with rock or mulch. Placing landscape fabric under the rock or mulch will help control weeds. Substantial savings can result from replacing lawn areas with low-water-use vegetation.

If the buffer strip area slopes more than 4 percent, add terraces to create gently sloping areas that effectively capture and infiltrate runoff and support vegetation.

Buffers can save water by decreasing runoff and overspray

Susan Donaldson

Susan Donaldson

It's very difficult to avoid overspray and runoff when sloping lawns end at the sidewalk or the street (top photo). It's especially difficult to use sprinklers to irrigate small areas such as this one without creating runoff. Often, much water is wasted. Buffers can be constructed between the sidewalk and lawn (bottom photo). Select low-water-use plants that can be irrigated using drip systems to save money, as well as decrease runoff.

Plants for vegetated swales and buffers

Plants for vegetated swales and buffer strips should meet the following criteria:

- Native or well-adapted to the local climate
- Low water use
- Low fertilizer requirements
- Minimal maintenance
- Attractive in all seasons

Plant species that are located in the lowest zone of vegetated swales must be able to withstand periodic flooding. Turf can also be used in vegetated swales and buffer strips. However, turf requires regular irrigation, fertilizer application and maintenance, which may result in reduced pollutant removal effectiveness. Densely planted native bunch grasses maintained at a height of 4 to 6 inches are recommended for maximum pollutant removal effectiveness. See LID in Northern Nevada: Plant Materials, FS-09-28, for a list of recommended plants for various LID practices, including vegetated swales and buffer strips, or go to www.unce.unr.edu/nemo.

Maintenance

Grassy swales need standard maintenance including irrigation, mowing, removal of debris, aeration and reseeding. Mow 4 to 6 inches high to avoid drought stress and decrease flow velocities. Monitor swales and buffer strips and adjust irrigation to meet plant water demands while avoiding seepage and runoff. Any standing water remaining after a storm should infiltrate or evaporate within 48 hours to avoid mosquito breeding.

Monitor swales and buffer strips on a regular basis, especially after intense rainstorms, for

Good places for swales and buffers

- Along streets and highways
- Within street medians
- Within and along the edges of parking lots
- At the edges of lawns

For additional detailed planning and design information, refer to the latest versions of the Truckee Meadows Low Impact Development Handbook and the Truckee Meadows Structural Controls Design Manual available at www.tmstormwater.com.

LID is used because it is:

EFFECTIVE in reducing and treating urban runoff;

ECONOMICAL, when less infrastructure is required for LID practices than for traditional stormwater features;

SIMPLE!
Most LID features are not highly engineered, expensive or elaborate;

FLEXIBLE and customized for each site;

USEFUL in achieving multiple objectives: stormwater management, landscape beautification, habitat improvement, open space connectivity, etc.; and

DESIRABLE, because it adds value when the landscape features used to achieve LID goals are also aesthetically pleasing. This can increase property values.

Technical review provided by Chris Conway, Certified Professional in Sediment and Erosion Control.

Rock-lined swales remove sediment, limit plant filtration

Melody Hefner

Some swales are lined with rock and have limited plant material. This makes it more difficult to remove accumulated sediment, and decreases pollutant processing by plants. Primary benefits include water retention/ infiltration and sediment removal.

damage to vegetation, erosion, sediment accumulation and ponded water. Periodic removal of accumulated sediments will be required, as will trash collection. Replace plants and repair eroded areas as needed.

To avoid adding nutrients to stormwater runoff, fertilizer use should be minimized in vegetated swales and buffer strips. Test the soil to determine actual fertilizer needs, and select well-adapted plant species with minimal fertilization requirements. After fertilization, irrigate in short cycles to avoid runoff, and don't fertilize when rain is expected. The use of well-adapted plant species will also allow minimal use of pesticides. Use mulch, landscape fabric and hand-pulling to control weeds.

Additional information about vegetated swales and buffers can be found at:

- U.S. Environmental Protection Agency, 1999, Stormwater Technology Fact Sheet, Vegetated Swales, 832-F-99-006, www.epa.gov/owm/mtb/vegswale.pdf
- LID Strategies and Tools for NPDES Phase II Communities, Vegetated Swales, www.lowimpactdevelopment.org/lidphase2/swales.htm
- California Stormwater BMP Handbook, New Development and Redevelopment, Vegetated Swale, TC-30, www.cabmphandbooks.com/Documents/Development/TC-30.pdf

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Appendix C

Design Matrices

Treatment Control Group	Treatment Control Design	Design Matrix 1. Land Use					
		Rural	Residential	Roads and Highways	Commercial/ High Density	Hotspots	Ultra Urban
Vegetative Treatment Systems	TC-10 Vegetated Swales	S	S	S	S	S	S
	TC-11 Vegetated Buffer Strips	A	A	S	S	S	S
Infiltration Systems	TC-20 Infiltration Trenches	A	A	A	A	X	S
	TC-21 Infiltration Basins	A	A	A	A	X	S
Bioretention Systems	TC-30 Landscape Detention	A	A	A	A	S	A
Extended Detention Basins	TC-40 Sedimentation Basins	A	A	S	A	S	S
	TC-41 Sand Filter Basins	A	A	S	A	S	A
Ponds and Constructed Wetlands	TC-50 Storm Water Ponds	A	A	A	S	X	X
	TC-51 Storm Water Wetlands	A	A	S	S	X	X
Media Filtration Systems	TC-60 Surface Sand Filter	X	S	A	A	A	A
	TC-61 Underground Sand Filter	X	S	S	A	A	A
	TC-62 Porous Pavement	S	S	S	A	X	S

A = Applies under most conditions
S = Applies under most conditions
X = Not applicable

Treatment Control Group	Treatment Control Design	Design Matrix 2. Site Physical Features				
		Soils	Water Table	Drainage Area (AC)	Site Slope	Head (ft)
Vegetative Treatment Systems	TC-10 Vegetated Swales	Native or engineered soils	>3 feet	10 max	No more than 5%	3 to 5 ft
	TC-11 Vegetated Buffer Strips			5 max	No more than 10%	NA
Infiltration Systems	TC-20 Infiltration Trenches	Min infiltration rate 0.5 inch/hr	>3 feet	10 max	Generally no more than 20%	~ 1 ft
	TC-21 Infiltration Basins			5 to 50	Generally no more than 15%	3 to 5 ft
Bioretention Systems	TC-30 Landscape Detention	Imported soil	>3 feet	1 max	Generally no more than 20%	~ 5 ft
Extended Detention Basins	TC-40 Sedimentation Basins	Native or engineered soils	>3 feet	5 min	Generally no more than 20%	~4 ft
	TC-41 Sand Filter Basins			10 max	Generally no more than 20%	~4 ft
Ponds and Constructed Wetlands	TC-50 Storm Water Ponds	HSG A soils may require liner	>3 feet	25 min	Generally no more than 15%	6 to 8 ft
	TC-51 Storm Water Wetlands				Generally no more than 8%	3 to 5 ft
Media Filtration Systems	TC-60 Surface Sand Filter	Native or engineered soils	>3 feet	5 max	Generally no more than 6%	~ 5 ft
	TC-61 Underground Sand Filter			1.5 max		5 to 7 ft
	TC-62 Porous Pavement			No Limit	Generally no more than 5%	NA
Oil and Water Separators	TC-70 Oil and Water Separators	Native or engineered soils	NA	No Limit	Generally no more than 10%	3 to 5 ft

Treatment Control Group	Treatment Control Design	Design Matrix 3. Storm Water Management Capability			
		Water Quality	Recharge	Channel Protection	Flood Control
Vegetative Treatment Systems	TC-10 Vegetated Swales	A	S	S	S
	TC-11 Vegetated Buffer Strips	A	S	A	X
Infiltration Systems	TC-20 Infiltration Trenches	A	A	S	S
	TC-21 Infiltration Basins	A	A	S	S
Bioretention Systems	TC-30 Landscape Detention	A	S	S	S
Extended Detention Basins	TC-40 Sedimentation Basins	A	S	S	A
	TC-41 Sand Filter Basins	A	S	S	A
Ponds and Constructed Wetlands	TC-50 Storm Water Ponds	A	S	S	A
	TC-51 Storm Water Wetlands	A	S	S	A
Media Filtration Systems	TC-60 Surface Sand Filter	A	X	S	S
	TC-61 Underground Sand Filter	A	X	S	S
	TC-62 Porous Pavement	A	S	S	S
Oil and Water Separators	TC-70 Oil and Water Separators	S	X	X	X

A = Practice generally meets storm water management goals
S = Practice can provide some benefit depending on site constraints
X = Practice can rarely be used to meet this goal

Treatment Control Group	Treatment Control Design	Design Matrix 4. Community and Environmental Factors					
		Cold Climate Limitations	Ease of Maintenance	Affordability	Community Acceptance	Safety	Habitat
Vegetative Treatment Systems	TC-10 Vegetated Swales	M	M	H	H	H	L
	TC-11 Vegetated Buffer Strips	M	M	H	H	H	L
Infiltration Systems	TC-20 Infiltration Trenches	M	M	M	M	H	L
	TC-21 Infiltration Basins	M	M	M	M	H	L
Bioretention Systems	TC-30 Landscape Detention	M	M	M	H	H	M
Extended Detention Basins	TC-40 Sedimentation Basins	M	M	M	H	M	L
	TC-41 Sand Filter Basins	M	M	M	H	H	L
Ponds and Constructed Wetlands	TC-50 Storm Water Ponds	M	M	M	M	M	H
	TC-51 Storm Water Wetlands	M	M	M	M	M	H
Media Filtration Systems	TC-60 Surface Sand Filter	L	M	L	M	M	L
	TC-61 Underground Sand Filter	H	M	L	H	H	L
	TC-62 Porous Pavement	L	M	M	H	H	L
Oil and Water Separators	TC-70 Oil and Water Separators	H	M	M	H	H	L

H = High benefit and/or low limitations
M = Medium benefit and/or limitations
L = Low Benefit and/or high limitations

Treatment Control Group	Treatment Control Design	Design Matrix 5. Pollutant Removal Effectiveness						
		Sediment	Nutrients	Trash	Metals	Bacteria	Oil and Grease	Organics
Vegetative Treatment Systems	TC-10 Vegetated Swales	M	L	L	M	L	M	M
	TC-11 Vegetated Buffer Strips	H	L	M	H	L	H	M
Infiltration Systems	TC-20 Infiltration Trenches	H	H	H	H	H	H	H
	TC-21 Infiltration Basins	H	H	H	H	H	H	H
Bioretention Systems	TC-30 Landscape Detention	H	M	H	H	H	H	H
Extended Detention Basins	TC-40 Sedimentation Basins	M	L	H	M	L	L	L
	TC-41 Sand Filter Basins	H	M	H	M	L	L	M
Ponds and Constructed Wetlands	TC-50 Storm Water Ponds	H	M	H	H	H	H	H
	TC-51 Storm Water Wetlands	H	M	H	H	H	H	H
Media Filtration Systems	TC-60 Surface Sand Filter	H	M	H	H	M	M-H	M-H
	TC-61 Underground Sand Filter	H	L	H	H	M	M-H	M-H
	TC-62 Porous Pavement	H	M	L	M	M	M-H	M-H
Oil and Water Separators	TC-70 Oil and Water Separators	L	L	M	L	L	M-H	L

H = High pollutant removal effectiveness
M = Medium pollutant removal effectiveness
L = Low pollutant removal effectiveness

Appendix D

Design Guidance Worksheets

TRUCKEE MEADOWS DESIGN GUIDANCE WORKSHEETS - INTRODUCTION

Truckee Meadows Version 2.0 Released 2015

Truckee Meadows Storm Water Quality Management Program

Purpose:	**This workbook is to be used as a design aid for storm water treatment controls while referencing the appropriate BMP fact sheets in the Truckee Meadows Structural Controls Design and LID Manual**
Function:	**To provide designers and reviewers with built-in tools that incorporate established criteria into the design of treatment control (TC) best management practices (BMPs) to improve storm water quality**

Content: **The workbook consists of the following sheets:**

SUMMARY	REQUIRED - Describes the project area and key site consideration
	REQUIRED - Design Parameters and Pass-Fail Checklist
TC-STA	Design-aid for Self-Treating Areas
TC-10	Design-aid for Swales
TC-11	Design-aid for Buffer Strips
TC-20	Design-aid for Infiltration Trenches
TC-21	Design-aid for Infiltration Basins
TC-30	Design-aid for Landscape Detention (Bioretention) Basins
TC-40	Design-aid for Sedimentation Basins
TC-41	Design-aid for Sand Filter Basins
TC-50	Design-aid for Storm Water Ponds
TC-51	Design-aid for Storm Water Wetlands
TC-60	Design-aid for Surface Sand Filters
TC-61(a)	Design-aid for Underground Sand Filters - D.C. Type
TC-61(b)	Design-aid for Underground Sand Filters - Delaware Type
TC-62(a)	Design-aid for Porous Pavement Detention
TC-62(b)	Design-aid for Open-Celled Block Pavers
TC-62(c)	Design-aid for Open-Jointed Block Pavers
TC-62(d)	Design-aid for Porous Asphalt and Concrete Pavement
TC-62(e)	Design-aid for Porous Turf
TC-62(f)	Design-aid for Porous Gravel
TC-62(g)	Design-aid for Open-Celled Plastic Grids

Instructions:
1. Complete Project Summary and PassFail Checklist Sheets.
2. Complete a TC worksheet for each sub-basin in the project area. Use worksheet TC-STA for self-treating areas.
3. Copy and re-name worksheets for multiple sub-basins, delete un-used worksheets.
4. Print Summary, PassFail and all other worksheets used in design.
5. Submit copies to appropriate agency for review.

Comments? Direct all comments regarding this spreadsheet workbook to: stormwater@reno.gov
Storm Water Program Coordinator, P.O. Box 1900, Reno, NV 89505

Revisions? Check for revised versions of this workbook at: TMstormwater.com

The original workbook used to develop these worsheets was created by the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado. The original workbook was modified with the permission of the UDFCD and adapted for use by the Truckee Meadows Regional Storm Water Quality Management Program, with assistance from Kennedy/Jenks Consultants and NCE.

Truckee Meadows Storm Water Quality Management Program
Project Summary Worksheet

*** Fill out worksheet from top to bottom** **Truckee Meadows Version 2.0 Released 2015**

Designer:
Company:
Date:
Project Name:
Location:

Project Characteristics

Total Project Area (acres):

Type of Development (new or redevelopment):

Total Area of New or Additional Impervious Surfaces (acres):

Type of Site Use (residential/commercial/industrial):

Storm Water Run-on to Project Area From Offsite (yes/no):

Is a Seasonal or Permanent Water Feature Onsite (yes/no):

Type (stream, spring, etc.) :

Average Site Slope (%):

Are Municipal Stormwater Collection/ Conveyance Facilities Nearby (yes/no):

Minimum Depth (ft) to Seasonal High Groundwater

Date Measured

Hazardous Materials to be Used/Stored Onsite (if known)

Material Quantity:

Material Quantity:

Identify Subbasins Where Hazardous Materials May Be Used/Stored

Vegetation for areas selected for Low Impact Development features, must be compatable with expected conditions. The final plans must have a stormwater quality treatment control vegetation plan stamped by a registered Landscape Architect.

Design Considerations

What are the soil types on the property NRCS Soil Type (i.e. A,B,C,D)?:

Is Infiltration Proposed? (Y/N):

Has Percolation Testing Been Conducted? (Y/N):

Comments on soil conditions or percolation tests?

What waterways could the drainage from this project ultimately contribute to (ex. Whites Creek, Steamboat Creek, Truckee River)?

Do any or all of these waterways have pollutants of concern or Total Maximum Daily Loads (TMDLs) identified on the EPA approved 303d list for the Truckee River Basin (http://ndep.nv.gov/bwqp/303dlist2012.htm)? If so, which waterways and which pollutants?

What Potential Pollutants that can be expected from this project? (see Table 3-2 in the Structural Controls and LID Manual)

In selection of the stormwater treatment control(s), reference the Design and Selection Matrices in Appendix C in the Structural Controls and LID Manual to document the appropriateness of the selection.

Design Matrix 1. Land Use:

Design Matrix 2. Site Physical Features:

Design Matrix 3. Storm Water Management Capability:

Design Matrix 4. Community and Environmental Factors:

Design Matrix 5. Pollutant Removal Effectiveness:

Notes & Additional Information:

Truckee Meadows Storm Water Quality Management Program
Project Pass/Fail Checklist

*** Fill out worksheet from top to bottom**

Truckee Meadows Version 2.0 Released 2015

Designer:

Company:

Date:

Project:

Location:

Key:	User Input	Calculated Result	***Italicized Font Indicates Value is Outside Recommended Range***

Project Characteristics from Summary Sheet	
Total Project Area (acres):	
Type of Development (new or redevelopment):	
New or Additional Impervious Surfaces (acres):	

Applicable Calculations

Water Quality Flow	**WQ_F=CIA**
Water Quality Volume	**WQ_V=(P*Rv*A)/12**
Rv	**Rv=0.05+0.009*I**
P = 90 Percentile for the Truckee Meadows = 0.60 inches	

Total Number of Drainage Subbasins:	0
Sub-basin acreage must equal total Project Acreage	0.00
more acreage must be addressed	
Total Post Subbasin WQ_f (ft^3/sec)	0.00
Total Post Subbasin WQ_v (ft^3)	0.00
Total Post-Pre Subbasin WQ_f (ft^3/sec)	0.00
Total Post - Pre Subbasin WQ_v (ft^3)	0.00
Total Actual Subbasin WQ_f (ft^3/sec)	0.00
Total Actual Subbasin WQ_v (ft^3)	0.00
Project %WQf	
Project %WQv	
Project	

Notes & Additional Information:

Continue to next page if there are more than 2 subbasins

Drainage Subbasin Characteristics

Subbasin #	
Subbasin Area (sq.ft.):	
Subbasin Area (acres):	
2-yr Rainfall intensity from IDF curve	
Pre-Development Impervious area (sq ft):	
Post Development Impervious area (sq ft):	
Pre-Development Runoff Coefficient:	
Post Development Runoff Coefficient:	
Pre-Development Percent Impervious:	
Post-Development Percent Impervious:	
Pre-dev.Subbasin WQ_f (ft^3/sec)	
Pre-dev. Subbasin WQ_v (ft^3)	
Post-dev.Subbasin WQ_f (ft^3/sec)	
Post-dev. Subbasin WQ_v (ft^3)	
Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
Enter Treatment Control or indicate if "self treating"	
Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
Actual Subbasin WQ_v (ft^3)	
Sub-basin %WQf	
Sub-basin %WQv	
Sub-basin	

Subbasin #	
Subbasin Area (sq.ft.):	
Subbasin Area (acres):	
2-yr Rainfall intensity from IDF curve	
Pre-Development Impervious area (sq ft):	
Post Development Impervious area (sq ft):	
Pre-Development Runoff Coefficient:	
Post Development Runoff Coefficient:	
Pre-Development Percent Impervious:	
Post-Development Percent Impervious:	
Pre-dev.Subbasin WQ_f (ft^3/sec)	
Pre-dev. Subbasin WQ_v (ft^3)	
Post-dev.Subbasin WQ_f (ft^3/sec)	
Post-dev. Subbasin WQ_v (ft^3)	
Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
Enter Treatment Control or indicate if "self treating"	
Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
Actual Subbasin WQ_v (ft^3)	
Sub-basin %WQf	
Sub-basin %WQv	
Sub-basin	

Truckee Meadows Storm Water Quality Management Program

*** Fill out worksheet from top to bottom**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Truckee Meadows Storm Water Quality Management Program

*** Fill out worksheet from top to bottom**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin #		Subbasin Area (sq.ft.):		**Subbasin #**		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):				Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve				2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):				**Pre-**Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):				**Post** Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:				**Pre-**Development Runoff Coefficient:	
		Post Development Runoff Coefficient:				**Post** Development Runoff Coefficient:	
		Pre-Development Percent Impervious:				**Pre-**Development Percent Impervious:	
		Post-Development Percent Impervious:				**Post-**Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)				**Pre-**dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)				**Pre-**dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)				**Post**-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)				**Post**-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment				**Post-Pre** WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment				**Post - Pre** WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"				Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf				Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)				Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf				Sub-basin %WQf	
		Sub-basin %WQv				Sub-basin %WQv	
		Sub-basin				Sub-basin	
Subbasin #		Subbasin Area (sq.ft.):		**Subbasin #**		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):				Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve				2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):				**Pre-**Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):				**Post** Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:				**Pre-**Development Runoff Coefficient:	
		Post Development Runoff Coefficient:				**Post** Development Runoff Coefficient:	
		Pre-Development Percent Impervious:				**Pre-**Development Percent Impervious:	
		Post-Development Percent Impervious:				**Post-**Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)				**Pre-**dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)				**Pre-**dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)				**Post**-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)				**Post**-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment				**Post-Pre** WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment				**Post - Pre** WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"				Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf				Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)				Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf				Sub-basin %WQf	
		Sub-basin %WQv				Sub-basin %WQv	
		Sub-basin				Sub-basin	

Truckee Meadows Storm Water Quality Management Program

*** Fill out worksheet from top to bottom**

Designer:
Company:
Date:
Project:
Location:

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Truckee Meadows Storm Water Quality Management Program

*** Fill out worksheet from top to bottom**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Subbasin #		Subbasin Area (sq.ft.):	
		Subbasin Area (acres):	
		2-yr Rainfall intensity from IDF curve	
		Pre-Development Impervious area (sq ft):	
		Post Development Impervious area (sq ft):	
		Pre-Development Runoff Coefficient:	
		Post Development Runoff Coefficient:	
		Pre-Development Percent Impervious:	
		Post-Development Percent Impervious:	
		Pre-dev.Subbasin WQ_f (ft^3/sec)	
		Pre-dev. Subbasin WQ_v (ft^3)	
		Post-dev.Subbasin WQ_f (ft^3/sec)	
		Post-dev. Subbasin WQ_v (ft^3)	
		Post-Pre WQ_f (ft^3/sec) Min.Requiring treatment	
		Post - Pre WQ_v (ft^3) Min. Requiring Treatment	
		Enter Treatment Control or indicate if "self treating"	
		Actual WQ_f (ft^3/sec), if 'self treating' enter min WQf	
		Actual Subbasin WQ_v (ft^3)	
		Sub-basin %WQf	
		Sub-basin %WQv	
		Sub-basin	

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Self-Treating Area TC-STA

*** Fill out worksheet from top to bottom** **Truckee Meadows Version 2.0 Released 2015**

Designer: _____ **page 1 of 1**

Company: _____

Date: _____

Project: _____ **Subbasin #**

Location: _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

A self-treating sub-basin is defined as an area that produces no runoff during a 90th percentile storm event. Examples include large landscaped areas, preserved natural areas and ponds. The designer is asked to justify their use of the self-treating area designation by identifying the slope and infiltration rate of the soils in the area to demonstrate that the water quality volume can be infiltrated. If infiltration rate is unknown or otherwise inapplicable (e.g. natural pond), the designer may provide a written description of the area in the space provided below and a justification for exemption from treatment. In general, the sub basin should have less than 20% impervious area and native infiltration rates greater than 0.5 in/hr.

1. Water Quality Volume (WQ_v) -

a) Percent of Watershed Impervious Area = I
NOTE: Maximum % Imperviousness is 20%

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- maximum drainage area 5 acres

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = 0.6 inches

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

d) WQ_V = _____ ft^3

2. Sub-basin Data

a) Sub-basin infiltration Area = A = Total Area - Impervious Area

b) Native Soils Infiltration/Percolation Rate = K_h (in/hr)
NOTE: K_h measured as near as possible to ground surface

A = _____ ft^2

K_h = _____ in/hrs

3. Sub-basin infiltration area ground surface slope
not to exceed 2%

_____ %

4. Describe vegetation / landscaping and provisions for maintenance

Notes and Additional Information/Justification:

Original worksheet developed by and used with the permission of the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado. The original worksheet was modified and adapted for the Truckee Meadows Regional Storm Water Quality Management Program by Kennedy/Jenks Consultants.

end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Swales TC-10

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality & Design Flow Rates

a) Time of concentration (t_c) in minutes — a) t_c = _____ min

b) Rainfall Intensities for 2, 5 and 100-year storm events (I_2, I_5, and I_{100})
(Reference Truckee Meadows Regional Drainage Manual) — b) I_2 = _____ in/hr; I_5 = _____ in/hr; I_{100} = _____ in/hr

c) List City or County name and Rainfall Region — c) _____

d) Subbasin Area (A) in acres (43,560 ft^2 = 1 acre)
(maximum drainage area = 10 acres) — d) A = _____ acres

e) Runoff Coefficient of Contributing Drainage Area = C
(Reference Truckee Meadows Regional Drainage Manual) — e) C = _____

f) Discharge Rates: Water Quality Flow = WQ_F = Q_2 (cfs)
Swale Design Flow: Q_5 (cfs) — f) WQ_F = _____ cfs; **Design Flow** Q_5 = _____ cfs; Q_{100} = _____ cfs; WQ_F = _____ cfs — Designer to input selected value for Water Quality Flow

2. Swale Geometry

a) Mannings Roughness Coefficient (*n*)
(Use 0.25 for grass and 0.40 for mixed vegetation and rocks) — *n* = _____

b) Swale Side Slopes (max 4H:1V or flatter) — **Left Side Slope** H:V = _____ :1; **Right Side Slope** H:V = _____ :1

c) Bottom Width (BW) of Trapezoidal Channel (10' maximum) — BW = _____ ft

d) Flow Depth (D): WQ_F depth (D_2) maximum = 3', Design Flow (Q_5) Depth = D_5
(Calculate using an external method, indicate method in notes below) — D_2 = _____ ft; D_5 = _____ ft

e) Minimum swale depth with 0.5 ft of freeboard — D_5 + 0.5' = _____ ft

e) Minimum swale Top Width (TW) with 0.5 ft of freeboard — TW = _____ ft

3. Swale Length, Slope & Flow Velcoity

a) Length of Swale (L_S), minimum = 100' — L_S = _____ ft

b) Longitudinal Slope (S), 0.5% minimum, 2.5% maximum — S = _____ %

c) Flow Velocity (V) (WQ_F velocity = V_2 , maximum = 2.0 ft/sec)
(Calculate using an external method, indicate method in notes below) — V_2 = _____ ft/sec; V_5 = _____ ft/sec

4. Vegetation (Check **"x"** to indicate type used or describe "Other")
(Minimum vegetation height of 4 - 6" is recommended)

_____ Dryland Grass
_____ Irrigated Turf Grass
_____ Other: _____

5. Underdrain & Outlet (Check **"x" to indicate** type used or describe "Other")

a) Check "x" if swale is in HSG C or D soils? _____ — _____ **Underdrain required if checked**
(Provide a 4" diameter PVC underdrain for proper drainage)

b) Outlet for flows greater than the WQ_F

_____ Grated Inlet
_____ Overland Flow to Valley Gutter or Downstream Swale
_____ Other: _____

Notes & Additional Information

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Vegetated Buffer Strips TC-11

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Flow Rate		
a) Rainfall Intensity = I (2-year storm - determine using site location and Truckee Meadows Regional Drainage Manual)	a)	I = _____ in/hr
b) List City or County name and Rainfall Region	b)	_____
c) Drainage Area = A (acres) (43,560 ft^2 = 1 acre) - maximum drainage area is 5 acres	c)	A = _____ acres
	d)	C = _____
d) Runoff Coefficient of Contributing Drainage Area = C	e)	WQ_F = _____ cfs
e) 2-Year Design Discharge = WQ_F (cfs)		WQ_F = _____ cfs — Designer to Input selected value for Water Quality Flow
2. Drainage Area Flow		
a) Design Length (Normal to runoff flow path): $L_G = WQ_F / 0.005$		L_G = _____ ft
3. Design Width Along Direction of Flow		
a) Length of Flow Path Over Upstream Impervious Drainage Area		L_L = _____ ft
b) Design Width of Buffer Strip: $W_G = 0.2 * L_L$ (8' minimum for turf grass, 14' minimum for other vegetation)		W_G = _____ ft
4. Flow Characteristic		
a) Interface Cross Slope (normal to flow direction)		S_I = _____ ft/ft
b) Flow Type (if concentrated, level spreader is required)		_____
5. Design Slope (preferably between 2% and 4%, maximum 8%)		S = _____ %
6. Flow Distribution (Check "x" the type used or describe "Other")		____ Slotted Curbing
		____ Modular Block Porous Pavement
Note: If Flow Type is "Concentrated", Level Spreader Will Be Checked Here		____ Level Spreader
		____ Other: _____
7. Vegetation (Check "x" the type used or describe "Other")		____ Irrigated Turf Grass
Note: Irrigation required during the dry season for vegetated buffer strips		____ Other: _____
8. Outflow Collection (Check "x" the type used or describe "Other")		____ Grass Lined Swale
		____ Street Gutter
		____ Storm Sewer Inlet
		____ Underdrain Used
		____ Other: _____

Notes & Additional Information

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Infiltration Trenches TC-20

*** Fill out worksheet from top to bottom** **Truckee Meadows Version 2.0 Released 2015**

Designer:
Company:
Date:
Project:
Location:

Subbasin #

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_V) - Infiltration Trench Storage

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- maximum drainage area 5 acres

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = 0.6 inches

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area ft^2
Sub-basin impervious area ft^2
% Imperviousness

b) A= ac

c) R_v =

e) WQ_V = ft^3

WQ_V = ft^3

Designer to select value for Water Quality Volume for actual design

2. Infiltration Trench Dimensions

a) Surface Area (SA) of Trench — SA = ft^2

b) Porosity (void space of rock matrix) (unitless)

c) Total Trench Voume = V_T — V_T = ft^3

d) Depth of Trench = D (recommended min 3 feet, max 6 feet) — D = ft

3. Infiltration Trench Floor Slope
not to exceed 1%

%

Notes & Additional Information

Original worksheet developed by and used with the permission of the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado. The original worksheet was modified and adapted for the Truckee Meadows Regional Storm Water Quality Management Program by Kennedy/Jenks Consultants.

end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Infiltration Basin TC-21

*** Fill out worksheet from top to bottom** **Truckee Meadows Version 2.0 Released 2015**

Designer: _____ **page 1 of 1**

Company: _____

Date: _____

Project: _____ **Subbasin #**

Location: _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v) - Landscape Detention Basin Storage

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- maximum drainage area 5 acres

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = P (inches)

e) Water Quality Volume = WQ_v (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Infiltration Basin Data

a) Native Soil Infiltration Rate = K_h (in/hr) — K_h = _____ in/hr

b) Basin Invert Area = A — A= _____ ft^2

c) Maximum Drain Time = t (168 hours or 7 days) — t= _____ hrs
$t = WQ_V/(0.5(K_h/12) \times A)$

3. Basin Side Slopes
(H:V = 3:1 or flatter) — H:V= _____ :1

4. Basin floor slope
not to exceed 5% — _____ %

Notes & Additional Information

Original worksheet developed by and used with the permission of the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado. The original worksheet was modified and adapted for the Truckee Meadows Regional Storm Water Quality Management Program by Kennedy/Jenks Consultants.

end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Landscape Detention (Bioretention) TC-30

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v) - Landscape Detention Basin Storage

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- drainage area 1 acre maximum

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = P (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Landscape Detention Basin Dimensions

a) Surface Area (SA) of basin

b) Ponding Depth = D_{WQV} (6-inch minimum, 12-inch maximum)

SA = _____ ft^2

D_{WQV} = _____ in

3. Site Soils, Drainage Area Characteristics and Drainage Requirements

Answer ALL questions 3a to 3e to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is an expansive clay _____
b) Subgrade is a poor-draining soil (Infiltration < 0.5 in/hr) _____
c) Subgrade is a well-draining soil (Infiltration > 0.5 in/hr) _____

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "y" or "n" _____

e) **Check "x" box if no storm drain system is available** _____
(e.g. downgradient storm drain pipe or drainage)

4. Infiltration Testing

If infiltration proposed, percolation testing required
a) Site infiltration testing conducted ("Y" **or** "N") _____
b) Test results: Ave infiltration rate at basin depth = _____ in/hr
Note: Minimum infiltration rate without an underdrain = 0.5 in/hr

_____ Infiltration with Permeable Filter Fabric Liner Or Pea Gravel (3c = x and 3d = N)

_____ Infiltration with Underdrain and Permeable Filter Fabric Liner or Pea Gravel (3b = x and 3d = N)

_____ No Infiltration, Install Underdrain with an Impermeable Liner (3a = x or 3d = Y)

_____ DO NOT USE TC-30 unless underdrain can be constructed to an alternative drainage feature (3a or 3b = x and 3e = x)

_____ Other: _____

5. Engineered Soil Mixture and Liner Requirements

a) 18" min depth well mixed combination of Clean Sand (50-65%), Certified Compost or Peat Moss (5-20%), and Topsoil (20-30%) overlying a pea gravel layer and an 8" Clean Coarse Aggregate subbase

b) Other

_____ Use a sand/compost/topsoil mix no underdrain pipe required if well-drained soils

_____ Use a sand/peat/topsoil mix with an underdrain pipe system

_____ Use a sand/peat/topsoil mix with an impermeable liner and an underdrain pipe system

_____ Other: _____

Notes & Additional Information

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Sedimentation Basin TC-40

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer:
Company:
Date:
Project:
Location:

Subbasin #

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v) - Sedimentation Basin Storage

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- minimum drainage area of 5 acres

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = P (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area ____ ft^2
Sub-basin impervious area ____ ft^2
% Imperviousness ____

b) A= ____ ac

c) R_v = ____

e) WQ_V = ____ ft^3

WQ_V = ____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Outlet Structure

a) Depth of water above the centerline of the bottom row of perforations, H (8' max.)

b) Number of perforations per column, n_{perf}

c) Target drain time, t. (48 hour min., 168 hour max.)

d) Detention basin bottom slope, S

e) Required Maximum Outlet Area per Column = A_o

f) Number of Columns, n_c

g) Area of Each Perforation = A_{perf}

h) Diameter of individual circular perforation, d

a) H = ____ feet

b) n_{perf} = ____

c) t= ____ hours

d) S= ____ ft/ft

e) A_o = ____ in^2

f) n_c = ____

g) A_{perf} = ____ in^2

h) d= ____ in
(Rounded to the nearest 1/16th of an inch)

3. Detention Basin length to width ratio (minimum L:W = 2:1)

L:W = ____ :1

4. Pre-sedimentation Forebay Basin - Enter design values

a) Volume

b) Surface Area

c) Connector Pipe Diameter
(Size to drain this volume in 5-minutes under inlet control)

d) Paved/Hard Bottom and Sides

a) ____ ft^3

b) ____ ft^2

c) ____ in

d) ____ yes(y) or no(n)

5. Basin Sizing

a) Basin Top Stage Depth (Depth D_{WQ} = 2' Minimum)

b) Total Volume: Vol_{tot} = Storage from 4A + 5A

a) D_{WQ} = ____ ft
Storage= ____ ft^3

b) Vol_{tot} = ____ ft^3

continue to next page

Truckee Meadows Regional Storm Water Quality Management Program
Design Guidance Worksheet: Sedimentation Basin TC-40

Designer:
Company:
Date:
Project:
Location:

Subbasin #

6. Basin Side Slopes (side-slopes within sedimentation basin) H:V = horizontal distance per unit vertical (minimum 4:1, flatter preferred)	H:V = ____ :1
7. Dam Embankment Side Slopes (exterior side slopes) H:V = horizontal distance per unit vertical, (minimum 3:1, flatter preferred)	H:V = ____ :1
8. Vegetation (Check "x" the method or describe "Other")	____ Native Grass ____ Irrigated Turf Grass ____ Other: ____

Notes & Additional Information

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Sand Filter Basins TC-41

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer:
Company:
Date:
Project:
Location:

Subbasin #

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v) - Sand Filter Basin Storage

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = P (inches)

e) Water Quality Volume = WQ_v (ft^3)

a) Sub-basin area ____ ft^2
Sub-basin impervious area ____ ft^2
% Imperviousness ____

b) A= ____ ac

c) R_v = ____

e) WQ_v = ____ ft^3

WQ_v = ____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Minimum Filter Surface Area: $A_s = (WQ_v/3)$

a) Filter Surface Elevation

b) Side Slope of the Filter Basin 4H:1V or flatter

A_s = ____ ft^2

a) Z = ____ ft

b) H:V = ____ :1

3. Basin Depth (D) (3' maximum)

D = ____ ft

4. Outlet Works

a) Sand Layer Thickness (18" min.) — a) ____ in

b) Gravel Layer Thickness (9" min.) — b) ____ in

c) Overflow Elevation At Top of Design Volume (Filter Surface Elev. + Estimate of Basin Depth (D)) — c) ____ ft

5. Site Soils, Drainage Area Characteristics and Drainage Requirements

Answer ALL questions 5a to 5d to determine design requirements

Check "x" only one appropriate box based on following criteria
a) Subgrade is a heavy or expansive clay
b) Subgrade is a silty or clayey sand
c) Subgrade is a well-draining soil
Answer Yes (Y) or No (N) to the following question
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"

6. Infiltration Testing

If infiltration proposed, percolation testing required
a) Site infiltration testing conducted (Y or N)
b) Test results: Ave infiltration rate at basin depth = ____ in/hr
Note: Minimum infiltration rate without an underdrain = 0.5 in/hr

____ Design: Infiltration with Permeable Fabric Liner (see # 4) 5c = x **and** 5d = N

____ Design: Underdrain with Permeable Fabric Liner 5b = x **and** 5d = N

____ Design: Underdrain with Impermeable Liner 5a = x **or** 5d = Y

____ Other: ____

7. Describe provisions for maintenance

Notes and Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Storm Water Ponds TC-50

*** Fill out worksheet from top to bottom**

Truckee Meadows Version 2.0 Released 2015

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = P (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Permanent Pool

a) Volume: Vol-Pool = 2 * WQ_V

b) Average Depth
Zone 1 = Littoral Zone - 1' to 2' deep
Zone 2 = Deeper Zone - 4' to 6' deep

c) Maximum Zone 2 Permanent Pool Depth (not to exceed 8 feet)

d) Permanent Pool Water Surface Area (Estimated Minimum)
(Zone 1 - Littoral Zone = 25% to 50% of the total surface area)
(Zone 2 - Deeper Zone = 50% to 75% of the total surface area)

Total Estimated Minimum Surface Area (A_{Total})

Vol-Pool = _____ ft^3

Zone 1 = _____ ft
Zone 2 = _____ ft

Max Depth = _____ ft

% = _____ _____ ft^2
% = _____ _____ ft^2

% = _____ _____ ft^2

3. Forebay Storage

a) Volume = 15% to 25% of Permanent Pool Volume in 2a

b) Depth = 3 feet minimum

Volume = _____ ft^3

Depth = _____ ft

4. Annual/Seasonal Water Balance (Q_{net} has to be positive)

Q_{inflow} = estimated base flow
Q_{evap} = loss to evaporation
$Q_{seepage}$ = loss (or gain) to seepage to groundwater
$Q_{E.T.}$ = loss to plant evapotraspiration (average plant area above water surface)
Q_{net} = net quantity of base flow

Q_{inflow} = _____ ft^3/yr
Q_{evap} = _____ ft^3/yr
$Q_{seepage}$ = _____ ft^3/yr
$Q_{E.T.}$ = _____ ft^3/yr

Q_{net} = _____ ft^3/yr

5. Outlet Structure

a) Outlet Type (Check One)

_____ Orifice Plate
_____ Perforated Riser Pipe
_____ Other: _____

b) Depth of water above centerline of bottom row of perforations, 2' max

c) Required Maximum Outlet Area per Row = A_o

d) Number of Columns

e) Number of Rows = nr

f) Total Area of Each Perforation = A_{perf}

D_{BS} = _____ ft

A_o = _____ in^2

nc = _____ number

nr = _____ number

A_{perf} = _____ in^2

continue to next page

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Storm Water Ponds TC-50

Designer: _____

Company: _____

Date: _____

Project: _____ **Subbasin #** _____

Location: _____

6. Basin length to width ratio (minimum L:W = 1.5:1)	L:W = _____ :1
7. Basin Side Slopes (H:V) a) Above the Permanent Pool (4H:1V or flatter)	H:V = _____ :1
b) Below the Permanent Pool	Zone 1, H:V = _____ :1 Littoral Zone Zone 2, H:V = _____ :1 Deeper Zone
8. Dam Embankment Side Slopes (H:V)	H:V = _____ :1
9. Vegetation (Check "x" the type used or describe if "Other")	_____ Native Grass _____ Irrigated Turf Grass _____ Emergent Aquatic Species* _____ Other: _____ *Specify types and densities:
10. Are underdrains included (Yes "Y" or No "N")	_____

Notes & Additional Information

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Storm Water Wetlands TC-51

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_V)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Wetland Pond Volume, Depth, and Water Surface Area (WS Area)

a) Minimum Calculated Permanent Pool: $Vol_{Pool} \geq 2 * WQ_V$

Calculated Required Minimums:
$Vol_{Pool} \geq$ _____ ft^3
WS Area = _____ ft, estimated

Enter the Actual Design Values:
$Vol_{Pool} \geq$ _____ ft^3, final design
WS Area = _____ ft^2, final design

b) Forebay
Depth minimum = 3', maximum = 4'
Vol = 15% to 25% of of Permanent Pool Volume in 2A

Depth= _____ ft
Volume= _____ ft^3
Area= _____ ft^2 % = _____

c) Wetland Zones with Emergent Vegetation (0.50' to 1.0' deep)
(Area not more than 50% of Design Water Surface Area)

Depth= _____ ft
Area= _____ ft^2 % = _____

d) Free Water Surface Areas (2' to 4' deep)
(Area = 30% to 50% of Design WS Area)

Depth= _____ ft
Area= _____ ft^2 % = _____
Total area (b+c+d) = _____ %

3. Average Side Slope Above Water Surface (4H:1V or flatter)

H:V = _____ :1

4. Outlet Works

a) Outlet Type (Check "x" One)

_____ Orifice Plate
_____ Perforated Riser Pipe
_____ Other: _____

b) Depth of water above the centerline of the bottom row of perforations = D_{BS} (2' max.)

D_{BS} = _____ ft

c) Recommended Outlet Area per Row = A_o

A_o = _____ in^2

d) Number of Columns = nc

nc = _____ Number

e) Number of Rows = nr

nr = _____ Number

f) Total Area of Each Perforation = A_{perf}

A_{perf} = _____ in^2

5. Basin Use for Quantity Controls
(Check "x" one or describe if "Other")

_____ Detention within the facility
_____ Detention upstream of the facility
_____ Other: _____

continue to next page

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Storm Water Wetlands TC-51

Designer:
Company:
Date: Thursday, April 16, 2015
Project:
Location:

Subbasin # _____

6. Basin length to width ratio (minimum L:W = 1.5:1)	L:W = _____ :1
7. Basin Side Slopes (no steeper than H:V = 4:1)	H:V = _____ :1
8. Annual/Seasonal Water Balance (Q_{net} has to be positive) Q_{inflow} = estimated base flow Q_{evap} = loss to evaporation $Q_{seepage}$ = loss (or gain) to seepage to groundwater $Q_{E.T.}$ = loss to plant evapotraspiration (average plant area above water surface) Q_{net} = net quantity of base flow	Q_{inflow} = _____ acre-ft/yr Q_{evap} = _____ acre-ft/yr $Q_{seepage}$ = _____ acre-ft/yr $Q_{E.T.}$ = _____ acre-ft/yr Q_{net} = _____ acre-ft/yr
9. Vegetation Check "x" the method being applied or describe if "other" - vegetation should be kept 2 feet from waters edge	_____ Native Grass _____ Irrigated Turf Grass Side Slopes _____ Wetland Species in Pool* _____ Other: _____ *Describe Species Density and Mix.

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Surface Sand Filter TC-60

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)
- drainage areas between 0.5 and 50 acres

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = 0.6(inches)

e) Water Quality Volume = WQ_v (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_v = _____ ft^3

WQ_v = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Sedimentation Basin Design

a) Depth of Sand Filter = d_f (ft)
(minimum depth of 3 ft)

b) Surface Area of the Sedimentation Basin = A_S (ft^2); minimum WQv/10

c) Basin Length

d) Basin Width

e) Basin length to width ratio (L:W, min. 2:1)

d_f = _____ ft

A_S = _____ ft^2

L = _____ ft

W = _____ ft

L:W = _____ :1

3. Sand Filter Basin Design

a) Sand bed depth = d_f (minimum depth 1.5 feet)

b) Coef of permeability for sand filter = k ft/hr (typically 1.18 ft/hr for clean, well-graded sand and gravel)

c) One half the maximum allowable water depth (2h) over filter bed = h

d) Time required for the WQ_v to pass through the filter = t_f

e) Surface area of the filter basin = A_f (ft^2)

d_f = _____ ft

k = _____ ft/hr

h = _____ ft

t_f = _____ hrs

A_f = _____ ft^2

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Underground Sand Filter - D.C. Type TC-61(a)

*** Fill out worksheet from top to bottom**

Truckee Meadows Version 2.0 Released 2015

Designer:

Company:

Date:

Project:

Location:

Subbasin #

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_V)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre); max 1.5 acres

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = P (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area ____ ft^2
Sub-basin impervious area ____ ft^2
% Imperviousness ____

b) A= ____ ac

c) R_v = ____

e) WQ_V = ____ ft^3

WQ_V = ____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Sand Filter Basin Design

a) Filter depth: $d_f = d_g + d_s$
d_g = gravel bed, minimum 16-inches thick
d_s = sand filter layer, minimum 18-inches thick

d_g = ____ in ____ ft
d_s = ____ in ____ ft
d_f = ____ ft

b) Coefficient of permeability for sand filter = k
(Use k = 1.18 ft/hr for clean, well-graded sand and gravel)

k = ____ ft/hr

c) Maximum allowable water depth in sand filter = h_{max}
h_{max} = inlet elevation - outlet elevation

h_{max} = ____ ft

d) One half the maximum allowable water depth (2h)
over filter bed = h (2h = $h_{max} - d_f$)

h = ____ ft

e) Time required for the WQ_V to pass through the filter = t_f
(max time = 48 hrs)

t_f = ____ hrs

f) Surface area of the filter basin = A_f (ft^2)

A_f = ____ ft^2

3. Filter Dimensions
a) Filter width = W_f
b) Length: Lf = Af/Wf

W_f = ____ ft
L_f = ____ ft

4. System Storage Volume

a) Available Storage Above Filter Bed: $V_{tf} = A_f \times 2h$

V_{tf} = ____ ft^3

b) Storage in Filter Voids: $V_v = 0.4 \times A_f \times d_f$

V_v = ____ ft^3

c) Flow Through the Filter During Filling
$V_q = kA_f(d_f + h)t_f/d_f$, assume t_f = 1 hr and k per 2.b above

V_q = ____ ft^3

5. Permanent Pool

a) Required net storage
Vst = WQv - Vtf - Vv - Vq

V_{st} = ____ ft^3

b) Minimum Length: $L_{pm} = V_{st}/(2h)(W_f)$

L_{pm} = ____ ft

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Underground Sand Filter - Delaware Type TC-61(b)

*** Fill out worksheet from top to bottom**

Truckee Meadows Version 2.0 Released 2015

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres): Maximum = 5 acres

c) Watershed Runoff Coefficient = R_v (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_v (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_v = _____ ft^3

WQ_v = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2 Sand Filter Basin Design

a) Filter depth = $d_f = d_g + d_s$
d_g = gravel bed, minimum 16-inches
d_s = sand filter layer, minimum 18-inches

d_g = _____ in _____ ft
d_s = _____ in _____ ft
d_f = _____ ft

b) Coef of permeability for sand filter = k ft/hr (typically 1.18 ft/hr for clean, well-graded sand and gravel)

k = _____ ft/hr

c) Maximum allowable water depth in sand filter = h_{max}
h_{max} = inlet elevation - outlet elevation

h_{max} = _____ ft

d) One half the maximum allowable water depth (2h) over filter bed = h (2h = $h_{max} - d_f$)

2h = _____
h = _____ ft

e) Time required for the WQ_v to pass through the filter = t_f (max time = 48 hrs)

t_f = _____ hrs

f) Sediment Chamber Area (A_S) and Filter Surface Area (Af) = Af = A_S (ft2)

$A_S = A_f$ = _____ ft^2

3. Sediment Chamber and Filter Length: $L_S = L_f = A_f/W_f$

$L_S = L_f$ = _____ ft

Width = $W_S = W_f$ (typically 18 to 30 inches wide)

W_f = _____ in _____ ft

4. System Storage Volume

a) Available Storage Above Filter Bed: $V_{tf} = A_f \times 2h$

V_{tf} = _____ ft^3

b) Through Filter Voids: $V_v = 0.4 \times A_f \times d_f$

V_v = _____ ft^3

c) Flow Through the Filter During Filling:
$V_q = kA_f(d_f + h)t_f/d_f$, tf = 1 hr

V_q = _____ ft^3

5. Permanent Pool

a) Required Net Storage:
V_{st} = WQv - Vtf - Vv - Vq

V_{st} = _____ ft^3

b) Minimum Length: $L_{pm} = V_{st}/(2h)(W_f)$

L_{pm} = _____ ft

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Pavement Detention TC-62(a)

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_V)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres): Maximum = 5 acres

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_V (ft^3)

f) Porous Pavement Surface Elevation

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

f) Elev. = _____ ft

2. Required Minimum Open-Celled Block Paver Surface Area
A = WQ_V/ 0.17
Overflow Inlet Elevation: Porous Pavement Elev. + 0.17 feet

A = _____ ft^2

Elev. = _____ ft

3. Open-Celled Block Paver Properties

Note: Blocks should have a minimum open surface area of 40%

Block Name: _____

Manufacturer: _____

Min. Open Surface Area = _____ %
Block Thickness = _____ in

4. Paver Block Infill (Check "x" the type used or describe "Other")

_____ Open-Graded Sand
_____ Other: _____

5. Base Course
The following three items are all required.
a) Leveling Course or Bedding Layer
- check "x" one, then enter thickness

_____ 1" Class B backfill, Sec. 200.03.03 SSPWC
_____ Other: _____

_____ inches

b) Filter Fabric Between Sand & Gravel (check "x" one, describe if other)
- Top of Base Course

_____ Woven Geotextile Fabric
_____ Other: _____

c) Gravel Base Course (Open-Graded Aggregate)
- check "x" one, describe if other

_____ 8" Class C backfill, Sec. 200.03.04 SSPWC
_____ Other: _____

- 8" layer minimum thickness

_____ inches

continue to next page

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Pavement Detention TC-62(a)

Designer: _____ **page 2 of 2**

Company: _____

Date: _____

Project: _____ **Subbasin #** ____

Location: _____

6. Perimeter Wall (check "x" type, describe if other)
   - recommended to be 6 inches thick in width
   - depth must extend 6 inches from the bottom of the base course

____ Concrete
____ Other _____

width = _____ in
depth = _____ in

7. Draining of porous pavement

Answer questions 7a through 7d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay ____
b) Subgrade is a silty or clayey sand ____
c) Subgrade is a well-draining soil ____

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N" ____

____ Design: Infiltration to subgrade with Woven geotextile fabric liner
7c = x **and** 7d = N

____ Design: Underdrain with 16-mil. Impermeable fabric
7a = x **or** 7d = Y

____ Design: Underdrain with Woven geotextile fabric
7b = x **and** 7d = N

____ Other: _____

8. Overflow For Larger Storms

____ Yes / No (y or n)

Notes & Additional Information:

Original worksheet developed by and used with the permission of the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado. The original worksheet was modified and adapted for the Truckee Meadows Regional Storm Water Quality Management Program by Kennedy/Jenks Consultants.

end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Celled Block Pavers TC-62(b)

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_V)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres): Maximum = 5 acres

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Open-Celled Block Pavers Properties

Note: Blocks should have a minimum open surface area void space of 20%

Block Name: _____
Manufacturer: _____

Min. Open Surface Area = _____ %
Block Thickness = _____ in

3. Block Paver Cells Fill Material (Check the type or describe "Other")

_____ Open-Graded Sand
_____ Turf
_____ Other: _____

4. Base Course

The following three items are all required.

a) Leveling Course or Bedding Layer - Open-Graded Aggregate
- check "x" one, describe if other

_____ Class B backfill, Section 200.03.03 SSPWC
_____ Other: _____

- recommended bedding layer thickness of 1 to 2 inches

_____ inches

b) Fitler Fabric Between Base Course & Bedding Layer
-Top of Base Course
(check "x" one, describe if other)

_____ Woven Geotextile Fabric
_____ Other: _____

c) Gravel Base Course (Open-Graded Aggregate)

_____ 8" min. Class C backfill, Sec. 200.03.04 SSPWC
_____ Other: _____

8" minimum thickness required

_____ inches _____ ft

5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2):

Ratio = _____ (A_{imp} / A_{POROUS})

6. Perimeter Wall (check "x" type, describe if other)
- recommended to be 6 inches thick in width
- depth must extend 6 inches from the bottom of the base course

_____ Concrete
_____ Other _____

width = _____ in
depth = _____ in

continue to next page

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Celled Block Pavers TC-62(b)

Designer: _____

Company: _____

Date: _____

Project: _____ **Subbasin #** [ ]

Location: _____

7. Contained Cells

a) Type (check "x" one) [ ] 16-mil. (min.) Impermeable Liner
[ ] Concrete Wall

b) Slope of the base course S_O = [ ] ft/ft

c) Distance between cutoffs (normal to flow, L) L = [ ] ft , L_{MAX} = [ ] ft

8. Draining of modular block pavement

Answer questions 8a to 8d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay [ ]
b) Subgrade is a silty or clayey sand [ ]
c) Subgrade is a well-draining soil [ ]

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N" [ ]

[ ] Design: Infiltration to subgrade with Woven geotextile fabric liner
8c = x **and** 8d = N

[ ] Design: Underdrain with 16-mil. Impermeable fabric
8a = x **or** 8d = Y

[ ] Design: Underdrain with Woven geotextile fabric
8b = x **and** 8d = N

[ ] Other: _____

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Jointed Block Pavers TC-62(c)

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # [ ]

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area [ ] ft^2
Sub-basin impervious area [ ] ft^2
% Imperviousness [ ]

b) A= [ ] ac

c) R_v = [ ]

e) WQ_V = [ ] ft^3

WQ_V = [ ] ft^3

Designer to select value for Water Quality Volume for actual design

2. Open-Jointed Block Paver Properties:

Note: Blocks shall have a minimum 8% open surface area

Block Name: [ ]

Manufacturer: [ ]

Min. Open Surface Area = [ ] %

Block Thickness = [ ] in

3. Joint-Fill Material (Check "x" the type, describe if "Other")

[ ] Class D backfill, Section 200.03.04 SSPWC

[ ] Other: [ ]

4. Base Course

The following three items are all required.

a) Bedding Layer or Leveling Course (Open-Graded Aggregate)
- check "x" one, describe if "other"

- recommended thickness of 1 to 2 inches

b) Filter Fabric Between Base Course & Bedding Layer (Top of Base Course)
- check "x" one, describe if "other"

c) Gravel Base Course (Class C backfill, 200.03.04 SSPWC)
7" minimum thickness required

[ ] Class B Backfill, Section 200.03.03 SSPWC

[ ] Other: [ ]

[ ] inches

[ ] Woven Geotextile Fabric

[ ] Other: [ ]

[ ] inches [ ] ft

5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2):

Ratio = [ ] (A_{IMP} / A_{POROUS})

6. Perimeter Wall (check "x" type, describe if other)
- recommended to be 6 inches thick in width
- depth must extend 6 inches from the bottom of the base course

[ ] Concrete

[ ] Other [ ]

width = [ ] in

depth = [ ] in

7. Contained Cells

a) Type (check "x" one)

[ ] 16-mil. (min.) Impermeable Liner

[ ] Concrete Wall

b) Slope of the base course

S_O = [ ] ft/ft

c) Distance between cutoffs (normal to flow, L)

L = [ ] ft , L_{MAX} = [ ] ft

continue to next page

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Celled Block Pavers TC-62(c)

Designer:

Company:

Date: April 16, 2015

Project:

Location:

Subbasin #:

8. Draining of Open-Jointed Block Pavers

Answer questions 8a to 8d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay

b) Subgrade is a silty or clayey sand

c) Subgrade is a well-draining soil

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N"

Design: Infiltration to subgrade with Woven geotextile fabric liner

8c = x **and** 8d = N

Design: Underdrain with 16-mil. Impermeable fabric

8a = x **or** 8d = Y

Design: Underdrain with Woven geotextile fabric

8b = x **and 8**d = N

Other:

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Concrete and Asphalt Pavement TC-62(d)

*** Fill out worksheet from top to bottom** **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # [ ]

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area [ ] ft^2
Sub-basin impervious area [ ] ft^2
% Imperviousness [ ]

b) A= [ ] ac

c) R_v = [ ]

e) WQ_V = [ ] ft^3

WQ_V = [ ] ft^3

Designer to select value for Water Quality Volume for actual design

2. Type of Installation

[ ] Porous Concrete
[ ] Porous Asphalt

3. Porous Concrete or Asphalt Surface

a) Porous Concrete Slab Thickness (5 inches minimum) [ ] in

b) Porous Asphalt Surface Thickness [ ] in

4. Design Impervious Area to Porous Pavement Area Ratio (Max = 2)

Ratio = [ ] (A_{IMP} / A_{POROUS})

5. Draining of porous pavement
Answer questions 5a to 5d to determine design requirements

Check "x" only one appropriate box based on following criteria
a) Subgrade is a heavy or expansive clay [ ]
b) Subgrade is a silty or clayey sand [ ]
c) Subgrade is a well-draining soil [ ]
Answer Yes (Y) or No (N) to the following question
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N" [ ]

[ ] Design: Infiltration to subgrade with Woven geotextile fabric liner
5c = x **and** 5d = N

[ ] Design: Underdrain with 16-mil. Impermeable fabric
5a = x **or** 5d = Y

[ ] Design: Underdrain with Woven geotextile fabric
5b = x **and** 5d = N

[ ] Other: _____

6. Base Course and Sub-Layer

a) Gravel Base Course [ ] inches [ ] ft

b) Bottom sand filter layer required? [ ]
Only required for installations with underdrains
- if yellow box above says "yes", **required**.

[ ] inches, 7"minimum

c) Liners
i) Woven geotextile fabric on top of base course
- check "x" one, desscibe if "other"

[ ] Woven Geotextile Fabric
[ ] Other: _____

ii) Liner under base course, between base course and sand filter layer
- check "x" one, descibe if "other"

[ ] Woven Geotextile Fabric
[ ] 16-mil. Impermeable Fabric Liner, **required** if checked
[ ] Other: _____

continue to next page

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Concrete and Asphalt Pavement TC-62(d)

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # [ ]

7. Contained Cells

a) Type (check "x" one)

[ ] 16-mil. (min.) Impermeable Liner
[ ] Concrete Wall

b) Slope of the base course

S_O = [ ] ft/ft

c) Distance between cutoffs (normal to flow, L)

L = [ ] ft , L_{MAX} = [ ] ft

Notes & Additional Information:

Original worksheet developed by and used with the permission of the Urban Drainage and Flood Control District (UDFCD) in Denver, Colorado. The original worksheet was modified and adapted for the Truckee Meadows Regional Storm Water Quality Management Program by Kennedy/Jenks Consultants.

end of worksheet

Truckee Meadows Storm Water Quality Management Program

Design Guidance Worksheet: Porous Turf Pavement TC-62(e)

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_V)

   a) Percent of Watershed Impervious Area = I

   b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

   c) Watershed Runoff Coefficient = R_V (unitless)

   d) 90th Percentile Precipitation Depth = 0.6 (inches)

   e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Drainage Requirements for Porous Turf

Answer questions 2a to 2d to determine design requirements

Check "x" only one appropriate box based on following criteria

a) Subgrade is a heavy or expansive clay ☐
b) Subgrade is a silty or clayey sand ☐
c) Subgrade is a well-draining soil ☐

Answer Yes (Y) or No (N) to the following question

d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N" ☐

☐ Design: Infiltration to subgrade with Woven geotextile fabric liner
2c = x **and** 2d = N

☐ Design: Underdrain with 16-mil. Impermeable fabric
2a = x **or** 2d = Y

☐ Design: Underdrain with Woven geotextile fabric
2b = x **and** 2d = N

Other: _____

3. Selection of Porous Turf to be used (check "x" one)

☐ Reinforced Grass
☐ Unreinforced Turf

4. Porous Turf Installation

a) Root Zone — _____ in — _____ ft

b) Base Course: Open-Graded Aggregate — _____ in — _____ ft

c) Woven Geotextile Fabric Between Leveling Course & Gravel (Top of Base Course)
check "x" one, describe if other

☐ Woven Geotextile Fabric
Other: _____

d) Liner Between Gravel & Subgrade (Bottom of Base Course)
check "x" one, describe if other

☐ Woven Geotextile Fabric
☐ 16-mil. Impermeable Fabric Liner **required if checked**
Other: _____

5. Turf Reinforcement
check "x" one or check "none" if using unreinforced turf

☐ Reinforcing Mesh
☐ Reinforcing Mat
☐ Integral Fibers
☐ None

6. Design Impervious Area to Porous Pavement Area Ratio
Maximum Ratio = 2

Ratio = _____ (A_{IMP} / A_{POROUS})

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Gravel Pavement TC-62(f)

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # [ ]

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_v)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area [ ] ft^2
Sub-basin impervious area [ ] ft^2
% Imperviousness [ ]

b) A= [ ] ac

c) R_v = [ ]

e) WQ_V = [ ] ft^3

WQ_V = [ ] ft^3

Designer to select value for Water Quality Volume for actual design

2. Porous Gravel Course
Depth of gravel base course (D)

D = [ ] inches [ ] ft

3. Draining of porous gravel pavement

Answer questions 3a to 3d to determine design requirements
Check "x" only one appropriate box based on following criteria
a) Subgrade is a heavy or expansive clay [ ]
b) Subgrade is a silty or clayey sand [ ]
c) Subgrade is a well-draining soil [ ]
Answer Yes (Y) or No (N) to the following question
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N" [ ]

[ ] Design: Infiltration to subgrade with Woven geotextile fabric liner
3c = x **and** 3d = N

[ ] Design: Underdrain with 16-mil. Impermeable fabric
3a = x **or** 3d = Y

[ ] Design: Underdrain with Woven geotextile fabric
3b = x **and** 3d = N

[ ] Other: [ ]

4. Base Course and Sub-Layer

a) Bottom sand filterlayer required? [ ]
Only required for installations over expansive soils and with underdrains

[ ] in (4" minimum)
[ ] Other: [ ]

b) Liners
i) With underdrain system:
(check "x" one, describe if "other")
- Liner to be installed on top of and below sand filter layer

[ ] Woven Geotextile Fabric
[ ] Other: [ ]

- Liner to be installed under base course and below underdrain trench if checked "x" to prohibit infiltration

[ ] 16-mil. Impermeable Fabric Liner **required** under base course with underdrain system

ii) Without Underdrain System
(check "x" one, describe if "other")

[ ] Woven Geotextile Fabric
[ ] Other: [ ]

5. Design Impervious Area to Porous Pavement Area Ratio (Max. = 2)

Ratio = [ ] (A_{IMP} / A_{POROUS})

continue to next page

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Porous Gravel Pavement TC-62(f)

Designer: _____

Company: _____

Date: _____

Project: _____ **Subbasin #** [ ]

Location: _____

6. Contained Cells

a) Type (check "x" one)

[ ] 16-mil. (min.) Impermeable Liner
[ ] Concrete Wall

b) Slope of the base course

S_O = [ ] ft/ft

c) Distance between cutoffs (normal to flow, L)

L = [ ] ft, L_{MAX} = [ ] ft

Notes & Additional Information:

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end of worksheet

Truckee Meadows Storm Water Quality Management Program
Design Guidance Worksheet: Open-Celled Plastic Grids TC-62(g)

*** Fill out worksheet from top to bottom** — **Truckee Meadows Version 2.0 Released 2015**

Designer: _____

Company: _____

Date: _____

Project: _____

Location: _____

Subbasin # _____

Key: User Input | Calculated Result | ***Italicized Font Indicates Value is Outside Recommended Range***

1. Water Quality Volume (WQ_V)

a) Percent of Watershed Impervious Area = I

b) Drainage Area = A (acres) (43,560 ft^2 = 1 acre)

c) Watershed Runoff Coefficient = R_V (unitless)

d) 90th Percentile Precipitation Depth = 0.6 (inches)

e) Water Quality Volume = WQ_V (ft^3)

a) Sub-basin area _____ ft^2
Sub-basin impervious area _____ ft^2
% Imperviousness _____

b) A= _____ ac

c) R_v = _____

e) WQ_V = _____ ft^3

WQ_V = _____ ft^3

Designer to select value for Water Quality Volume for actual design

2. Open-Celled Plastic Grid Properties:

Model: _____
Manufacturer: _____

Min. Open Surface Area = _____ %
Grid Thickness = _____ in

3. Fill Material (Check "x" the type or describe "Other")

_____ Open-Graded Aggregate
_____ Turf
_____ Other: _____

4. Reinforced Grass Pavement

a) Setting Layer for Open-Celled Plastic Grid — _____ in _____ ft

b) Base Course — _____ in _____ ft

c) Liner Between Base Course and Subgrade (Bottom of Base Course)
- check "x" one, describe if "other"

_____ Woven Geotextile Fabric
_____ 16-mil. Impermeable Fabric Liner **required** (from #5)
_____ Other: _____

5. Drainage Requirements for Open-Celled Plastic Grids

Answer questions 5a to 5d to determine design requirements
Check "x" only one appropriate box based on following criteria
a) Subgrade is a heavy or expansive clay _____
b) Subgrade is a silty or clayey sand **x**
c) Subgrade is a well-draining soil _____
Answer Yes (Y) or No (N) to the following question
d) Does tributary drainage area have land uses with outdoor use or storage of chemicals or materials that could spill (e.g. a gas station, a hardware store, etc.)? "Y" or "N" **n**

_____ Design: Infiltration to subgrade with Woven geotextile fabric liner
5c = x **and** 5d = N

_____ Design: Underdrain with 16-mil. Impermeable fabric
5a = x **or** 5d = Y

x **Design: Underdrain with Woven geotextile fabric**
5b = x **and** 5d = N

_____ Other: _____

Notes & Additional Information:

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end of worksheet

Appendix E

Sample Maintenance Agreement

EXAMPLE

STORMWATER TREATMENT DEVICE
ACCESS AND MAINTENANCE AGREEMENT

Recorded at the request of:
CITY OF RENO

_____
After recording, return to:
CITY OF RENO

STORMWATER TREATMENT DEVICE
ACCESS AND MAINTENANCE AGREEMENT

OWNER: _____

PROPERTY ADDRESS: _____

APN: _____

THIS AGREEMENT is made and entered into in Reno, Nevada, this ____ day of _____, 200_, by and between _____, hereinafter referred to as "Owner" and the City of Reno, a municipal corporation, hereinafter referred to as "City";

WHEREAS, the Owner owns real property ("Property") in the City of Reno, County of Washoe, State of Nevada, more specifically described in Exhibit "A" and depicted in Exhibit "B", each of which exhibits is attached hereto and incorporated herein by this reference;

WHEREAS, at the time of initial approval of the development project known as _____ within the Property described herein, the City of Reno Planning Commission Conditions of Approval No. _____ of the Notice of Decision and Findings of Fact required the project to employ on-site control measures to minimize pollutants in urban runoff;

EXAMPLE

WHEREAS, the Owner has chosen to install a _____, hereinafter referred to as "Device", as the on-site control measure to minimize pollutants in urban runoff;

WHEREAS, said Device has been installed in accordance with plans and specifications accepted by the City;

WHEREAS, said Device, with installation on private property and draining only private property, is a private facility with all maintenance or replacement, therefore, the sole responsibility of the Owner in accordance with the terms of this Agreement;

WHEREAS, the owner is aware that periodic and continuous maintenance, including, but not necessarily limited to, filter material replacement and sediment removal, is required to assure peak performance of Device and that, furthermore, such maintenance activity will require compliance with all Local, State, or Federal laws and regulations, including those pertaining to confined space and waste disposal methods, in effect at the time such maintenance occurs;

NOW THEREFORE, it is mutually stipulated and agreed as follows:

1. Owner hereby provides the City or City's designee complete access to the Device and its immediate vicinity at any time, upon twenty-four (24) hour advance notice in writing, of any duration for the purpose of inspection, sampling and testing of the Device. City shall make every effort at all times to minimize or avoid interference with owner's use of the Property.

2. Owner shall use its best efforts diligently to maintain the Device in a manner assuring peak performance at all times. All reasonable precautions shall be exercised by Owner and Owner's representative or contractor in the removal and extraction of material(s) from the Device and the ultimate disposal of the material(s) in a manner consistent with all relevant laws and regulations in effect at the time. As may be requested from time to time by the City, the Owner shall provide the City with documentation identifying the material(s) removed, the quantity, and disposal destination.

3. In the event Owner, or its successors or assigns, fails to accomplish the necessary maintenance contemplated by this Agreement, within five (5) days of being given written notice by the City, the City is hereby authorized to cause any maintenance necessary to be done and chare the entire cost and expense to the Owner or Owner's successors or assigns, including administrative costs and interest thereon at the maximum rate authorized by the RMC from the date of notice of expense until paid in full.

EXAMPLE

4. The City may require the Owner to post security in a form and for a time period satisfactory to the City to guarantee the performance of the obligations stated herein. Should the Owner fail to perform the obligations under this Agreement, the City may, in the case of a cash bond, act for the Owner using the proceeds from it, or in the case of a surety bond, require the sureties to perform the obligations of the Agreement.

5. This Agreement shall be recorded in the Office of the Recorder of Washoe County, Nevada, at the expense of the Owner and shall constitute notice to all successors and assigns of the title to said Property of the obligation herein set forth, and also a lien in such amount as will fully reimburse the City, including interest as hereinabove set forth, subject to foreclosure in event of default in payment.

6. In the event of legal action occasioned by any default or action of the Owner, or its successors or assigns, then the Owner and its successors or assigns agree(s) to pay all costs incurred by the City in enforcing the terms of this Agreement, including reasonable attorney's fees and costs, and that the same shall become a part of the lien against said Property.

7. It is the intent of the parties hereto that burdens and benefits herein undertaken shall constitute covenants that run with said Property and constitute a lien thereagainst.

8. The obligations herein undertaken shall be binding upon the heirs, successors, executors, administrators and assigns of the parties hereto. The term "Owner" shall include not only the present Owner, but also its heirs, successors, executors, administrators, and assigns. Owner shall notify any successor to title of all or part of the Property about the existence of this Agreement. Owner shall provide such notice prior to such successor obtaining an interest in all or part of the Property. Owner shall provide a copy of such notice to the City at the same time such notice is provided to the successor.

9. Time is of the essence in the performance of this Agreement.

10. Any notice to a party required or called for in this Agreement shall be served in person, or by deposit in the U.S. Mail, first class postage prepaid, to the address set forth below. Notice(s) shall be deemed effective upon receipt, or seventy-two (72) hours after deposit in the U.S. Mail, whichever is earlier. A party may change a notice address only by providing written notice thereof to the other party.

IF TO CITY:	IF TO OWNER:
Director of Public Works	_____

EXAMPLE

City of Reno
P. O. Box 1900
Reno, NV 89505

_____
_____
_____

IN WITNESS THEREOF, the parties hereto have affixed their signatures as of the date first written above.

APPROVED AS TO FORM:

_____
City Attorney

OWNER:

_____

Title:_____

_____

CITY OF RENO

_____
Director of Public Works

OWNER:

_____

Title:_____

_____

ATTEST:

_____
City Clerk Date

NOTARIES ON FOLLOWING PAGE

EXAMPLE

EXHIBIT A
[Legal Description]

EXAMPLE

EXHIBIT B
[Map/Illustration]

EXAMPLE

Appendix F

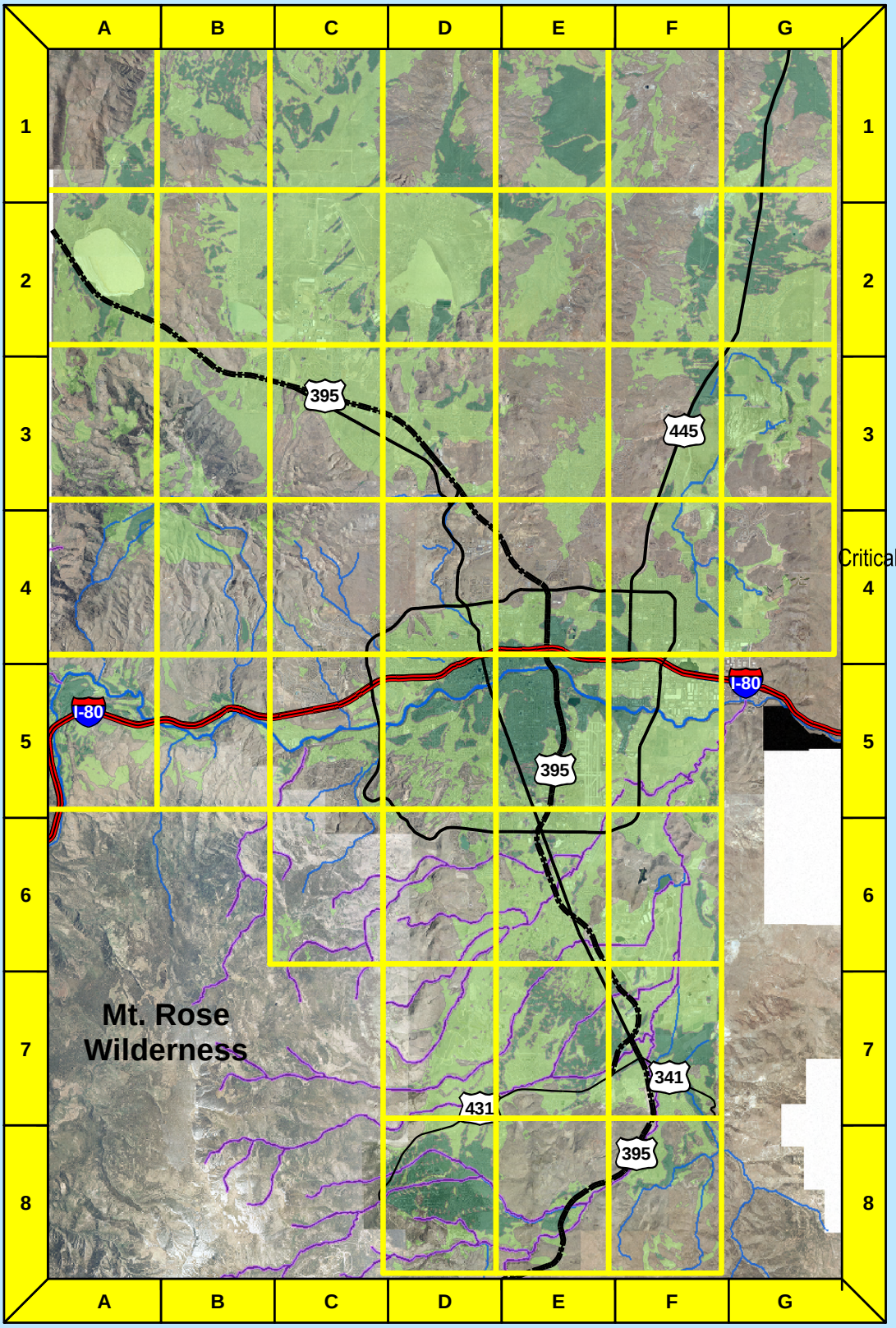
Groundwater Recharge and Stream Buffer Zones

Buffer Zones

The maps that follow provide general information about areas in the Truckee Meadows where natural groundwater recharge likely occurs and stream buffer zones exist. The maps are intended to assist planners and developers in the preliminary assessment of areas to be protected from development. Areas of medium and high groundwater recharge potential were defined based on GIS data compiled as part of the *Southern Washoe County Recharge Analysis* report prepared for the Regional County Water Planning Commission in 2001. The stream buffer zones shown on the maps define the critical (30-ft) and sensitive (150-ft) perennial stream buffer zones described in the Washoe County Development Code (Section 110.418.15) and are based upon stream data provided by Washoe County.

The hydrology/geology matrix data from the *Southern Washoe County Recharge Analysis* was redefined into two classifications depicting areas of medium and high groundwater recharge potential. Areas of medium groundwater recharge potential are associated with a hydrology/geology matrix ranking of 2.2 to 3.1, whereas areas of high groundwater recharge potential are associated with a ranking of 3.1 to 4.0. The hydrology/geology matrix was derived from four main data sets: annual precipitation, landform slope, soil type, and lithology. Annual precipitation data was provided by the National Oceanic and Atmospheric Administration (NOAA) data center. This data was converted into a GIS from a one-inch interval hyetagraph. Landform slope data were developed from standard USGS Digital Elevation Models (DEM) and Digital Line Graphs (DLG). These three-dimensional data files were analyzed with ArcView Spatial Analyst to group common slope values together. The range of landform slope classifications was selected to coincide with Washoe County's land use suitability criteria. The value of slope in the matrix is inversely proportional to its steepness. Shallow slopes have slower runoff rates than steeper slopes. Soil type data was taken from the *NRCS Soil Survey of Southern Washoe County* (1983). Soils in the United States fall into one of four hydrologic soil groups (A, B, C, or D). These groups were established based on general soil characteristics and common performance data such as porosity, homogeneity, depth to groundwater, erodibility, and structure. All data used in the 2001 study was analyzed using raster grids of 30 meters to coincide with the DEM data. Original study data was converted into raster grids from 7.5-minute resolution maps.

The enclosed maps were created using the SGC Map Atlas tool of ArcMAP 8.3. A predefined grid or index was utilized to produce a series of maps for the study area. The grid created for this map atlas consists of 44 individual cells, each corresponding to a page in the map atlas. An index overview map was created to provide a graphical display of each map contained within the map atlas document. The index map allows the user to quickly locate areas of interest. The base map was created using a 2000 aerial photograph of southern Washoe County and was the most current available at the time of this writing. This GIS data depicting major roads and water features located in the study area were also added to the map atlas to provide the reader with relevant reference information.



N

Not To Scale

LEGEND

Stream Buffer Zones

Critical (30-ft. Buffer)

Sensitive (150-ft Buff)

Groundwater Recharge

Medium

High

Lakes, Rivers & Other Streams

Index Map

Groundwater Recharge Potential & Stream Buffer Zones

2000-Aerial Photo Southern Washoe County 2001-Washoe County Stream Buffer Zones 2001-Washoe County Groundwater Recharge Analysis	Drawn By: Kennedy/Jenks Consultants Date: July 28, 2005

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